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Guidebook: How to develop a Climate Action Plan for cities in India

Rivas S., Bertoldi P. (editors)
Yagnik K., Vetters N., Pittalis M., Palermo V., Lo Vullo E., Treville A., Ortega A.

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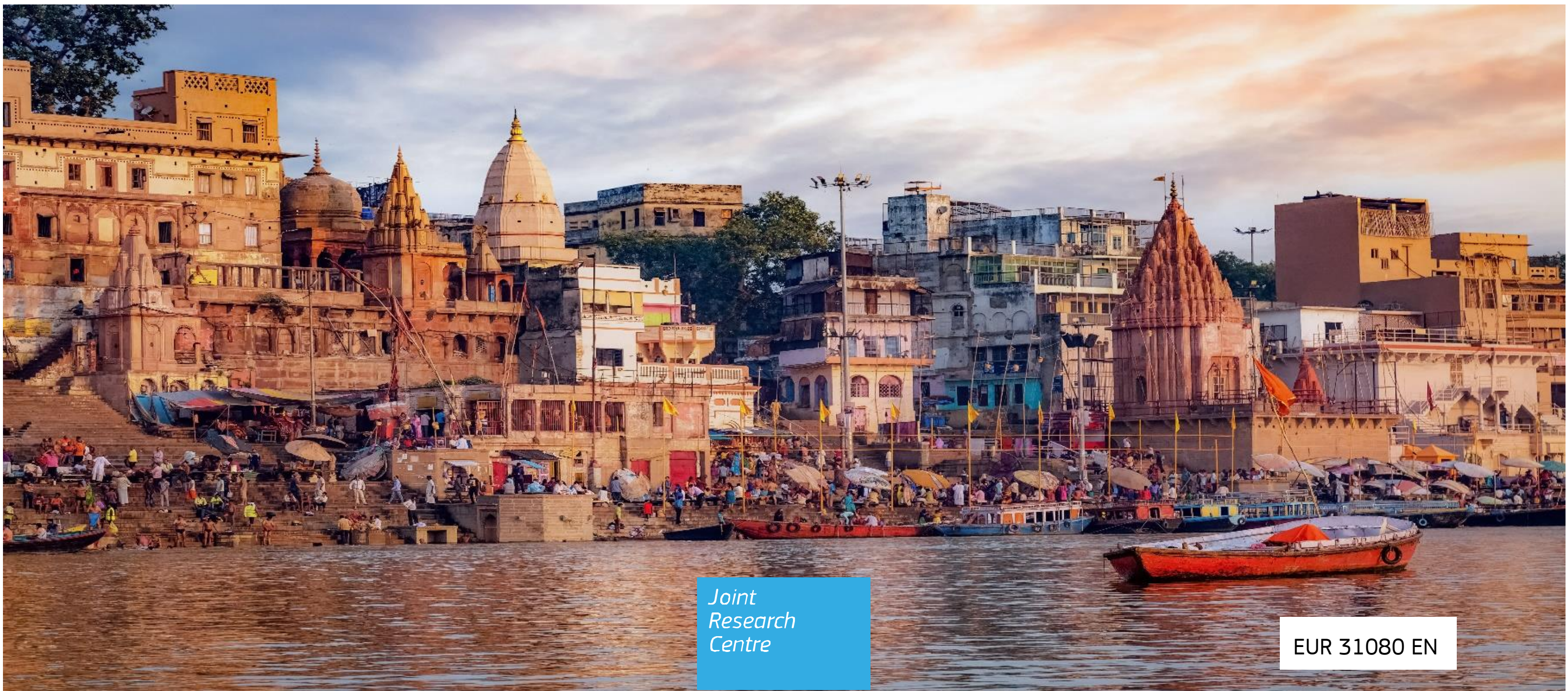

Joint Research Centre

EUR 31080 EN

Contact information
Name: Silvia Rivas
Address: European Commission, Joint Research Centre, Via Enrico Fermi 2749 - 21027 Ispra (VA), Italy
Email: silvia.rivas-calvete@ec.europa.eu

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Abstract

The Global Covenant of Mayors in South Asia supports local authorities in India in the climate challenge and in their efforts in ensuring access to clean energy. It is the "regional covenant" of the Global Covenant of Mayors for Climate & Energy (GCoM). Under The Global Covenant of Mayors in South Asia, local authorities are invited to make a voluntarily political commitment to implement climate and energy actions in their communities and agree on a long-term vision to tackle 3 pillars, namely access to energy, climate mitigation and climate adaptation. In order to translate the political commitment into practical measures, signatory cities commit to elaborating and implementing a Sustainable Energy Access and Climate Action Plan (CAP).

This document has been prepared to assist Indian cities in preparing a Climate Action Plan. It provides step-by-step guidance and examples of measures relevant for local authorities in India context. Despite being framed and definite, the process of developing a CAP allows flexibility. The choice and sequence of actions can vary according to the policies and measures already in place. This flexibility allows local governments to develop a CAP that is coherent with and effective for their local circumstances and objectives.

This document has been partly adapted from previous Joint Research Centre's (JRC) experience in Europe and other regions of the world (see for example the JRC report: JRC113188 "Guidebook: How to develop a Sustainable Energy and Climate Action Plan (CAP) in the MENA Region" and the JRC112986 "Guidebook - How to develop a Sustainable Energy and Climate Action Plan" released in 2018).

It should be noted that the content of this Guidebook aims to be coherent with the wider framework of the GCoM initiative.

At the date of the preparation of the present Guidebook, two official reporting platforms are accepted in the GCoM framework, The common reporting framework (CRF) of GCoM and CDP/ICLEI Unified Reporting System. CRF of GCoM unites local voices and raises the bar on data transparency, while recognizing the critical impact of city climate action. Unified Reporting System of CDP/ICLEI is a simplified reporting process to streamline how local and regional governments report their climate data. ICLEI, Local Governments for Sustainability, is a leading network of local and regional governments worldwide while CDP, (formerly the Carbon Disclosure Project) is the world's leading environmental disclosure platform.

Other guidance material as referred in Annex 8 on climate action planning in India is a useful complement to the present document.

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Authors

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Executive summary

In a welcome move, while presenting Union Budget 2022-23, Union Finance Minister highlighted climate action as one of the priority areas in the budget, along with inclusive development, energy transition, financing of investments, among others. The Climate crisis is among the strongest negative externalities affecting India. Several measures are proposed by the Government to help the country transition to a low-carbon economy.

India is in the process of building a climate change mainstreamed framework, giving priority to the integration of development and economic statistics with Green metrics. Overall, cities are responsible for around 70 per cent of global energy-related greenhouse gas emissions and are among the most vulnerable areas to climate change impacts.

Global Covenant of Mayors for Climate and Energy serves cities and local governments by mobilizing and supporting ambitious, measurable and planned climate and energy action in their communities.

Intergovernmental Panel on Climate Change (IPCC) has finalized the first part of the Sixth Assessment Report, 'Climate Change 2021: The Physical Science Basis', for the first time, gave cognisance to the role of compound extremes and multiple climate change drivers operating in tandem in maximising disaster impacts in India and elsewhere. This report also spelt out with "moderate confidence" how urbanisation has pushed up intense rainfall in cities across South Asia using several scientific evidences generated on India's cities.

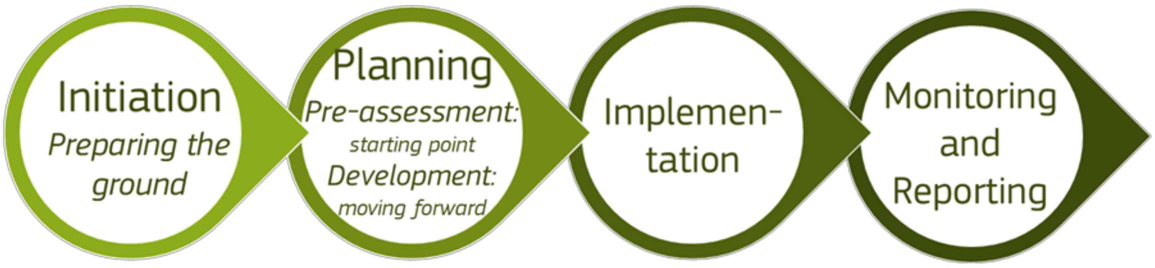
The Global Covenant of Mayors in Asia supports local authorities in India in the climate challenge and in their efforts in ensuring access to clean energy. It is the "regional covenant" of the Global Covenant of Mayors for Climate & Energy (GCoM). Under GCoM Asia cities are invited to make a voluntarily political commitment to implement climate and energy actions in their communities and agree on a long-term vision to tackle 3 pillars, namely access to energy, climate mitigation and climate adaptation. In order to translate the political commitment into practical measures, GCoM signatory cities commit to elaborating and implementing a Sustainable Energy Access and Climate Action Plan (CAP).

This guidebook has been adapted partly from previous Joint Research Centre's (JRC) experience in Europe and other regions of the world and **is intended to be coherent with the Global Covenant of Mayors for Climate and Energy (GCoM) approach.** The newly established GCoM Common Reporting Framework (CRF) introduces the first global reporting framework that will allow cities across the world to use one standardised approach for sharing information on their climate activities. The GCoM altready provided guidance to cities in India in assessing their greenhouse gas emissions, climate change risks and vulnerabilities, as well as planning and reporting in an integrated and coherent way.

This document aims at presenting the framework for the three pillars of the initiative and provides step-by-step recommendations for the entire process of elaborating a climate action plan (CAP), from initial political commitment to monitoring. Climate action planning is performed in four phases (**Figure 1**):

- Initiation phase- preparing the ground: Chapter 3 provides detailed guidance throughout the initiation phase on the commitment to address climate change mitigation and adaptation as well as access to energy.
- Planning phase: including a Pre-assessment phase and a Development phase. Detailed guidance throughout the pre-assessment phase of elaborating a CAP is provided :
    - undertaking a Baseline Emission Inventory (BEI) (see chapter 4.2) and setting objective and targets (see chapter 5.1),
    - undertaking a Risk and Vulnerability Assessment (RVA) (see chapter 4.3)
    - assessing the state of energy access (see chapter 4.4).
    - Detailed guidance on the elaboration of the climate action plan throughout the elaboration of the CAP mitigation measures (5.2); key adaptation measures (5.3); access to energy actions (5.4).
- Implementation of the actions planned and monitoring the progress towards the target (6)
- Monitoring the progress towards the target (7)

Figure 1: The CAP Process: Main Phases



Source: Guidebook for CoM, SSA

Moreover, the document includes a section on financing the action plan (chapter 8) and some insights on specific issues in the annexes.

Signatories commit to preparing and implementing the plan and reporting on the status of their implementation progress. At the date of the preparation of this document, two reporting platforms are accepted in the GCoM framework: My Covenant and CDP. Other guidance material on climate action planning in India is a useful complement to the present document. A specific Guidance document was as well prepared by the GCoM Data Technical Working Group ([1]).

The Global Covenant of Mayors in Asia addresses specifically the adaptation to the Indian context of the European experience. However, it is important to note that local authorities can use other equivalent reporting platform. The climate action plan that local authorities shall develop within the initiative, can be named CAP, which is the most common name used by many Indian cities for their plans.

Minister of State for Housing and Urban Affairs (I/C) has launched the Climate Smart Cities Assessment Framework (CSCAF) 2.0.in Sept 2020 during an event organized by the Smart Cities Mission, Ministry of Housing and Urban Affairs (MoHUA) of Government of India.

CSCAF initiative intends to inculcate a climate-sensitive approach to urban planning and development in India. The objective of CSCAF is to provide a clear roadmap for cities towards combating Climate Change while planning and implementing their actions, including investments.

Cities are key actors in the fight of climate change. Therefore, their contribution is crucial to reach the climate targets. For this reason, there is the need for a flexible framework, in which local authorities can develop and build their strategy according to their peculiarities and potentials.

The guidebook provides a flexible but coherent set of principles and recommendations. The flexibility will allow local authorities to develop a CAP in a way that suits their own circumstances, permitting those already engaged in energy and climate action to come on board of the Global Covenant of Mayors, while continuing to follow the approaches they have used before with as little adjustments as possible.

GCoM and the CRF are already known to many local Governments and other stakeholders in India. It is befitting to initiate a dialogue with Government of India on the applicability of the CRF in the Indian context and any potential adaptations of the CRF. From an initial assessment on the energy and green building indicators of CSCAF, there seems to be a strong coherence between the two frameworks.

In this setting it is imperative to evolve a strategy to incorporate the CRF in the CSCAF. Such integration of CRF and CSCAF will be a step to adopt, implement, and disseminate the best practices adopted by Indian cities and further set standards in comparison to the international efforts towards the green, sustainable, and resilient urban habitats.

Moving forward will help Indian cities improving the indicators, assessment methodology, scoring criteria and respective evidences that are to be captured to conduct a holistic assessment.

([1]) A team of multi-disciplinary experts from GCoM partners with the aim of providing a harmonized definition of a common reporting framework

1 Introduction

In the midst of global brainstorming on climate change, on behalf of India, Prime Minister Mr Narendra Modi took a pledge by presenting five nectar elements, 'Panchamrit', to deal with this challenge during CoP 26 at Glasgow on 2 November, 2021([2]).

First - India will take its non-fossil energy capacity to 500 GW by 2030. Second - India will meet 50 per cent of its energy requirements from renewable energy by 2030. Third - India will reduce the total projected carbon emissions by one billion tonnes from now till 2030. Fourth - By 2030, India will reduce the carbon intensity of its economy by more than 45 per cent. And fifth -By the year 2070, India will achieve the target of Net Zero.

These 'Panchamrits' will be an unprecedented contribution of India to climate action. Ramping up India's fight against climate change and global warming, Prime Minister announced these ambitious targets for the country.

At the 15th EU-India Summit in July 2020, both parties placed a strong focus on climate change and reaffirmed their commitment to the implementation of the Paris Agreement and to engaging constructively in its first global stocktaking in 2023. The EU and India committed to continue the Clean Energy and Climate Partnership established at the 2016 Summit.

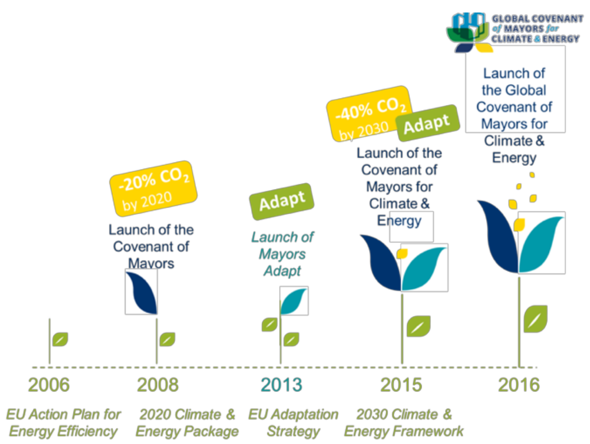
At the EU-India Leaders' Meeting in May 2021, both parties agreed to seek an even closer cooperation to combat climate change, speed up the deployment of renewable energy, promote energy efficiency, collaborate on smart grid and storage technology and modernise the electricity market ([3]).

The EU-funded International Urban Cooperation programme (IUC) aims to strengthen the EU-India policy dialogue on sustainable urban development and climate action. EU also supports the participation of Indian cities in the Global Covenant of Mayors for Climate and Energy.

1.1 Global Covenant of Mayors for Climate & Energy evolution

The **Global Covenant of Mayors** (GCoM) initiative is a voluntary commitment by local governments (regions, cities, towns) to implement measures on three pillars: climate change mitigation, adaptation to climate change and access to energy. The implementation of the agreed measures should take place at the local level in the territory within the competence of the local authority and, where relevant, with the consultation and participation of regional and national authorities. The political commitment undertaken by all GCoM signatories is declared in the GCoM commitment letter, which must be approved by the municipal corporation.

Figure 2: Covenant evolution through the years.



Source: CoM Office Europe

([2]) https://mea.gov.in/Speeches-Statements.htm?dtl/34466/National+Statement+by+Prime+Minister+Shri+Narendra+Modi+at+COP26+Summit+in+Glasgow

([3]) https://ec.europa.eu/clima/eu-action/international-action-climate-change/cooperation-non-eu-countries-regions/india_en

The initiative was first established in Europe in 2008. In 2017, Covenant of Mayors Europe merged with the Compact of Mayors ([4]) to become the **Global Covenant of Mayors for Climate and Energy (GCoM)**. **(Figure 2)**

The Global Covenant of Mayors for Climate & Energy has, hence, become the broadest international alliance of cities and local governments with a shared long-term vision of promoting and supporting voluntary action to combat climate change and move to a low-emission and climate resilient society. GCoM is a response by the world's cities to address the climate challenge, building on the commitment of over 10,000 cities and local governments from six continents and 139 countries representing more than 981 million residents (over 12% of the world's population ([5])). Regional chapters of the GCoM, managed by local, regional and global city networks ([6]) are core partners of the GCoM, serving as the primary support for participating cities and local governments. Focusing on the sectors of activity where cities have the greatest impact, the Global Covenant of Mayors supports ambitious, locally relevant solutions, captured through strategic action plans that are registered, implemented and monitored as well as publicly available. The GCoM supports cities and local governments to be active contributors to a global climate solution, mirroring the commitments their national governments have set to ensure the goals of the Paris Climate Agreement are met. Detailed information on the GCoM initiative can be found on the GCoM web site (https://www.globalcovenantofmayors.org/).

GCoM incorporates, under a single umbrella, the commitments of individual cities and local governments originally put forth either through the Covenant of Mayors, Compact of Mayors, pre-existing Regional/National Covenants, and now newly developing Regional/National Covenants operating under the shared vision of the GCoM and principles and methods that best suit each region ([7]).

It is a bottom-up and voluntary initiative that invites cities to define and meet ambitious and realistic energy and climate targets set by themselves, in line with GCoM requirements. This means that targets are at least as ambitious as the respective government's Nationally Determined Contribution (NDC) under the Paris Agreement. Furthermore, targets need to be in line with National Adaptation Plans (where these exist) and be consistent with the principles around energy access and urban sustainability embodied in the Sustainable Development Goals (SDGs). Local authorities are encouraged to voluntarily commit to the implementation of a climate and energy action plan in their area of influence. They are also encouraged to define long-term vision actions towards a sustainable future based on the pillars of climate change mitigation and adaptation, and sustainable, affordable and secure Access to Energy.

In 2018, the GCoM launched the Common Reporting Framework (CRF) as a standardized set of reporting requirements that apply across all GCOM regional covenants, while allowing for regional flexibility to respond to local circumstances and priorities but also sufficient consistency for global aggregation and comparison of reported data.

Developed by multi-disciplinary experts including GCoM partners and in collaboration with stakeholders, cities and local governments around the world, the CRF is the first framework of its kind that allows for cities of all shapes and sizes to use a single harmonised approach to sharing information on climate action. The CRF is the reference document for GCoM signatories throughout all phases of engagement with the initiative. It ensures robust assessment, target setting, integrated climate action planning and monitoring, as well as streamlined reporting across all three pillars of the initiative.

There are several resources available to help explain the requirements of the CRF for the mitigation and adaptation pillars:

- Full CRF text ([8]) – containing all the requirements, serving as a reference framework in all Regions.

([4]) Launched in 2014 by UN Secretary General Ban Ki-moon and former New York City Mayor Michael Bloomberg (former UN Special Envoy for Cities and Climate Change), the Compact of Mayors was a global coalition of city leaders addressing Climate Change by pledging to cut greenhouse gas emissions and prepare for the future impacts of Climate Change (Barron-Lopez, Laura. "UN launches global mayors network to fight climate change". The Hill. Retrieved 2015-12-03.)

([5]) Figures updated at December 2020. For more recent updated and more information on GCoM, please refer to www.globalcovenantofmayors.org

([6]) The terms "cities" and "local governments" are used throughout this document, understanding that the geo-political institutions of local governments may vary from country to country and terminology used may differ. In this document, a city refers to a geographical subnational jurisdiction ("territory") such as a community, a town, or a city that is governed by a local government as the legal entity of public administration. The term "city boundary" refers to a local government's administration boundary

([7]) https://www.globalcovenantofmayors.org/region/south-asia/

([8]) https://www.globalcovenantofmayors.org/wp-content/uploads/2019/04/FINAL_Data-TWG_Reporting- Framework_website_FINAL-13-Sept-2018_for-translation.pdf

- CRF guidance note([9]) – providing a more practical interpretation on the use of the CRF. It offers examples and references to help understand and correctly interpret all the requirements and recommendations laid out by the CRF.

If a Regional Covenant has identified a strong case for adaptations to the requirements of the CRF, these suggested variations can be considered on a case-by-case basis based on a formal request to the Data-TWG.

1.2 Global Covenant of Mayors in India

Globally, the GCoM is operating in 10 different GCoM regions. A Regional/National Covenant consists of all relevant local, regional and national partners and city networks that support and contribute to the implementation of the mission and vision of the GCoM in a given geographic area. A Regional/National Covenant engages with cities and local governments in its geographic area to encourage local level climate action while simultaneously building a community of committed signatories to a single purpose global initiative, while adapting these common principles to meet local realities.

On 5 May 2018, in New Delhi India, GCoM launched a regional chapter for South Asia. The Global Covenant of Mayors for Climate & Energy - South Asia (GCoM-SA) aims to support the efforts of cities in India, Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka to reduce greenhouse gas (GHG) emissions and make their communities more resilient toward the effects of climate change. Currently, GCoM-India functions through support from the EU-funded International Urban Cooperation programme in India (https://www.globalcovenantofmayors.org/region/south-asia/).

Indian cities will host 200 million more people by 2030, and two-thirds of India's buildings that will exist by 2030 remain to be built ([10]). The country's future urban planning and implementation will have a decisive influence on the global efforts to curb greenhouse gas emissions. In addition, many of India's cities are highly vulnerable to sea level rise, as they are situated along the country's extensive coastline or along major rivers and are already feeling the impacts of extreme weather events, including heat waves and floods.

GCoM-India aims to encourage and support Indian sub-national authorities to promote the economic and health benefits of cities' climate action. As of 31 Dec 2021, 23 Indian cities have joined GCoM, namely Ahmedabad, Bhavnagar, Gandhinagar, Gangtok, Gwalior, Jamnagar, Junagadh, Kochi, Nagpur, Panaji, Patna, Rajkot, Shimla, Surat, Vadodara, Mumbai, Thane, Udaipur, Siliguri, Coimbatore, Dehradun, Tiruchirapalli and Tirunelveli representing a population of more than 47.90 million ([11]). To support India's Intended Nationally Determined Contribution (NDC), through their commitments to take action on climate change, cities in the region could reduce the Emissions Intensity of India's GDP by 33 to 35 Per Cent by 2030 from 2005 Level ([12]).

The 15th Summit between India and the European Union (EU) was held on 15th July 2020. India was represented by Prime Minister Shri Narendra Modi, the EU by Mr. Charles Michel, President of the European Council, and Ms. Ursula von der Leyen, President of the European Commission. At the Summit, the leaders from both sides adopted the 'EU-India Strategic Partnership: A Roadmap to 2025' to guide cooperation between India and the European Union for the next 5 years. In a joint statement both sides agreed to strengthen the Clean Energy and Climate Partnership ([13]). This partnership will consolidate efforts of GCoM in India. As the second phase of the International Urban Cooperation programme (IUC) (2016-2020), International Urban and Regional Cooperation (IURC) aims to lead and develop a form of decentralised international urban and regional cooperation in the fields of sustainable urban development and innovation, in key partner countries and regions in line with the external dimension of "Europe 2020." ([14])

India's overall potential to curb emissions is even greater, and GCoM-SA officially launched a campaign to further invite mayors and commissioners from India to join the Global Covenant of Mayors and commit to transitioning to a low-carbon and climate resilient economy. GCoM-SA helpdesk was hosted by the ICLEI, Local

([9]) https://www.globalcovenantofmayors.org/wp-content/uploads/2019/08/Data-TWG_Reporting-Framework_GUIDENCE-NOTE_FINAL.pdf

([10]) McKinsey Global Institute. 2010. "India's Urban Awakening." Mumbai: McKinsey & Company. https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Urbanization/Urban%20awakening%20in%20India/MGI_Indias_urban_awakening_full_report.ashx

([11]) https://www.globalcovenantofmayors.org/our-cities/

([12]) https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

([13]) https://mea.gov.in/bilateral-documents.htm?dtl/32827/Joint_Statement_of_the_15th_IndiaEU_Summit_July_15_2020

([14]) https://www.iurc.eu

Governments for Sustainability, South Asia. The helpdesk provided administrative, logistical, and technical support to signatory cities, as well as those cities interested in joining the initiative and other stakeholders.

Box 01. GCoM India signatories' pledge

India signatories pledge to:

— Formally commit to the GCoM;

— Engage with local stakeholders throughout the development and implementation of the climate strategy and action plan;

— Develop a community-scale greenhouse gas (GHG) emissions inventory and adopt ambitious, measurable and time-bound target(s) to reduce/limit GHG emissions;

— Develop a climate risk and vulnerability assessment and adopt ambitious climate change adaptation vision and goals, based on quantified scientific evidence, when possible, to increase local resilience to climate change;

— Develop the status of access to energy and adopt ambitious and just goals to improve access to secure, affordable and sustainable energy;

— Develop stand-alone or integrated climate action plan(s) to address climate change mitigation / low emission development, climate resilience and adaptation, and access to sustainable energy;

— Approve the developed climate action plan;

— Monitor the implementation of the plan and report achievements and progress on common reporting platforms, including provisions for regular progress reports.

Figure 3: Pillars of the Covenant of Mayors in India

Source: Guidebook for CoM, SSA

In order to translate the political commitment into practical measures, GCoM India signatories commit to producing and implementing a strategic and operational document called Climate Action Plan (CAP). As shown in **Figure 3** Low Emission Development, Climate Change Adaptation and Access to Sustainable Energy form the three pillars of Covenants of Mayors in India.

Cities are key actors in the fight against climate change, their contribution being crucial to reach the climate targets. There is the need for a flexible framework, in which local authorities can develop and build their strategy according to their specific situation and potentials.

The guidebook provides a flexible but coherent set of principles and recommendations. The flexibility will allow local authorities in Indian cities to develop a climate action plan in a way that suits their own circumstances, permitting those already engaged in energy and climate action to come on board of the Global Covenant of Mayors, while continuing to follow the approaches they have used before with as little adjustments as possible.

Climate change is a complex, all-encompassing, scientific, economic, political and social problem that, for most of us, can seem far removed from our everyday lives. However, looking at the scientific evidence, it is difficult to imagine a future where anyone's life isn't touched by climate change. This India Guidebook breaks down this issue in a manner that anyone can understand. It will provide a clear roadmap for Indian cities towards combating climate change while planning and implementing their actions. It will also facilitate policymakers, planners, administrators to inculcate a climate-sensitive approach to urban planning and development in India. India is a vast country. There is no 'one-size fits all' approach for cities and communities to anticipate, plan, and adapt to the changing climate. Projected climate impacts are not expected to be the same in every state of the country. Local awareness of climate change vulnerabilities differs. Available resources to assess and adapt, financial and technical, vary. This guidebook will help cities and communities understand their climate change mitigation potential and their vulnerabilities and take action.

Each State in India has prepared its own State Action Plan on Climate Change (SAPCC) following a consultative process and aims to ensure success of these measures and realization of the 'ambitious and progressive' vision for development. Under the EU-funded International Urban Co-operation (IUC) project, seven Indian cities have developed CAPs under the GCoM. These cities have geared up to face future challenges through the formulation of their CAPs. The CAPs should pave a seamless synergy between City, State and National climate actions. Some of their experiences and lessons learned will be presented in Chapter 2 of this guidebook.

2 Climate Action Plan (CAP)

India released its much-awaited National Action Plan on Climate Change (NAPCC) ([15]) to mitigate and adapt to climate change on June 30, 2008. The action plan outlines a number of steps to simultaneously advance India's development and climate change-related objectives. In 2009 the Government of India directed all state governments and union territories to prepare State Action Plans on Climate Change (SAPCC), consistent with the strategy outlined in the NAPCC ([16]). The SAPCC preparation process started with an aim to mainstream climate change action into city planning.

As of October 2021, 32 States/UTs namely Andaman and Nicobar Islands, Andhra Pradesh, Telangana, Arunachal Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Kerala, Karnataka, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Puducherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh and West Bengal have prepared their SAPCCs. These SAPCCs provide a mapping of regional climate vulnerability, examine future projections, arriving at sectoral implications, and framing actionable strategies ([17]).

Government of India in June 2015 launched a number of schemes for transformation and rejuvenation of urban areas including Smart Cities Mission, under these Smart Cities Mission, 100 smart cities are planned with the objective to develop new generation cities, which will provide core infrastructure and a decent quality of life to its citizens by building a clean and sustainable environment. Smart solutions like recycling and reuse of waste, use of renewables, protection of sensitive natural environment will be incorporated to make these cities climate resilient.

In September 2020 Ministry of Housing and Urban Affairs (MoHUA) of Government of India launched Climate Smart Cities Assessment Framework (CSCAF) 2.0. Earlier in February 2019 Government of India had launched CSCAF 1.0, initiative which intended to inculcate a climate-sensitive approach to urban planning and development in India.

The objective of CSCAF is to provide a clear roadmap for cities towards combating Climate Change while planning and implementing their actions, including investments. The Climate Centre for Cities under National Institute of Urban Affairs (NIUA) is supporting MoHUA in implementation of CSCAF. The framework has 28 indicators across five categories namely:([18])

- Energy and Green Buildings.
- Urban Planning, Green Cover & Biodiversity.
- Mobility and Air Quality.
- Water Management.
- Waste Management.

As per EU funded ICLEI's CRF-CSCAF comparison report ([19]), majority of the Indian cities, presently reporting under the CSCAF, lack adequate capacities to generate, collate and report baseline sectoral information and subsequently to undertake a gap analysis and use it as a basis to develop, implement and monitor climate action plans; this should be the logical next step for CSCAF.

Here regionally contextualized GCoM Common Reporting Framework (CRF) could form the basis of such a comprehensive framework. Though as one of the CSCAF indicators, cities are required to develop greenhouse gas emissions inventories, the identification of climate hazards, risks and the assessment of vulnerabilities, the framework falls short in ensuring formulation of city level targets and goals. The CRF framework could be used as a reference by CSCAF to develop locally specific guidelines to encourage local government to develop climate target(s) and goal(s) and report on actions envisaged by the local government which should be sufficient and adequate to meet the targets and goals set by the city. Furthermore, the CSCAF could also integrate monitoring and evaluation principles of CRF wherein it is ensured that each signatory has to keep track on the progress toward achieving the mitigation target(s) and adaptation goal(s) set within the submitted plans.

([15]) http://www.nicra-icar.in/nicrarevised/images/Mission%20Documents/National-Action-Plan-on-ClimateChange.pdf
([16]) http://moef.gov.in/division/environment-divisions/climate-changecc-2/state-action-plan-on-climate-change/
([17]) https://www.cprindia.org/projects/state-action-plans-climate-change-india
([18]) https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf
([19]) Understanding the provisions and synergies between CRF and CSCAF, Feb 2021, ICLEI

At city level India's CSCAF strives for facilitating 'City Climate Leadership' by scaling up climate actions. Cities are supported by robust and comparable data that will help them to track and improve their policies, create momentum and confidence to manage climate change impacts. CSCAF also provides science-based evidence to other cities to make efforts towards planning and investing in sustainable, inclusive and climate resilient cities. This would facilitate cities achieving climate compatible urban development contributing to India's NDCs and achievement of Sustainable Development Goals (SDGs). There is potential of synergising the CRF with the CSCAF, by offering to the MoHUA, the guidance that is already in-built in the CRF and enabling the adoption of that guidance into the CSCAF process, thereby, creating a nationally contextualised CRF-CSCAF guidance, that will enable reporting both at the national and global levels.

In the GCoM framework, at the local level **the Climate Action Plan (CAP) is the key document that sets the strategies, plans and actions** for a sustainable and low greenhouse gas (GHG) emission development while including climate adaptation actions and ensuring access to secure, affordable and sustainable energy, in response to the current and future impacts of climate change in the territory.

The CAP is both a strategic and an operational document. It uses the results of the Baseline Emission Inventory (BEI) to identify the best fields of action and opportunities for reaching the local authority's greenhouse gases (GHG) emissions target. It is based on the climate change Risk and Vulnerability Assessment (RVA), which identifies the most relevant city climate hazards and vulnerabilities. It also includes an Access to Energy Assessment, which articulates a plan to improve the access to secure, sustainable, affordable and reliable energy. The CAP defines concrete measures for climate mitigation, adaptation and access to sustainable energy, with timeframes and assigned responsibilities, translating the long-term strategy into action. Signatories commit themselves to submitting their climate action plans within 3 years from joining the initiative.

The CAP can and shall be updated based on revision of NAPCC of Government of India and respective SAPCC. It should not be regarded as a fixed and rigid document: as circumstances change and as the ongoing actions provide results and experience, it may be useful/necessary to revise the plan. Apart from the mandate in CSCAF and recommendation in SAPCC, a multitude of factors drive climate action in cities. It becomes important for Indian cities to understand these drivers to ensure effectiveness, scalability, and continuity of climate action. The drivers for the climate action can be divided into 6 categories ([20]):

1. Centrally mandated action (National mandate for cities to have Solid Waste Management under Solid Waste Management Rule, 2016)
2. Event driven action (Ahmedabad city prepared a Heatwave Action Plan after a devastating heatwave in 2010)
3. Partnerships with transnational organisations (Effective implementation of climate action in Surat as a part of the Asian Cities Climate Change Network)
4. Political willingness (Mayor of the city of Rajkot pledging emission reductions)
5. Civil Society driven action (Citizen level action leading to effective conservation of lakes in the city of Bengaluru)
6. City Administration and NGO Partnership (Mahila Housing Trust collaborating with the Municipal Corporation of Ahmedabad in preparation of extreme heat during summer)

The CAP shall lead to climate change mitigation, adaptation and access to energy actions being integrated into development policy and planning at every level. The cities understand while preparing their CAP that mitigation and adaptation should complement each other and should be mainstreamed into existing sectorial policies in order to foster synergies and optimize the use of available resources. Opportunities to make cities more climate-resilient arise with every new development project to be approved by the local authority. The impacts of missing such an opportunity can be significant and will last for a long time. This means that climate-related considerations should be taken into account for all new developments, even if the CAP has not yet been finalised or approved.

([20]) Drivers of Climate Action in Indian Cities, TERI, 2019

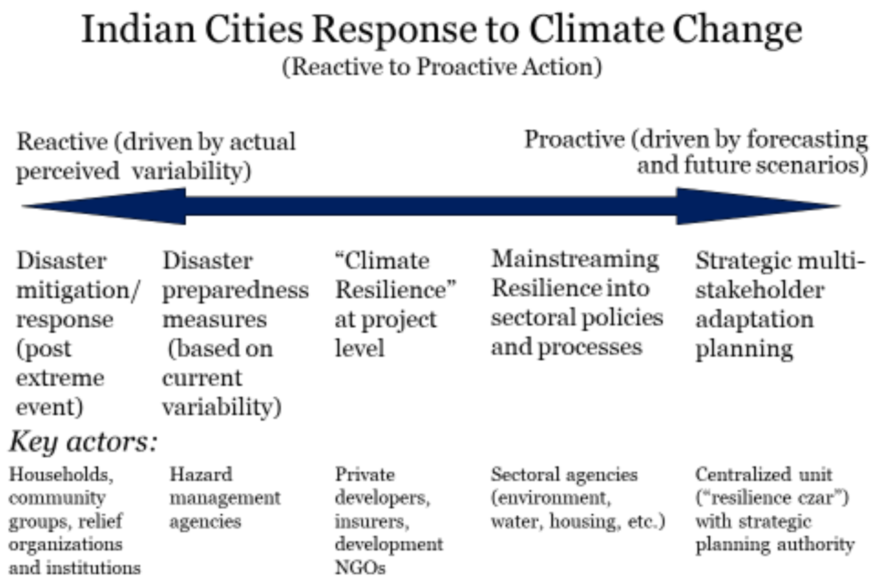
A well-designed CAP, developed in collaboration with local stakeholders and the community, provides local governments with political visibility, reduces their energy consumption costs as well as impacts related to CO2 emissions. Moreover, citizens will benefit from the reduction of the health and safety issues related to emissions associated with energy consumption and its related CO2 emissions. At the same time, the CAP helps to improve the local governments' image, makes the city more attractive to international donors and investors, when good financial figures are included for the implementation of the identified actions.

The CAP should consolidate and integrate existing initiatives. If a city has already developed a municipal action plan in the past, or any other development and climate related plans, it should prepare a CAP as a natural extension of the already ongoing activities and measures.

Several recent activities of Indian Government in its electricity, agriculture and transport sectors have the clear objective of reducing greenhouse emission and enhancing climate resilience while maintaining social and economic development ([21]). These activities have the potential to produce strong social (health), economic (jobs and investment) and environmental (lower GHG emissions) dividends for India. The international community can help fast-track these benefits by providing financial and technical support, among other things. India's multi-sectorial transition is also a part of the Prime Minister's vision to construct a new 'modern' identity for India, which is significantly compatible with the broader international 'action on climate change' narrative, readily deployed by UNFCCC. Such activities and measures can form a part of CAP.

CAP should be integrated with other sectoral plans for the cities. Each State in India has a town planning or urban planning legislation that mandates the preparation of a 'plan' for cities. Different states follow different nomenclature and have different levels of plans to be prepared based on their legislation. Mainstreaming climate change in planning process is a need of the hour. There is a need of proactive planning, shift from being reactive to forecasting driven planning as shown in **Figure 4**.

Figure 4: Reactive to Proactive Planning



Source: Climate Change Strategy, Surat

([21]) https://sustainable.unimelb.edu.au/__data/assets/pdf_file/0008/2756807/MSSI-Briefing-Paper3_India2015.pdf

Principles of CRF should be addressed while preparing plan for city. Many Indian cities, instead of being reactive to impact of climate change are working towards main-streaming climate resilience into planning driven by forecasting and future scenarios.

Box 02. CAP Definition

— Principles: the criteria defining the scope, boundaries and sector coverage of the plan (chapter 2.1).

— Elements: the components of a well-designed CAP, from political support to well-designed actions (chapter 2.2).

— Process: different phases suggested to be followed to develop an integrated local climate action plan (chapter 2.3).

2.1 CAP principles

The principles of CAPs in terms of spatial and temporal boundaries, scopes, sector coverage and elaboration of the document are described in the following paragraphs.

2.1.1 Spatial and temporal scope

The CAP covers the geographical area under the jurisdiction of the local authority and includes actions both in public and private sectors.

The CAP has to contain a clear outline of the actions that the local authority intends to take in order to ensure GHG emission reduction, taking into account the country's Nationally Determined Contributions (NDCs). In some cases, there may be a non-emission instead of a reduction.

Planning in detail for such a long-time span is difficult; hence, the local authority may distinguish between:

- A vision, with long-term strategy and goals until 2030 and/or beyond, including firm commitments in areas like land-use planning, transport and mobility, public procurement, standards for new/renovated buildings etc.
- Detailed measures for the next 3-5 years, which translate the long-term strategy and goals into real actions.

Both the long-term vision and the detailed measures shall be an integral part of the CAP. This is particularly true for adaptation targets: local decision-makers might want to focus on the immediate benefits of a measure, whilst adaptation is known to have long-term benefits. A robust planning of climate action must integrate short-term needs with long-term threats and consider the full range of interactions between sectors and policies. The CAP may as well cover a longer period, in which case it is advised that the plan contains intermediate targets and goals for the year 2030, to be comparable with the NDC.

2.1.2 Sector coverage

As per GCoM Common Reporting Framework, on mitigation, local governments shall report GHG emissions from at least three main sectors: stationary energy, transportation and waste. They should also report GHG emissions from Industrial Processes and Product Use (IPPU) and Agriculture, Forestry and Other Land Use (AFOLU) sectors ([22]) where these are significant. Additionally, GHG emissions from upstream activities, such as material extraction, or other out-of-boundary sources can be reported.

The emissions target boundary shall be consistent with all emissions sources included in the GHG emissions inventory, with the possibility to exclude sources that are not unde the competence of by the local government.

It is worth noting that the industrial sector is not a key target of the Global Covenant of Mayors, so the local government may choose or not to include actions in this sector.

([22]) Please refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories for more details on these sectors.

On adaptation, the local government shall identify the most significant climate hazards faced by the community. For each identified climate hazard, the following information shall be reported:

- Current risk level (probability x consequence) of the hazard.
- Description of expected future impacts.
- Expected intensity, frequency, and timescale of the hazard.
- All relevant sectors, assets, or services that are expected to be most impacted by the hazard in future and the magnitude of the impact for each of them.

Local governments shall develop plans for climate change mitigation, adaptation (climate resilience) and for access to energy, which may be presented in separate plans or an integrated plan. All actions of priority sectors (identified from GHG emissions inventories and risk/vulnerability assessments and energy access assessment) shall be included in the plan.

The CAP should address areas where the local government can influence energy consumption, land use planning and climate change resilience on the long term.

For low emission development / climate change mitigation, action in the following sectors is carried out: building subsector including: residential, institutional and commercial buildings and facilities, industry and agriculture, forestry and fisheries (belonging to stationary energy sector), transportation and waste. The CAP may also include actions related to local electricity production (development of PV, wind power, CHP, improvement of local power generation), and local heating/cooling generation. In addition, the CAP should cover areas where local authorities can influence energy consumption on the long term (as land use planning), encourage markets for energy efficient products and services (public procurement), as well as changes in consumption patterns (working with stakeholders and citizens).

For adaptation to the impacts of climate change, the CAP should include actions in the sectors and areas that are likely to be most vulnerable to climate change in a local authority (hotspots). Vulnerable sectors vary considerably within urban boundaries, from one city to another and from urban areas to more rural areas: this is why gaining a deep understanding of the hazards and vulnerabilities of the local authority is of paramount importance.

For access to energy the attributes of secure, sustainable and affordable energy shall be taken into consideration when developing an assessment, in order to catch its multi-faced characterisation. The fields to be considered to assess the energy access in India are: affordable, secure and cleaner energy including clean cooking and electricity in households and public buildings and activities ([23]).

Finally, mitigation and adaptation should complement each other, and should be mainstreamed into existing sectorial policies in order to foster synergies and optimize the use of available resources. A climate lens should be applied whenever a mitigation policy or action is formulated, planned and/or implemented, to see whether it works in favour of or against the adaptation goals and – if relevant - adjust it, and vice versa.

2.1.3 Elaboration of the document

Local authorities are advised to follow the recommended structure when preparing their CAPs, with the following content:

A. CAP executive summary

B. Strategy

  1. Vision

  2. Commitments for mitigation adaptation to climate change and access to energy

      a. For mitigation, the CAP document should clearly indicate the emission reduction target by 2030, and possibly beyond (*[24]*) clearly stating the Baseline Emission Inventory (BEI)

([23]) https://www.ceew.in/sites/default/files/MeasuringEnergyAction.pdf

([24]) in-line with the reporting guidelines of the UNFCCC, i.e. report in 5 year increments if targets go beyond 2030.

year and the reduction target type (absolute reduction / per capita reduction/ Baseline scenario target).

   b. For adaptation, the CAP should include a certain number of adaptation goals, coherent with the identified vulnerabilities, risks and hazards.

   c. For access to energy, the document should include a set of sustainable affordable and secure access to energy goals

3. Coordination and organizational structures created /assigned
4. Staff capacity allocated
5. Involvement of Stakeholder and citizens / Participatory processes
6. Overall budget allocated for implementation and financing sources
7. Implementation
8. Monitoring process
9. Assessment of the adaptation options
10. Strategy in case of extreme climate events

C. BEI and related information, including data on:

1. Inventory year
2. Number of inhabitants in the inventory year
3. Emission factors approach (IPCC or LCA)
4. Emission reporting unit (CO_2 or CO_2-equivalent)
5. Responsible body/department (main contact)
6. Detailed BEI results in terms of final energy consumption and GHG emissions

If relevant, please also specify:

7. Inclusion of optional sectors and sources
8. Assumptions made, references or tools used
9. Reference to the BEI inventory report

D. Climate Change Risk and Vulnerability Assessment (RVA)

1. Expected climate events particularly relevant for the local authority or region
2. Vulnerabilities of the local authority or region
3. Expected climate impacts in the local authority or region
4. Assets and people at risk from climate change impacts

E. Access to Energy Assessment

Sustainability, security and affordability attributes of energy access including:

1. Percentage of population or households having access to electricity (grid/off-grid) [%] and
2. Percentage of population/households with clean cooking access [%]
3. Other potential indicators according to CRF

F. Mitigation actions and measures for the full duration of the plan. For each measure/action, please specify (whenever possible):

1. Description
2. Department, person and/or company in charge of the implementation,
3. Timeline (start, end, major milestones)
4. Cost estimation (Investment and running costs)
5. Estimated energy savings and/or increased renewable energy production by target year (MWh/year)
6. Estimated CO_2 reduction by target year (tonnes/year)
7. Indicators for monitoring

G. Adaptation actions and measures for the full duration of the plan. The actions should be coherent with outcomes of the city vulnerability and risk assessment (RVA). For each measure/action, please specify (whenever possible):

1. Sector
2. Title
3. Description
4. Responsible body/department/ and contact point
5. Timing (end-start, major milestones)
6. Action also affecting mitigation?
7. Stakeholders involved/advisory group
8. Impacts, vulnerabilities and risks tackled
9. Costs (LC) (Investment and running costs)
10. Indicators for monitoring

H. Set of Access to energy actions to be implemented

1. Sector
2. Title
3. Description
4. Responsible body/department/ and contact point
5. Field
6. Cost
7. Co-benefits

Box 03. Defining actions: detailed versus general

The level of detail in the description of each measure/action is to be decided by the local authority according to expected results, data availability and quality. However, bear in mind that the CAP is at the same time:

— A working instrument to be used during implementation (at least for the next few years);

— A communication tool towards the stakeholders;

— A document that is agreed at the political level by the various parties in charge within the local authority: the level of detail should be sufficient to avoid further discussion at the political level over the meaning and scope of the various measures.

2.1.4 CAPs with multiple partners: Shared CAPs

Since climate change has a regional scale in many sectors (e.g., water management) collaboration at regional level between municipalities and with regional agencies is needed. For instance, cities within the same risk zone and with similar vulnerability factors can create a network which could facilitate data and good-practice exchange, better use of available resources (e.g., river basin management), and define common goals and monitoring systems by submitting a shared CAP. Neighboring local authorities may choose to elaborate a CAP with multiple partners.

In the State of Gujarat, a sub-national Covenant of Mayors of Gujarat (CoMG) is formed under International Urban Co-operation (IUC) program of EU with the support from Climate Change Department of Government of Gujarat. Eight cities of State of Gujarat consisting of Ahemedabad, Surat, Vadodara, Rajkot, Bhavnagar, Jamnagar, Junagadh and Gandhinagar are the members of CoMG. CoMG provides a platform to the cities for shared learning. It is an opportunity to cities to have shared CAPs including their challenges and best practices to combat climate change with other member cities of the same region. This model is a replicable model that can be accepted by various States of India.

2.2 CAP elements

The following elements are presented to guide Indian GCoM signatories in the elaboration of their CAPs. These steps are linked to the commitments taken by GCoM signatories and constitute key ingredients of success.

2.2.1 Strong political support

Strong political support by municipal corporations or equivalent decision-making body is a prerequisite for the successful design, implementation and monitoring of a CAP. Local authorities must ensure that the vision and actions proposed in the approved CAP are aligned with and integrated into relevant national and/or state/regional plans, strategic development plans or land-use plans. The CAP should therefore be approved by the municipal corporation.

2.2.2 Commitment to ambitious targets

The principle behind the chapter on mitigation of the CAP is a meaningful, actionable commitment by local authorities to implement low emission development strategies to ensure that local authorities develop in a way that limits the GHG emissions in their jurisdictions. For signatories in India, the CAP must include the signatory's statement of commitment to reduce emissions beyond the country’s NDCs by 2030 within the geographical area under its responsibility for the areas of activity, relevant to its mandate.

Box 04. India’s NDC

In its INDC, India has pledged to improve the emissions intensity of its GDP by 33 to 35 per cent by 2030 below 2005 levels. It has also pledged to increase the share of non-fossil fuels-based electricity to 40 per cent by 2030. It has agreed to enhance its forest cover which will absorb 2.5 to 3 billion tonnes of carbon dioxide (CO2, the main gas responsible for global warming) by 2030.

https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

The commitment should be based on the quantification of associated GHG emitted in the baseline year. It is preferred that the base year shall be the same as the base year used in the NDC. In many of the Indian cities, due to lack of historic data availability, the base year is different from the NDC, i.e.,2005. Using Compounded Annual Growth Rate (CAGR) and considering Business-as-Usual (BAU) scenario base year data can be calculated. Targets on the other hand should be based on a reference BAU scenario, as explained in chapter 5.

In addition to the mitigation commitment, adaptation goals have to be specified coherently with the main outcomes of the RVA, and levels of improvement in access to energy services based on the outcomes of the assessment.

2.2.3 Suitable assessment of the current situation

The CAP should be elaborated based on a sound knowledge of the local situation in terms of energy and GHG emissions, as well as of climate hazards, vulnerabilities and access to energy. Therefore, an assessment of the current framework should be carried out. This includes calculating a Baseline Emission Inventory (BEI), preparing a Climate Change Risk and Vulnerability Assessment (RVA), and an Access to Energy Assessment (AEA). The main results of the three assessments, BEI, RVA and AEA have to be included in the CAP document.

2.2.4 Strategies, development and prioritization of actions

The CAP must provide a long-term vision and clear objectives in selected and/or mandatory sectors, as well as other relevant areas under the jurisdiction of the local authority, as well as a clear outline of the specific actions the local authority intends to take to reach its commitments. Local authorities should identify and prioritize the required and/or most effective sectors in which to implement mitigation actions. Those measures should be aligned with identified priorities and measurable in terms of energy consumption and GHG emissions reduction.

Adaptation to climate change requires a multilevel approach and is a shared competence between City, State and National Government. It should be defined according to a city´s peculiarities and needs, which might not be sufficiently covered by a solely large-scale national or State framework. Based on recognized local risks and vulnerabilities, the local authority should identify actions aimed at enhancing local adaptive capacity to respond to climate change impact or/and reducing city sensitivity to climate extremes.

Local authorities (LAs) should identify the most suitable measures to their situation. Medium and long-term visions allow prioritization and keep track of the progresses. **Measures can be selected according to the needs identified in the assessment.**

Suggestions for measures and actions in various sectors are provided in the Section 5.

The mitigation, adaptation and access to energy strategies could be part of the CAP and/or developed or mainstreamed in separate documents.

Box 05. Key principles for a successful CAP

— Document approved by the municipal corporation;

— Build strong political support; secure a long-term commitment;

— Commit to concrete and ambitious emission reduction targets under the municipal jurisdiction;

— Based the plan on assessments: Baseline Emission Inventory (BEI), Risks And Vulnerabilities Assessment (RVA) and Access to Energy Assessment (AEA);

— Develop comprehensive measures covering key municipal sectors;

— Define concrete actions to 2030 but strategies beyond;

— Mobilization of all municipal departments involved;

— Engagement of all relevant stakeholders and empowerment of citizens;

— Ensure adequate financial resources;

— Ensure proper management, including monitoring and reporting, during implementation.

2.2.5 Governance

An appropriate governance structure is fundamental to the successful implementation of the CAP. The CAP should outline which structures are in place or how they will be organized to implement the proposed actions successfully. Local authorities should ensure that the CAP is taken into account at different levels and by different departments, including those at a state and national level. The CAP should also specify the human resources required and how they will be made available, as well as the implementation and monitoring strategy. A coordinated interaction and cooperation between mitigation and adaptation through the mobilization of all municipal departments involved should be ensured.

Furthermore, the local authority should consider training and capacity-building to avoid delays in implementation. Municipalities with limited autonomy or opportunity for recruiting staff should draft recommendations to national and state authorities, including a request for suitable technicians and administrators to carry out some actions foreseen in the CAP.

2.2.6 Engagement of citizens and stakeholders

The involvement of relevant stakeholders, in particular Civil Society Organizations, throughout drafting and implementing the CAP is crucial in order to develop a realistic and implementable plan as well as successful mitigation and adaptation coherence. The CAP should describe how citizens and stakeholder were and will be involved during the preparation of the CAP document since the very first steps of the planning process until the end of the whole process, and how each will participate in the implementation and monitoring of the planned actions. It is important to make a clear distinction betweenstakeholders and citizens because the two collectives often have different relationships with projectorganisers and policymakers, and both groups bring different types of knowledge, experience, values and expectations and concerns to the process. [25]Moreover, paritcipatory groups should be created to ensure an exhaustive understanding of city specificities and problems, meet end-user expectations, guarantee a common agreement about selected indicators, and ensure a full uptake of the main outcomes and their inclusion into decision-making.

In city of Surat, while developing CAP with IUC support, COVID-19 restrictions significantly hampered key activities, such as data collection and analysis as well as meetings. The work had to be flexible. The generic steps that were followed to develop CAP included commitment by the city and mobilisation of resources, engagement of local stakeholders, assessment of the local context, identification of key emission sources, development of the GHG inventory, and identification of strategies regarding energy, transportation, and municipal solid waste management. The CAP was developed through a combination of primary and secondary data collection and analysis as well as stakeholder engagement and participatory processes **(Figure 5)**. These activities took place from 2019-2021.

Figure 5: Participatory process in Surat in October 2020

Source: IUC India Project

[25] SPACE MATTERS: HOW TO DEVELOP A COMMON METHODOLOGY FOR CITYLABS. Citizen and Stakeholders engagement. Dunlop and Pereira

2.2.7 Financing

The CAP should identify the potential financing sources for each step of its development, implementation and monitoring. It should take into consideration the financial resources needed to build capacity within the municipality and to compensate external stakeholders such as architects, consultants, banks, developers and facility management involved in elaborating the CAP. More details can be found in chapter 8.

2.2.8 Document submission

The Covenant signatories commit to submitting their CAPs within three years following their commitment.

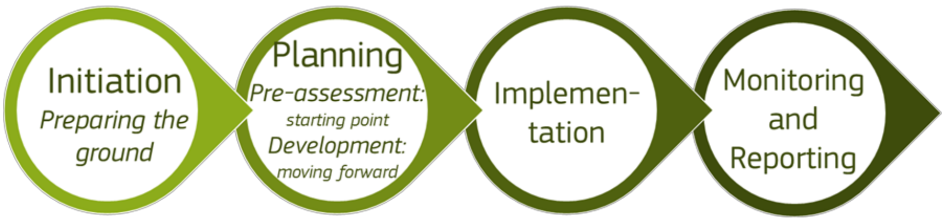
2.2.9 Monitoring and reporting

Regular monitoring using relevant indicators, followed by adequate revisions of the CAP allows local authorities to evaluate progress towards targets over time and adopt corrective measures if necessary. The CAP should briefly outline how the local authority (or relevant decision-making body) intends to ensure the follow up and monitoring throughout implementation of the planned actions. Signatories must submit a monitoring report every two years following the submission of the CAP.

2.3 CAP process

Figure 6 illustrates the main phases within the Climate Action Plan elaboration process, while **Figure 7** includes, for each of the phases, milestones and time frame ([26]).

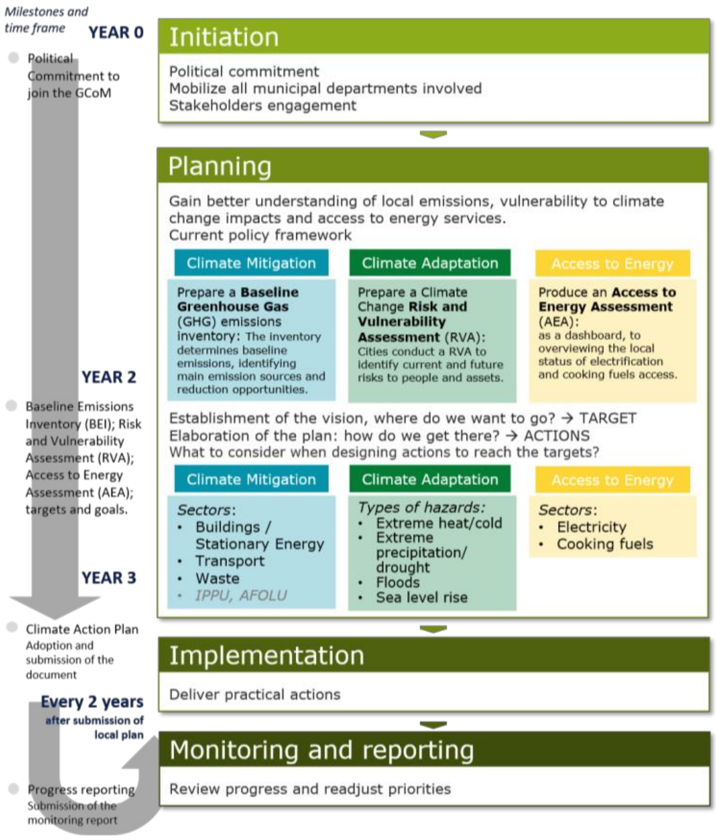
Figure 6: The CAP Process: Main Phases



Source: JRC SEACAP guidebook CoM SSA

([26]) The reporting scheme follows the GCoM recommendations. See Annex 2(1).

Figure 7: The CAP process: main phases, milestones and timeframe.



Source: JRC SEACAP guidebook CoM SSA

3 Climate Action Plan (CAP) process: initiation phase / preparing the ground

The CAP process includes several phases: initiation, planning (pre-assessment, elaboration of the plan), implementation and monitoring and reporting. Outlined below are steps and recommended measures involved in each phase. Note that some steps repeat or overlap among phases and/or may already be established or underway in a municipality. Local authorities will select and sequence the steps as appropriate to their situation.

3.1 Secure political commitment

Sufficient empowerment and support for the municipal staff in charge of the CAP from Mayor, Commissioner and other elected representatives are essential to its success. Although the 74th amendment to the Constitution of India in 1992 brought constitutional validity to municipal or local governments, State and National governments can extend or control the functional sphere through executive decisions without an amendment to the legislative provisions. Hence, a political conducive environment is needed during the entire CAP process.

Political commitment and leadership should be sought early, as they are driving forces of the overall process. The formal approval of the CAP by the municipal corporation, along with budgets for the first year(s) of implementation, are crucial to ensure successful implementation.

The local authority is best situated to know who to contact and how to raise the political commitment needed (mayor, commissioner, municipal council, ministries, national agencies, future partners, specialized committees, etc.). Before seeking this political commitment and support, ensure proposed CAP actions are aligned with, and even help to achieve, relevant approved SAPCC and NAPCC. Doing so promotes buy-in and approval of the necessary resources from higher levels during implementation.

Establishing broad political consensus at all levels for CAP actions is highly recommended. It provides long-term support and stability, regardless of changes in political leadership, especially in countries where local and regional authorities depend heavily on national policies and budget.

3.2 Municipal support

The municipal corporation and local authority should further support the process by ensuring that adequate human resources are in place to prepare and implement the CAP (this may require identifying, engaging and allocating, or recommending and requesting support from other levels of government to ensure the plan feasibility and success), including the provision of a clear mandate and sufficient time and budget. They should also involve relevant technical departments from the local authority in the CAP elaboration process to gain their acceptance and backing.

Other support activities within the municipal corporation and local authority's purview include taking steps to:

- Integrate the CAP vision with the actions and initiatives undertaken at the national and/or regional level;
- Make the CAP a part of the municipality's overall planning;
- Solicit the long-term commitment of relevant authorities and departments to implementation and monitoring;
- Foster the participation of different stakeholders, including citizens;
- Reinforce the local authority and citizen "ownership" of the CAP process.
- Network with other GCoM signatories to share experiences and best practices, through peer-to-peer learning, webinars, workshops etc.

As the responsible entity and authority, the municipal corporation must follow the implementation process closely. For GCoM signatories, municipal corporation approval is required. The CAP should be updated as necessary and the updates circulated to relevant bodies for visibility and/or approval.

3.3 Establish governance structure

Developing and implementing a CAP is a challenging and time-consuming process. It requires well-planned and continuous collaboration and coordination among local and higher level authorities and administrative departments, such as environmental protection, land use and urban planning, economics and social affairs, buildings and infrastructure management, mobility and transport, budget and finance, procurement, internal and external communications, etc. The CAP process should be integrated in the everyday work of each department.

3.3.1 Local resource coordination

City authorities, after having gained political commitment to the vision and approval of the planned actions and ensured the allocation of required human and financial resources, should coordinate with the local individuals, institutions, industry and NGOs to adjust or develop a clear organisational structure and assignment of responsibilities. If appropriate, they can use organisational structures established for related policies in the context of the CAP's development and monitoring. A multistakeholder, Surat Climate Change Trust was established by Surat Municipal Corporation having representations from elected representatives, municipal corporation, Chamber of Commerce, Research Institutions, Technical and Medical Colleges, NGOs and subject experts with an objective to work on various issues related to climate change.

Sustainable energy and climate management should be integrated into other actions and initiatives of relevant municipal departments and become part of the local authority's overall planning. Multi- departmental and cross-sector involvement is required, and their organisational targets need to be aligned with and integrated into the CAP.

Whenever required in the CAP elaboration process, adequate training should be planned for city administrators and provided in different fields, including technical competencies (energy efficiency, renewable energies, energy management, etc.), project management, data management, financial management, investment project development, and communication (how to promote behavioral changes, etc.). Lack of skills in data management can be a particular barrier to CAP elaboration. Cities can directly access resources available with Climate Change Centre at National Institute of Urban Affairs (NIUA), New Delhi, established with support from Government of India to create synergy across all climate actions which are being undertaken in Indian cities by various stakeholders. (https://www.niua.org/c-cube/about-us)

3.3.2 CAP Co-ordinator

Local authorities can appoint a CAP Co-ordinator at the outset of the process. In many municipal corporations where a CAP Co-ordinator is not appointed, either City Engineer or Environment Engineer acts as a CAP Co-ordinator. In India, support may be sought from the Environment, Climate Change & Resilience Group at National Institute of Urban Affairs ([27]) in identifying role and responsibilities of CAP Co-ordinator. NIUA could support the CAP Co-ordinator, as well as provide the necessary time and budget to carry out the role. In large cities, the role may require a dedicated unit of staff at its disposal.

Past experience recommends establishing two CAP groups: a steering committee (including politicians and senior managers at the city/municipality level if necessary) and a project committee comprising of people from various municipal departments, representatives of public agencies and others. The first will provide strategic direction and political support, while the latter undertakes the actual CAP elaboration and follow-through to ensure stakeholder participation, organize monitoring, report progress, etc. Larger municipalities may need a core group member dedicated to data collection and BEI. The project committee may establish additional working groups, to which non-municipal stakeholders directly involved in CAP actions could be invited. Both the steering and project committees require distinct and specific objectives, functions and leaders, as well as a well-defined meeting schedule/agenda and a project-reporting strategy.

The project committee should assign responsibilities to important municipal actors to ensure strong CAP ownership. A specific communication campaign may help to reach and convince municipal workers in different departments. The campaign should include a citizens' awareness promotion plan at the municipal and/or national level.

([27]) https://www.niua.org/our-work-1#theme

City project committee should approach state government coordination bodies for further organisation/coordination assistance. At a State level Department of Environment or Department of Climate Change is responsible for State Action Plan on Climate Change, while city engineer or environmental engineer is responsible for the implementation of CAP in cities. If CAP is aligned with State Action Plan on Climate Change, city can get support for the implementation of its CAP.

3.3.3 External support

Depending on their size and human resources availability, local authorities may benefit from the assistance of private or state-owned agencies, city networks, CSOs etc. It is even possible for them to subcontract some specific tasks (e.g. compilation of a BEI or of an RVA) or to use interns (Masters or PhD students can do much of the work associated with the collection and compilation of data into a GHG calculation tool to produce the BEI or to develop a RVA). Local authorities, which do not have sufficient skills or resources to draft and implement their own CAP, should be supported by public administrations like the National Institute of Urban Affairs funded by Ministry of Urban and Housing Affairs with such capacity.

3.4 Stakeholders' engagement

Citizens and other stakeholders should be engaged at important stages of the CAP elaboration process: building the vision, defining the objectives and targets, setting the priorities and defining the necessary human and financial resources. Such stakeholder involvement constitutes a formal commitment by local actors to a future vision. Whenever possible, local authorities and significant actors should define together the paths to transform the vision into action.

In Indian cities, the stakeholder engagement for CAP development essentially aimed to:

- provide an opportunity to introduce the GCoM CRF to a wider audience and explore synergies;
- initiate a participatory process with researchers, practitioners, civil society actors and policymakers working on climate change-related issues;
- deliberate on the challenges and enablers of adaptation response, planning and implementation in the city and thus draw on existing knowledge and capacities.

In the city of Panaji in Goa, a broad assessment of institutional and regulatory framework was also conducted to derive enabling policy and institutional recommendations for climate planning. The proposed recommendations were reviewed and validated by the expert committee constituted under the project through city stakeholder engagement. The participation of city stakeholders in the validation process ensured that their inputs were integrated throughout the project. The committee was comprised of a mix of experts and professionals working in the areas of coastal cities/settlements, disaster management, climate resilience planning, and urban planning, and included officials from various departments at the city level.

Following were carried out by at Panaji committee ([28]):

1. Identification of vulnerable hotspots and critical infrastructure on spatial scale.
2. Inventory of city's urban infrastructure assets in the form of a Database Management System (DBMS) to support governments to address the impacts of sea level rise in city planning.
3. A generalized methodology for vulnerability assessment of coastal cities to climate variability and sea level rise.
4. Broad sector-wide recommendations to the cities as starting points to initiate climate resilience planning and retrofitting of infrastructure assets and services. However, further detailed studies and expert participatory process will be required to appropriately implement these actions.

Box 06. Stakeholders Engagement is key

Stakeholders Engagement is really about initiating and sustaining constructive external relationships over time. The core values of such engagement are as follows ([29]):

([28]) Panaji City Climate Action Plan 2021, EU, IUC
([29]) https://www.oecd.org/gov/innovative-citizen-participation-and-new-democratic-institutions-339306da-en.htm.

— Say in decisions about actions that could affect their lives.

— Ensure that the public's contribution will influence the decision.

— Promote sustainable decisions by recognizing and communicating the needs and interests of all participants, including decisionmakers.

— Seek out and facilitates the involvement of those potentially affected by or interested in a decision.

— Seek input from participants in designing how they participate.

— Provide participants with the information they need to participate in a meaningful way.

— Communicate to participants how their input affected the decision.

3.4.1 Identifying the stakeholders

It is important to involve in the CAP process stakeholders whose interests are affected or whose activities affect the issue at stake, those who possess or control information, resources or expertise needed for strategy and/or implementation, and/or whose involvement is needed for successful implementation. Therefore, stakeholders from the following divisions should be considered:

- Local administration, relevant municipal departments and companies (e.g. electricity distribution companies, gas companies, transport companies, etc.);
- Ministry of Housing and Urban Affairs, New Delhi, Ministry of Environment, Forest & Climate Change, New Delhi or State Administrations and/or neighbouring municipalities, to ensure coordination and consistency with plans and actions that take place at the regional and national level;
- Institutional stakeholders such as chambers of commerce, professional organizations (e.g. architects, engineers), universities, professionals and research centres, observatories, experts;
- Local and regional energy agencies, suppliers, utilities, facilities management companies, Energy Services Companies (ESCOs), supporting structures, national energy agencies;
- Financial partners, banks, private funders (including international);
- Transport/mobility actors (e.g. private/public transportation companies);
- Construction sector (e.g. Local City Confederation of Real Estate Developers Association of India);
- Businesses and industries, including tourism where it represents a large share of the local Authority's CO_2 emissions;
- NGOs and other civil society representatives, including students, trade unions and consumer associations;
- Small Scale businesses and community service organisations (e.g. waste collectors);
- Informal businesses;
- Citizens
- Youth and women organisations.

3.4.2 Approaches and tools for stakeholders' engagement

Local authorities use various methods to involve different stakeholders according to the different levels of participation in the municipality. The roles of local authorities and potential stakeholders are summarized in **Table 1**. Past experiences show that involving a neutral moderator during stakeholders' meetings can be useful for reaching consensus.

Many indicate long-term partnerships and require ongoing communications about CAP implementation to motivate and maintain the necessary stakeholder involvement. Such requirements should factor into a CAP communications strategy.

Table 1. Approaches and tools for stakeholders' engagement

Approach	Approaches	Tools
Provide information and education	Informing	Brochures, newsletters, advertisement, exhibitions, site visits
Provide information and elicit feedback	Engagement	Telephone hotline, website, public meetings, teleconferences, surveys and
Bring about involvement	Partnership	Workshops, focus groups, forums, open house
Bring about extended involvement	Delegated power	Community advisory committees

Source: JRC own elaboration.

3.5 Communication

Communication, both to expedite CAP actions and promote their adoption, is an essential mean of keeping external and internal stakeholders motivated and supportive. The CAP should include a clear communication strategy that is feasible, efficient and adapted to local needs and cultural context as well as using accessible language. Good communication is particularly essential during the implementation phase, both internally among different departments of the local authority, the associated public authorities and all those involved (e.g. local building managers), and externally with relevant stakeholders, including citizens.

A good communication plan will promote visibility, investment, awareness, behavioural change and broad support throughout implementation.

Lack of communication channels at all levels can be a major challenge. Local authorities may need to invent the necessary strategy, channels and tools and/or enlist a dedicated communications officer or external partner (schools, private sector, NGOs, etc.). Consider creating a "Citizen Awareness Promotion Plan'' as part of the CAP communications strategy to ensure effective implementation.

Networking with other local authorities, especially GCoM signatories, to exchange experiences and best practices is highly recommended. It accelerates learning and highlights the actions taken by each local authority, which may also attract investors and additional funding to support pilot and/or demonstration projects.

Box 01. Effective communication.

— Have a clear message to produce the desired outcome;

— Identify the audience for each message;

— Establish indicators to evaluate the impacts of the communication (Head count at a seminar, quantitative/qualitative surveys, hits on website, feedback via e-mails, etc.);

— Specify the most appropriate communication channel(s) (i.e. the most accessible and the easiest to implement and finance): face-to-face (most effective), advertising, mail, e-mail, internet, blogs, talks/meetings, brochures, posters, newsletters, printed publications, media releases, sponsorship, etc.

— Specify planning and budget;

— Set up internal communication to improve collaboration among departments.

Entire CAP process exhibiting the main steps and role of key actors are shown in **Table 2.**

Table 2. CAP process: the main steps – role of key actors

PHASE	STEP	ROLE OF THE ACTORS		
		Municipal Corporation or equivalent body	Local administration	Stakeholders
Initiation	Political commitment and signing of the Covenant	Make the initial commitment. Sign the Covenant of Mayors Provide the necessary impulse to the local administration to start the process.	Encourage the political authorities to take action. Inform them about the multiple benefits (and about the necessary resources).	Awareness raising among political authorities to take action (if necessary).
	Mobilize all municipal departments involved	Allocate sufficient human resources and make sure adequate administrative structures are in place (e.g. horizontal offices ensuring collaboration amongst different departments of the administration) to ensure a coordinated action between mitigation and adaptation.		
	Build support from stakeholders and establishing a governance structure	Provide the necessary impulse for stakeholders' participation. Show that you consider their participation and support as important.	Prepare an inventory of the relevant stakeholders, decide what channels of communication/participation you want to use, establish collaboration practices. Inform them about the process that is going to start, and collect their views.	Express their views, explain their potential role in CAPs development and implementation.
Planning phase (Pre-assessment and development	Assessment of the current framework: Where are we?	Make sure the necessary resources are in place for the planning phase.	Conduct the initial assessment, collect the necessary data, and elaborate the CO_2 baseline emission inventory, the climate risks and vulnerabilities assessment and the access to energy assessment. Make sure the stakeholders are properly involved.	Provide valuable inputs and data, share the knowledge.
	Establishment of the vision: Where do we want to go?	Support the elaboration of the vision. Make sure it is ambitious enough. Approve the vision (if applicable).	Establish a long-term vision and objectives that support the vision. Make sure it is shared by the main stakeholders and endorsed by the political authorities.	Participate in the definition of the vision, express their view on the city's future.
	Elaboration of the plan: How do we get there?	Support the elaboration of the plan. Define the priorities, in line with the vision previously defined.	Elaborate the plan: define policies and measures in line with the vision and the objectives, establish budget and financing sources and mechanisms, timing, indicators, responsibilities. Keep the political authorities informed, and involve stakeholders. Make partnerships with key stakeholders.	Participate in the elaboration of the plan. Provide input, feedback. Contribute to initiating and designing the processes.
	Plan approval and submission	Approve the plan and the necessary budgets, at least for the first year(s).	Submit the CAP and Communicate the plan.	Put pressure on political authorities to approve the plan (if necessary)

PHASE	STEP	ROLE OF THE ACTORS		
		Municipal Corporation or equivalent body	**Local administration**	**Stakeholders**
Implementation and monitoring of the CAP	Implementation	Provide long-term political support to the CAP process.	Coordinate the implementation. Make sure each stakeholder is aware of its role in the implementation.	Each stakeholder implements the measures that are under its responsibility and shares the results.
		Make sure that the energy and climate policy is integrated in the everyday life of the local administration.	Implement the measures that are under responsibility of the local authority. Be exemplary. Communicate the actions.	Put pressure / encourage the local administration to implement the measures under its responsibility (if necessary).
		Show interest in the plan implementation, encourage stakeholders to act, show the example.	Motivate the stakeholders to act (information campaigns). Inform them properly about the resources available for EE, RES and adaptation.	Changes in behaviour, EE, RES and adaptation action, general support to CAP implementation.
		Networking with other CoM signatories, exchanging experience and best practices, establishing synergies and encouraging their involvement in the Covenant of Mayors in Sub-Saharan Africa.		Encourage other stakeholders to act
	Monitoring	Ask to be informed regularly about the advancement of the plan.	Proceed to a regular monitoring of the plan: advancement of the actions and evaluation of their impact.	Provide the necessary inputs and data.
	Reporting and submission of the report	Approve the report (if applicable).	Report periodically to the political authorities and to the stakeholders about the advancement of the plan. Communicate about the results. Every second year, submit a report.	Provide comments on the report and report on the measures under their responsibility.
	Review	Ensure that plan updates occur at regular intervals.	Periodically update the plan according to the experience and the results obtained and based on new opportunities. Involve political authorities and stakeholders.	Participate in plan update.

Source: adapted from: Bertoldi P. (editor),2018. Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030.

Figure 8 depicts CAP process followed by seven Indian cities as per GCoM's Common Reporting Framework.

Figure 8: Pictorial Depiction of CAP Process in India

Source: https://www.globalcovenantofmayors.org/journey/

With support from EU-IUC seven cities, as shown in **Figure 9**, in India have formulated their CAPs using CRF. Of these seven cities, cities of Vadodara, Bhavnagar, Gandhinagar, Panaji and Gangtok did not have any prior experience of preparing CAPs while Surat and Kochi worked in areas of Climate Change and Urban Resilience earlier.

Figure 9: Under EU IUC program Seven Indian Cities prepared CAPs

Source: EU IUC India

Figure 10 shows which steps were undertaken by seven Indian cities while carving out their Climate Action Plan.

Figure 10: Steps undertaken by seven Indian cities for CAP

Source: IUC India

As of February 2021, twenty-two Indian cities have signed the Global Covenant of Mayors for Climate and Energy, 7 cities out of them are the first ones to embark on the development of their CAPs.

4 Climate Action Plan (CAP) process planning phase: pre-assessment

This chapter provides detailed guidance throughout the pre-assessment phase of the elaboration of a CAP: Baseline Emission Inventory (BEI) (see section 4.2), Risk and Vulnerability Assessment (RVA) (see sextion 4.3) and Access to Energy Assessment (see section 4.4).

4.1 Assess current policy framework on mitigation, adaptation & access to energy

Before starting the detailed planning process at the municipal level, it is recommended to review the policy framework in which the plan will be established – taking into consideration relevant international frameworks, national policies and regulations as well as existing strategies and plans at the regional and local level.

A review of the existing policy and regulatory framework is a good starting point towards better policy integration and makes sure that potential synergies or conflicting policies and procedures are addressed early on in the planning process.

A first step is to identify the existing municipal, regional and national policies, plans, procedures and regulations that affect energy and climate issues within the local authority (Annex 8). For example, National Adaptation Strategies serve as a good entry point for existing information on adaptation at country level. The National Adaptation Fund for Climate Change (NAFCC) was established in August 2015 to meet the cost of adaptation to climate change for the State and Union Territories of India that are particularly vulnerable to the adverse effects of climate change ([30]). Cities sometimes can also build on existing national RVAs and available climate projections, and may come across adaptation-related instruments, but also ongoing actions at the city level (i.e. disaster risk reduction, biodiversity protection, land use planning, existing regional or sectoral plans).

The next step is to go through, check and compare the objectives and goals in the identified documents with the ones for a sustainable energy policy and resilient sectoral development. The aim is to establish whether these objectives and goals are supporting or conflicting. If such conflicts are detected in policy goals, ideally, they should be amended and aligned with the CAP goals. In order to do so, the local authority should, where possible, invite all the relevant actors and stakeholders to discuss the conflicts identified, trying to reach an agreement on the changes that are necessary to update policies and plans.

Box 08. International policy frameworks for CAP development

SUSTAINABLE DEVELOPMENT GOALS:

In 2015, more than 150 world leaders pledged common action to protect the planet and ensure prosperity for all. They adopted the new 2030 Agenda for Sustainable Development, including the SDGs. Each goal has specific targets to be achieved over the next 15 years. The SDGs recognize the massive role of energy access (SDG 7) and the interdependency with other SDGs, including economic growth (SDG 8), infrastructure (SDG 9), making cities and communities more resilient and sustainable (SDG 11) and climate change (SDG 13).

SUSTAINABLE ENERGY FOR ALL:

The Sustainable Energy for All (SE4All) is the global initiative, led by former UN Secretary General Ban Ki-moon. It is the instrumental partnership that accelerates action toward achievement of SDG7, universal access to sustainable energy by 2030, and the Paris Climate Agreement, reducing greenhouse gas emissions to limit global warming to below 2 degrees Celsius, compared to pre-industrial levels. Presently, India has identified opportunities for renewable energy development, improved energy efficiency and energy access. India's achievements in the energy sector in recent years have been outstanding. The Government of India is implementing reforms towards a secure, affordable and sustainable energy system to power a robust economic growth ([31]).

PARIS AGREEMENT AND NATIONALLY DETERMINED CONTRIBUTIONS:

([30]) https://www.nabard.org/content.aspx?id=585
([31]) IEA India 2020 Energy Policy Review

As per the Economic Survey of 2020 India is on track to achieve its Nationally Determined Contributions under the Paris Agreement. India has strived to ensure that it follows a growth path that delivers sustainable development and protects the environment by investing in various schemes aligned with its NDC under the Paris Agreement in accordance with principles of equity and common but differentiated responsibilities ([32]).

NEW URBAN AGENDA:

The UN-HABITAT III conference held in Quito in late 2016 revolved around the first SDG with an exclusively urban focus. In India, UN-Habitat is devising an integrated and demand-driven approach that combines refining urban planning and design frameworks, providing infrastructure upgrading policy and technical guidance, implementing pilot projects for learning-by-doing, and mainstreaming innovations through testing technology solutions to transform India's urban landscape. UN-Habitat interventions are focused under following broad pillars -

- Safe, Inclusive, Resilient and Sustainable Cities and Regions: To improve policy for inclusive planning and sustainable development.
- Affordable, Green, and Resilient Housing Environment: To design tools and mechanisms to promote social housing.
- Promote Safe, Well Planned and Serviced Neighborhoods: To promote sustained economic and social mobility.
- Accountable and Efficient Urban Governance: To ensure sustained universal access to basic services and resilient livelihoods.

Knowledge Systematization and Learning: To empower city authorities to effectively and efficiently mainstream SDG-11.

Box 09. Indian policy frameworks for CAP development

1. Urban Transport ([33])

Urban Transport Wing of Ministry of Urban Development is the nodal division for coordination, appraisal and approval of Urban Transport matters including Metro Rail Projects at the central level. All the interventions in the urban transport by the Ministry of Urban Development such as Bus Rapid Transit System (BRTS), urban transit infrastructure or financing of metro rail projects etc, are carried out as per the provisions of National Urban Transport Policy, 2006.

2. Smart Cities Mission ([34])

The Government of India has launched the Smart Cities Mission on 25 June 2015. The objective is to promote sustainable and inclusive cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on sustainable and inclusive development and the idea is to look at compact areas, create a replicable model which will act like a lighthouse to other aspiring cities. The Smart Cities Mission is meant to set examples that can be replicated both within and outside the Smart City, catalysing the creation of similar Smart Cities in various regions and parts of the country.

3. Climate Smart Cities Assessment Framework (CSCAF 2.0) ([35])

([32]) https://pib.gov.in/PressReleasePage.aspx?PRID=1601251
([33]) http://mohua.gov.in/cms/Schemes-and-other-initiatives.php
([34]) http://smartcities.gov.in/content/
([35]) https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf

The Government of India has eight missions under the National Action Plan on Climate Change (NAPCC) to address the impact of climate change. The National Mission on Sustainable Habitat is one of the eight climate missions and, aligning to the National Mission on Sustainable Habitat, the Smart Cities Mission under the Ministry of Housing and Urban Affairs (MoHUA) launched "Climate Smart Cities Assessment Framework" in February 2019. This framework was first-of-its-kind city assessment framework on climate relevant parameters, including those of the recently launched National Clean Air Programme. The "Climate Smart Cities Assessment Framework" serves as a tool for cities to assess their present situation and provides a roadmap for cities to adopt and implement relevant climate actions.

In addition, the dissemination of best practices adopted by Indian cities has supported in setting contextual standards in green, sustainable and resilient urban development. The objective of this framework is to provide a roadmap for Indian cities in combating climate change. The Climate Smart Cities assessment framework consists of indicators across five categories namely; (i) Energy and Green Buildings, (ii) Urban Planning, Green Cover and Biodiversity, (iii) Mobility and Air Quality, (iv) Water Management and (v) Waste Management.

The framework provides assessment of both, mitigation and adaptation measures. The indicators are progressive in nature to support cities in assessing where they stand and encourage them to adopt appropriate actions enabling them to improve their score in the future and consequently build climate resilience. To enable this progress, MoHUA aims to conduct the assessment on an annual basis.

4. Swachh Bharat Mission (Clean India Mission) ([36])

The Swachh Bharat Mission - Urban (SBM-U), launched on 2nd October 2014 aims at making urban India free from open defecation and achieving 100% scientific management of municipal solid waste in 4,041 statutory towns in the country. Main objectives of the mission are mentioned below:

Elimination of open defecation

Modern and Scientific Municipal Solid Waste Management

To effect behavioural change regarding healthy sanitation practices

Generate awareness about sanitation and its linkage with public health

Capacity Augmentation for ULB's

To create an enabling environment for private sector participation in Capex (capital expenditure) and Opex (operation and maintenance)

5. Atal Mission for Rejuvenation and Urban Transformation (AMRUT)([37])

The Government of India has launched the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) with the aim of providing basic civic amenities like water supply, sewerage, urban transport, parks as to improve the quality of life for all, especially the poor and the disadvantaged. The focus of the Mission is on infrastructure creation that has a direct link to provision of better services to the citizens.

The purpose of "AMRUT" mission is to (i) ensure that every household has access to a tap with assured supply of water and a sewerage connection (ii) increase the amenity value of cities by developing greenery and well maintained open spaces e.g. parks and (iii) reduce pollution by switching to public transport or constructing facilities for non-motorized transport e.g. walking and cycling.

The major project components are Water Supply system, Sewerage, Septage, Storm Water Drainage, Urban Transport, Green Space and Parks, Reforms management and support, Capacity building etc. in that order of priority. The universal coverage of water supply and sewerage services have first charge in the Mission. There is maximum allocation of 2.5% of project cost for development of parks with children and elderly friendly features.

The Mission covers covering 500 cities that includes all cities and towns with a population of over 100,000 with notified Municipalities.

India's Initiative at the International Stage:

([36]) https://swachhbharatmission.gov.in/sbmcms/index.htm
([37]) http://amrut.gov.in/content/

In the Solar Sector, the International Solar Alliance (ISA) has institutionalized 30 fellowships from the member countries; got the lines of credit worth US$2 billion from EXIM Bank of India and US$1.5 billion from Agence Francaise de Development (AFD), nurtured initiatives like the Solar Risk Mitigation Initiative and developed tools to aggregate demand for 1000 MW solar panels.

India recently launched the Coalition for Disaster Resilient Infrastructure (CDRI) on sidelines of UN Secretary General's Climate Action Summit in September 2019. CDRI aims to promote resilience of new and existing infrastructure systems to climate and Disaster Risks to reduce the infrastructure losses from Disasters.

India recently hosted the 14th session of the Conference of Parties (COP 14) to the United Nations convention to Combat Desertification (UNCCD) from 2-13 September 2019. The New Delhi declaration: Investing in Land and Unlocking Opportunities was adopted in the COP 14. India also announced support for enhanced South-South cooperation. Global Water Action Agenda for land water management was also launched

4.2 Baseline Emission Inventory (BEI)

4.2.1 Principles and requirements for emission accounting

By developing a Baseline Emission Inventory (BEI) a local authority is measuring its GHG emission level in a base year, according to a common methodological approach. It identifies the principal anthropogenic sources of CO_2 (and other GHGs) emissions and prioritises the reduction measures accordingly. In these guidelines, the requirements for emission inventories and reporting outlined in the Common Reporting Framework (CRF) under the GCoM ([38]) are explained, and advice and recommendations for compiling the BEI and successive monitoring emission inventories (MEIs) under the GCoM are provided.

The BEI will show where the local authority (LA) was at the beginning (in its baseline year), and the successive MEIs will show the progress towards the target set by the LA. Elaborating these reference emission inventories is of critical importance, as they will be the instrument allowing the LA to measure the impact of its CAP and adjust it over time. They are also very important elements to maintain the motivation of all parties willing to contribute to the local authority's emissions reduction objective, allowing them to see the results of their efforts.

Box 10. Tips on language used

To indicate which provisions of the GCoM CRF are requirements and which are optional, language is used as follows:

The term "shall" is used to indicate what is required (indicated as "mandatory").

The term "should" is used to indicate a recommendation, so is not a requirement (indicated as "recommended").

The term "may" is used to indicate an option that is permissible or allowable that local governments may choose to follow (indicated as "optional").

Box 11. Notation keys

Notation keys may be used to accommodate limitations in data availability and differences in emission sources between local governments. Where notation keys are used, an accompanying explanation shall be provided.

"NO" (not occurring): An activity or process does not occur or exist within the city. This notation key may also be used for insignificant sources.

([38]) In order to ensure robust climate action planning, implementation and monitoring phases, as well as streamline measurement and reporting procedures, a set of new global recommendations have been developed by the GCoM in consultation with partners, cities and local governments around the world, with the intention of providing flexibility to meet specific local or regional circumstances. The common reporting framework can be found at: https://www.globalcovenantofmayors.org/common-global-reporting-framework/.

"IE" (included elsewhere): GHG emissions for this activity are estimated and presented in another category in the same inventory, stating where it is added. This notation key may be used where it is difficult to disaggregate data into multiple sub-sectors.

"NE" (not estimated): GHG emissions occur but have not been estimated or reported, with a justification why.

"C" (confidential): GHG emissions which could lead to the disclosure of confidential information, and as such are not reported publicly.

The GCoM principles, concepts and methodologies to elaborate an emissions inventory are presented in **Error! Reference source not found.**, followed by recommendations and tips on the data collection of energy-related activity sectors.

4.2.1.1 *Principles for emission accounting*

The emission inventory should conform to the following principles:

- *Relevance*: The Emission Inventory data should allow assessing final energy consumption and CO_2 emissions by energy carrier and by activity sector. They should be relevant to the particular situation of the local authority. Signatories are encouraged to prefer local data over national estimates – whenever relevant and available – as it allows reflecting the efforts made the LA to reach its CO_2 reduction targets.
- *Flexibility*: The methodology is based on the principles of simplicity of use and flexibility to suit various regional and local situations, and accommodate cities of various sizes and resources, reflecting the specific activities and policy-making needs of the city by taking into account its capacity and regulatory context.
- *Completeness*: The GCoM emission inventories are not meant to be exhaustive GHG inventories but to focus on emissions from final energy consumption in GCoM key sectors (see details below). In order to be complete, the emission inventories shall cover all emission sources included in the GCoM framework in these sectors.
- *Data availability*: The data should allow building emission inventories until the target year. Therefore, the sources of data used should be available in the future: it is important to identify from the beginning all the data sources, including departments and external stakeholders that likely will be able to provide data over such a long time period.
- *Accuracy*: Within the limits of possibility, the emission inventories should be accurate, or at least represent a vision of the reality. This requires, in particular, using reliable local activity data and robust methodologies, based on internationally agreed definitions, standards and emission factors, including those presented in this guidebook.
- *Consistency*: The methodology, data sources and emission factors should be in line with GCoM specifications and consistent through the years. When defining the methodology, it is important to ensure a consistent choice of the different options.
- *Documentation*: The data collection process, data sources and methodology for calculating the emission inventory should be well documented, if not in the CAP official document ([39]), then at least in the local authorities' records. The methodological choices and the main aggregated results of the emission inventories should be included in the CAP document.

4.2.1.2 *Reporting requirements*

The emission inventory should be elaborated based on a sound knowledge of the local situation in terms of energy use and greenhouse gas emissions. The requirements for accounting the emissions in the inventory are based on the sources, the type of GHGs and the boundary of the inventory. Each of these elements will be defined in further detail in the following sections.

Acquiring this sound knowledge may require some initial efforts by the local authority and a close collaboration with local expertise like universities, consultants and NGOs and in some cases external technical

([39]) See chapter 5 of this guidebook for further details on how to elaborate a CAP.

assistance. However, it should be stressed that the picture acquired is extremely useful both for the CAP and service delivery planning in the local government. In this respect, the CAP process can be complementary to existing activities and goals, particularly where capacity is constrained.

Local authorities should use **activity-based emission factors** (also referred to as IPCC emission factors) for GHG emissions reporting at the national level. The emission reporting unit to be chosen is **"tonnes CO_2 equivalent"**. The emissions of other greenhouse gases than CO_2 are converted to CO_2-equivalents by using the Global Warming Potential (GWP) values (see **Error! Reference source not found.**), which shall be kept constant all along the CAP implementation period. At the date of the preparation of this document, **two reporting platforms are accepted in the GCoM framework**: My Covenant ([40]), and the CDP/ICLEI Unified Reporting System([41]).

Box 12. LCA and Activity based Approach

Life cycle assessment

A widely used technique defined by ISO 14040 as a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle". The results of LCA studies are strongly dependent on the system boundaries within which they are conducted. The technique is intended for relative comparison of two similar means to complete a product. The approach considers the overall life cycle of the fuels/electricity. This includes all emissions of the energy chain that also take place outside the territory (such as transport losses, refinery emissions or energy conversion losses). It is particularly suitable for assessing potential trade-offs between different types of environmental impacts associated with specific policy and management decisions, as it includes the emissions from the whole supply chain and not only from the final combustion. This is of special relevance for biofuels and biomass ([42]).

Activity based approach

In the activity-based approach, all the direct GHG emissions or indirect emissions (due to consumption of grid supplied energy) are included. The GHG emissions are directly estimated from the carbon content of the fuel, though a small amount of carbon is un-oxidized (less than 1 %). It is the approach used for the national reporting in the frame of UNFCCC. Most of the GHG emissions are CO_2 emissions, whereas emissions of CH_4 and N_2O are of secondary importance for the combustion processes in the residential and transport sectors.

The **geographical boundaries** of the "local territory" are the administrative boundaries of the entity (municipality, region) governed by the local authority, which is a signatory to the GCoM, and shall remain the unchanged over time for consistency reasons.

4.2.1.2.1 Type of emissions to be included

Local authorities shall account for emissions of the following gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) ([43]). The three main sources of GHG emissions to be potentially included in the emission inventory are ([44]):

1) **Direct emissions** due to fuel combustion in the buildings, equipment/facilities and transportation sectors within the city boundaries. These emissions physically occur inside the city boundary ([45]).
2) **Non-energy related:** Other direct emissions that are not related to fuel combustion, including: fugitive emissions from disposal and treatment of waste (including wastewater) generated within the city

([40]) https://mycovenant.eumayors.eu/site/landing
([41]) https://www.cdp.net/en/guidance/guidance-for-cities
([42]) In these guidelines, biofuel refers to all liquid/gaseous biofuels and biomass to solid biomass.
([43]) When reporting IPPU, it will include hydro fluoro-carbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3).
([44]) Emissions from biogenic carbon are not required to be reported
([45]) These are often referred to as Scope 1 emissions in some other commonly used GHG inventory standards

boundaries, which may occur inside or outside the city boundary ([46]), and fugitive emissions from natural gas distribution systems (such as equipment or pipeline leaks).

3) **Indirect emissions** due to consumption of grid-supplied energy (electricity, heat or cooling) within the geographic boundary ([47]). Depending on where energy is generated, these emissions may occur inside or outside the city boundaries.

The points 1) and 2) refer to emissions that physically occur in the local territory. Inclusion of these emissions follows the principles of the IPCC used in the reporting of the national GHG inventories to the United Nations Framework Convention on Climate Change (UNFCCC, 2017).

4.2.1.2.2 Emission sources

Under the GCoM, **LAs shall consider all categories of emission sources and report all emissions that are significant**. Exclusion of emission sources shall be disclosed and justified, using notation keys. Local authorities shall report activity data ([48]) and emission factors for all sources of emissions, disaggregated by activity / fuel type. Based on these principles, **LAs shall report GHG emissions from the main sectors described in the following** Error! Reference source not found.**.**

LAs should also report GHG emissions from Industrial Processes and Product Use (IPPU) and Agriculture, Forestry and Other Land Use (AFOLU) sectors where these are significant ([49]).

Table 3. Emission sources to be included in the emission inventory

Type of Emission sources	
Stationary energy	All GHG emissions (direct emission from fuel combustion and indirect emission due to consumption of grid-supplied energy) occurring in stationary sources within the local authority boundary **shall** be reported. These emissions come from final energy consumption in residential, commercial and institutional buildings and facilities, as well as from industrial buildings and facilities ([50]) and agriculture/forestry/fisheries. GHG emissions from sources covered by a regional or national emissions trading scheme (ETS), or similar, should be identified. GHG emissions from "energy generation" industries **should not** be reported under this sector to avoid double counting of emissions. All fugitive emissions within the city boundary **shall** be reported.
Transportation	All GHG emissions (direct emission from fuel combustion and indirect emission due to consumption of grid-supplied energy) occurring for transportation purposes within the local authority boundary **shall** be reported. In addition, local authorities **shall where possible** further disaggregate by mode: on-road, rail, waterborne navigation and off-road and it is recommended to disaggregate road and rail travel by fleet type: municipal, public, private and commercial transport. Local authorities may use the "fuel sales", "geographic (territorial)", "resident activity" and "city-induced" methodologies to estimate activity data in the transport sector (see section

([46]) Emissions occurring outside the city boundary as a result of city activities, such as emissions from waste generated by the city but treated outside the city boundary, are often referred to as Scope 3 emissions in some other commonly used GHG inventory standards.
([47]) These are often referred to as Scope 2 emissions in some other commonly used GHG inventory standards
([48]) Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period of time (e.g., volume of gas used, kilometres driven, tons of solid waste sent to landfill, etc.).
([49]) Guidance note accompanying the Global Covenant of Mayors Common Reporting Framework
([50]) This includes all emissions from energy use in industrial facilities, construction activities, and energy industries, except emissions from the generation of energy for grid-distributed electricity, steam, heat and cooling.

Type of Emission sources	
	Error! Reference source not found. for further details).
Waste / Other non - energy related	Non energy –related GHG emissions from disposal and treatment of waste and wastewater generated within the city boundaries **shall** be reported and disaggregated by treatment type. Where waste/wastewater is used for energy generation, emissions **should not** be reported under this sector to avoid double counting of indirect emission (instead the notation key IE should be used).
Energy Supply	All GHG emissions from generation of grid-supplied energy within the local authority boundary, and all GHG emissions from generation of grid-supplied energy by facilities owned (full or partial) by the local authority outside the local authority boundary **shall** be reported, disaggregated by electricity-only, CHP and heat/cold production plants. *To avoid double counting, these emissions* ***will not be part*** *of the total direct emissions but accounted through the local emission factor for indirect emissions.* In addition, local authorities are **recommended** to report all activity data for distributed renewable energy generation.

Source: JRC own elaboration.

4.2.2 Emissions inventories

For some activities, local governments may be able to use direct measurements of GHG emissions (e.g., through use of continuous emissions monitoring systems at power stations). However, for most emission sources, local governments will need to estimate GHG emissions. To build the emission inventories, the GHG emissions from final energy consumption are calculated for each energy related activity sector, by multiplying the activity data by the emission factor per energy carrier (electricity, heat/cold, fuels).

Box 13. How to calculate GHG emissions from activity data?

(Equation 1) GHG Emissions = Activity data x Emission factor

Activity data quantifies the human activity occurring in the local territory.
Examples of activity data are: amount of natural gas used for space heating in residential buildings, measured in MWh; distance travelled by private car journeys, measured in vehicle kilometres travelled (VKM); amount of waste sent to landfill, measured in Tonnes. The main activity data in the GCoM key sectors are related to final energy consumption, disaggregated per type of energy carrier. The energy carrier refers to the form of energy input (electricity, heat/cold, fossil fuels, municipal waste or renewable energy) required by the energy-related activity sectors of the society to perform their functions.

Emission factors are coefficients which quantify the emissions associated with each unit of activity, for example: amount of CO_2 emitted per litre of petrol combusted, amount of CH_4 emitted per tonne of waste sent to landfill. The local authority can either use local emission factors (based on the detailed properties of the fuels used) or default (national/global) emissions factors, such as the IPCC (2006).
In order to ensure the consistency of the time-series, the local authorities using national/global EFs shall apply the same emission factors to all inventories (base year and monitoring years), in order to identify the changes in local emissions that are due to local mitigation actions. Only when local emission factors reflecting changes in the fuel properties are used, different emission factors may be used in the emission inventories.

The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis. Converting the amount of consumed fuel to energy units using Net Calorific Values ([51]) (NCV) allows aggregating all the data. NCV values for different types of fuels are available as default (IPCC, 2006)

([51]) A calorific value is a conversion factor (e.g. in MWh/t, MJ/l) used to convert a fuel quantity between natural units (mass or volume) and energy units (energy content).

and country specific (e.g., IEA, 2017) values. All the energy related activity data shall be reported in MWh. The conversion factor from the other commonly used energy units is provided in Error! Reference source not found..

Table 4. Conversion table of basic energy units

To	TJ	Mtoe	GWh	MWh
From	Multiply by:			
TJ	1	2.388×10^{-5}	0.2778	277.8
Mtoe	4.1868×10^{4}	1	11630	11630000
GWh	3.6	8.6×10^{-5}	1	1000
MWh	0.0036	8.6×10^{-8}	0.001	1

Source: JRC own elaboration.

The following sections provide recommendations and tips, based on GCoM key concepts and guiding principles for building an emission inventory for the data collection regarding local sources of GHG in the GCoM activity sectors.

4.2.2.1 *Buildings/ stationary energy*

The stationary energy sources are among the largest contributors to energy consumption in urban areas and also the sectors on which local authority has generally a large degree of influence. The focus of the GCoM is to reduce direct and indirect emissions in these sectors. The subsectors described in Error! Reference source not found. are mandatory and thus shall be covered in the emission inventory.

Table 5. Buildings/stationary sources accounted in the emission inventory.

Buildings/Stationary energy Sector	
Subsector	**Description**
Institutional / Municipal buildings and facilities	All final energy consumption and related GHG emissions occurring in buildings and facilities public or owned by the local authority for cooking, heating & cooling, lighting and appliances usage; e.g. government offices, schools, police stations, hospitals, public lighting. All final energy consumption (and related GHG emissions) due to operation (ex. electricity for pumping, natural gas for heating, etc.) of municipal water supply system, solid waste and wastewater treatment and disposal facilities are also included here. All non-energy related emissions (e.g. methane) produced in these facilities shall be reported under Waste sector.
Commercial/ Tertiary buildings and facilities	All final energy consumption and GHG emissions occurring in buildings and facilities of the tertiary sector (services) cooking, heating & cooling, lighting and appliances usage; e.g. offices of private companies, banks, commercial and retail activities, private schools, hospitals, etc. All final energy consumption (and related GHG emissions) due to operation (ex. electricity for pumping, natural gas for heating, etc.) of private water supply system,

Buildings/Stationary energy Sector	
Subsector	**Description**
	solid waste and wastewater treatment and disposal facilities are also included here.
Residential buildings	All final energy consumption and GHG emissions occurring in buildings (including informal settlements and social housing) that are primarily used as residential buildings for cooking, heating & cooling, lighting and appliances.
Industrial Buildings and facilities	All energy consumption and GHG emissions occurring in industrial (manufacturing and construction industries) buildings and facilities. Also GHG emissions from sources covered by a regional or national emissions trading scheme (ETS), or similar (e.g. above 20 MW as thermal energy input), should be identified. Energy generation industries should not be reported here (to avoid double counting).
Agriculture/ Forestry/Fisheries	Emissions from energy use in agriculture, forestry and fishing activities, including energy use associated with plant and animal cultivation, afforestation and reforestation activities, and fishery activities. This could include for example the on-site operation of farm vehicles and machinery, generators to power lighting, pumps and heaters.
Fugitive emissions (52)	All fugitive emissions from the extraction, transformation and transportation of primary fossil fuels within the city boundaries, including: 1)Fugitive emission from mining, processing, storage and transportation of coal 2)Fugitive emissions from oil and natural gas systems, such as equipment or pipeline leaks, evaporation and flashing losses, venting, flaring, incineration, and accidental releases etc.

Source: JRC own elaboration.

4.2.2.2 *Activity data collection*

Collecting information from every individual energy consumer within the local territory is not always possible or practical. Therefore, a variety of approaches are likely to be needed to develop an estimate of energy consumption. Several options are available, and often a combination of them is necessary to have an overall picture of the energy consumption within the local territory (see Error! Reference source not found.). Before starting the data collection process, it is recommended to investigate if there are already national or regional mechanisms, which could help to collect relevant data for the building of the local GHG inventory (see **Error! Reference source not found.**).

(52) This is usually a small emission source in a city. Emissions data may be directly measured at facility level, or cities can estimate emissions using default emission factors from national inventories or the IPCC.

Figure 11: Step by step guidance for emission data collection

Source: Covenant of Mayors in Sub-Saharan Africa (CoM SSA). Guide available at http://comssa.org/wp-content/uploads/2018/07/data-collection-low-res.pdf

Open Government Data (OGD) Platform is a platform for supporting Open Data initiative of Government of India. The portal is intended to be used by Government of India Ministries and Departments to publish their datasets, documents, services, tools and applications collected by them for public use. Certain selected data related to water, transport, health and economy can be accessed by cities for its CAPs ([53]).

Further, in India Smart cities continuously strive towards making the right data available to the right people at the right time to help build solutions to complex urban challenges. City Governments deal with a large number of issues like mobility, management of water, waste water and solid waste, safety and security services, energy, housing, education and health amongst many others. Data pertaining to these sectors can directly be accessed by City. The Smart Cities Mission-Ministry of Housing & Urban Affairs intends to harness IoT potential through its 'DataSmart' Cities Strategy ([54]).

([53]) https://data.gov.in/about-us
([54]) https://smartcities.data.gov.in/

Table 6. Steps of the activity data collection

STEP	ACTION
1	Getting data for municipal/institutional buildings and facilities
2	Getting data from regional/ national sources
3	Getting data from the market operators
4	Getting data from a consumer survey
5	Making and reporting estimates

Source: JRC own elaboration.

Each of these 5 steps is explained in more detail below.

Step 1 - Getting data for municipal/institutional buildings and facilities

Firstly, the local authority should be able to collect accurate and comprehensive final energy consumption data related to its own buildings and facilities. Well-advanced local authorities already have a full energy accounting system in place. For other local authorities who have not yet initiated such a process, the energy data collection could require the following steps (Error! Reference source not found.).

The local authority should be able to collect all data regarding public lighting. If it is not the case, an identification and data collection process similar to the one indicated in the previous paragraph may have to be initiated. In some cases, it may be necessary to place additional meters, for instance when an electricity supply point feeds both public lighting and building/facilities.

Table 7. *Activity* data collection steps for institutional buildings

STEP	ACTION
1	Identify all buildings and equipment/facilities owned/managed by the Local Authority
2	Identify all energy delivery points (electricity, natural gas, fuel oil tanks...)
3	Identify the person / department receiving the invoices and energy data
4	Organise a centralised collection of these documents/data
5	Select an appropriate system to store and manage the data (a simple spreadsheet or elaborated software)
6	Make sure the data is collected and introduced in the system every year. Tele measurement can ease the process of data collection.

Source: JRC own elaboration.

Note that this process of data collection may be the opportunity to deal with other important energy related issues:

a. Rationalise the number of energy delivery and invoicing points; regarding heating oil or other energy carriers delivered periodically as bulk, it is often preferable to install a measurement device (gauge, metre …) to help determine exactly the quantity of energy consumed during a given period. An alternative is to assume that the fuel purchased each year is equal to fuel consumed. This is a good assumption if the fuel tanks are filled at the same period each year, or if many deliveries of fuel occur each year.

b. Renew/improve contractual arrangements with energy suppliers; if the local authority buys electricity from renewable sources with guaranteed origin or similar, this will not affect its energy consumption, but it may be counted as a bonus to improve the CO_2 emission factor.

c. Initiate a real energy management process within the local territory: identify buildings which consume most energy and select them for priority action, such as daily/weekly/monthly monitoring of energy consumption allowing identifying abnormalities and taking immediate corrective action.

Step 2 - Getting data from regional/ national sources

National central databases and tools:

Before starting the data collection process, it is valuable to check what local data is already available at regional or national level (from statistical, energy, environmental or economic ministries or agencies or from regulatory authorities for gas and electricity). Table 8 provides examples of regional/national data centres providing energy and GHG emissions data to the local authorities (Error! Reference source not found.).

Table 8. Examples of regional/national energy data collection.

Data Source	Description of Availability of Data
National Sample Survey Organization of Ministry of Statistics of the Government of India (NSSO) http://www.mospi.gov.in/nsso	Consumer expenditure
Centre for Monitoring Indian Economy (CMIE) https://www.cmie.com/	Economic and business databases
The Energy and Resources Institute https://www.teriin.org/	Energy, environment, climate change and sustainability
National Institute of Urban Affairs (NIUA) https://www.niua.org/	Cutting-edge research in the urban sector, innovative solutions, challenges of a fast urbanization. Climate change, Smart cities, and Urban Resilience
Ministry of Power, Government of India https://powermin.nic.in/	Electrical energy.
Ministry of New and Renewable Energy https://mnre.gov.in/	New and renewable energy.

Source: JRC own elaboration.

Step 3 - Getting data from the market operators

When demand side data is not available it becomes essential to compile data from supply side. In many cities when coal is consumed as fuel, its data is to be compiled from its market supply. In order to get data from market operators, local authorities have to identify which suppliers are active on their local territory and prepare a table that they would have to fill. As several energy suppliers may be active, it may be simpler to contact grid operators (for heat, gas and electricity) whenever possible (it is not very likely that more than one of them is active on the local territory, for each energy carrier).

Because such data is generally considered as commercially sensitive, in the best case it will probably be possible to only get aggregated data. Ideally, a disaggregation between the residential, tertiary and industry activity sectors, for the different energy carriers for all the wards that relate to the local municipality should be obtained.

If a greater level of disaggregation is available, then it is recommended to ask for it (e.g. to distinguish between the various sub-sectors for services and industry, private or public, individual houses or apartments).

Other interesting information relates to the names and addresses of the largest energy consumers within the local territory, and their overall energy consumption (individual energy consumption is not likely to be available as it would be commercially too sensitive). This may be useful for targeted actions and questionnaires (see step 4).

In the absence of an established practice at national level, it is highly recommended to require that the communicated results are delivered with detailed information on the assumptions made when aggregating the results (e.g. the definition of the sectors). This information should be useful for the supplier when repeating the procedure for the subsequent inventories and should be stored and used in further correspondence during the monitoring phase.

Step 4 - Getting data from a consumer survey

If not all data can be obtained in the desired format from the market operators or from other entities, it may be necessary to make some inquiries directly to the energy consumers, in order to obtain the missing data. This is especially the case for energy carriers which do not pass through a centralised grid (fuel oil, wood, natural gas supplied in bulk, etc.). If it is not possible to identify all suppliers active in the local territory and to get data from them, it may be necessary to ask the consumers themselves.

It is worth bearing in mind that energy or statistical agencies may already be collecting such data, so make sure that data is not available elsewhere before considering sending a questionnaire.

Several options are possible:

- For sectors where there is a large number of small consumers (like the residential sector), it is recommended addressing a questionnaire to a representative sample of the population (depending on the size of the population ([55]), spread over all districts of the Local Authority. The questionnaire may be online, but in this case make sure that this does not prevent some categories of customers from providing data, otherwise the results will be biased.
- For sectors where the number of players is limited, it may be worthwhile addressing the questionnaire to all energy consumers (this may be the case for example for the industrial sector).
- For sectors where there is a great number of players, but where there are some large ones (e.g. tertiary sector), it may be worthwhile making sure to address the questionnaire at least to all large players (e.g. all supermarkets, hospitals, universities, housing companies, large office buildings, etc.). Their identification can be done through previous knowledge, statistical or commercial data (such as telephone directories) inquiry to the grid operator (ask who the main electricity/gas consumers in the local territory are). Another option to identify large electricity consumers is to ask grid operators the identity all consumers connected to the middle and high voltage distribution networks (or even to the transmission network in some rare cases).

([55]) Using sample size calculator, e.g. https://www.checkmarket.com/sample-size-calculator/

What to ask?

It may be tempting to ask a lot of questions in the questionnaire (e.g. "is your building insulated?", "do you have solar panels?", "have you recently done energy efficiency improvements?", "do you have air conditioning?" etc.).

However, it should be kept in mind that it is very important to keep the questionnaire simple and short (1 page), in order to obtain a satisfactory rate of answers. Besides the type and quantity of energy consumed and eventual local energy production (renewable, CHP, ...), 1 or 2 questions related to indicators of energy consumption (e.g. floor space (m^2) of a building, number of inhabitants, number of pupils in a school) could be included for comparison or extrapolation purpose. For industry or services, ask the sector they belong to (propose some categories, if possible). For the residential sector, it is useful to ask questions that would allow extrapolation of the collected data. This depends on what kind of statistical information is available at the municipal level. It could be for example: household size (number of occupants), class of revenue, location (postal code and/or rural/urban area), dwelling type (detached house, semi-detached house or apartment), size of the dwelling (m^2), etc.

Box 14. Tips to build a questionnaire

- Make sure the questions are clear and precise so that they will be understood by all in the same manner. Provide some short instructions if necessary.
- To increase the amount and quality of answers, inform clearly about the purpose of the questionnaire (energy statistics and not tax purpose for example). Motivate people to answer (for example, inform that the questionnaire allows to measure progress in reaching the CO_2 reduction objectives of the local authority, or provide any other relevant incentive).
- Make the inquiries anonymous (especially in the residential sector) and explain that the data will be kept confidential.
- Do not hesitate to send reminders to those who do not reply on time, in order to increase the rate of answers; and to call directly the largest energy consumers to make sure they reply.
- Make sure that the collected data sample is representative of the population both in terms of the number of people surveyed but also in coverage of income groups. You should be aware that the response rate is generally low and those who respond are generally the most educated and climate-aware, and therefore there is the risk that the data collected is strongly biased, even if the questionnaire was addressed to a representative sample of the population. It may be advisable to organise data collection via face-to-face or phone interviews, especially in the residential sector.
- Decide in advance what you want to do with the data collected, to make sure that you really ask the useful and necessary questions.
- Decide whether using paper-based or digital questionnaires. Collecting data with paper questionnaire is easier but time consuming when it comes to analysing the data. Digital questionnaires providing drop-down menus simplify data processing but require having adequate equipment. Consider the possibility to partner with national institutions to get access to this equipment. Do not hesitate to get the help of specialists (statisticians, incl. from local universities) to design your inquiry. It is advisable to communicate in advance your aims (CAP development) through the local media, explaining the context and expected benefits for your local community.
- Make sure to keep adequate record of the metadata (methodology, timescale and scope of the data collected)

What to do with the data?

Data collected via questionnaires should help the local authority to develop and energy and CO_2 database related to the local territory. Here are few examples of possible usages:

- Aggregated data should be broken down into sectors and sub-sectors, in order to target the actions and measure the results achieved by different target groups.

– Fuel ratios obtained from the sample can be used to assess the overall energy consumption for each individual fuel. For example, if the overall energy and gas consumption for a given sector is available, but not the heating fuel oil consumption, the electricity/fuel oil ratio or the natural gas/fuel oil ratio of the sample can be extrapolated to the whole population, provided that the sample is representative.

– Data on the energy consumption per square metre or per inhabitant in the household sector for different types of buildings and different classes of revenues can be extrapolated to the entire sector using relevant local statistical data.

Ideally, this kind of exercise should be done with the help of statisticians to make sure the data collected and method of extrapolation provide results that are statistically meaningful. In addition, checks should be carried out to make sure that the overall results are compatible with the data available at a more aggregate level.

Step 5 - Making and reporting estimates

The energy consumption estimated from the data collected will then need to be disaggregated (e.g. between biofuels/non biofuels fractions) or aggregated into the GCoM energy carrier categories and activity sectors. Only if energy consumption data cannot be disaggregated between all above individual activity sectors, aggregated data can be reported at the level of the macro-sector.

The level of energy consumption and related CO_2 emissions in buildings is linked to a significant number of parameters related to construction design and the usage of the facilities. The main variables on which it is convenient to undertake actions to reduce the energy consumption are:

- Geometry, orientation, urban design and functional design of the building;
- Usage patterns and levels of indoor comfort;
- Building envelope, such as insulation, windows and solar protections;
- Equipment and systems, such as type of heat boilers, air conditioners and lighting;
- On-site energy production and renewable energy sources (RES), such as photovoltaic (PV) and thermal collectors;
- Building automation and control systems, able to continuously monitor, analyse and adjust the energy usage.

4.2.2.2.1 Final energy consumption in the building stock

Key aspects in the assessment of the final energy consumption in the building stock are the following:

- Share of built-up areas in residential sector (formal/informal), commercial and industrial sectors;
- Share of households with access to electricity;
- Share of households using fuelwood and or charcoal;
- Typology of the existing building stock: end-usage (residential, commerce, services, social…), age, thermal insulation and other energy-related characteristics, energy consumption and trends (if available), protection status, rate of renovation, tenancy, etc.;
- Characteristics and energy performance of new constructions and major renovations; minimal legal energy requirements for new constructions and major renovations;
- Existence of initiatives for the promotion of energy efficiency and deployment of renewables in the various categories of buildings. What results have been achieved?

Two methods are available for estimating the final energy consumption in the building stock ([56]):

Scaling national data: the share of final energy consumption in the local authority per type of energy carrier (charcoal, electricity, etc.) is similar to the share of the national energy consumption. In this case the activity data at municipal level can be calculated using the national level ones by using the following formula.

([56]) http://www.cityenergy.org.za/uploads/resource_461.pdf

$$Activity\ data\ at\ municipal\ level\ = \frac{Local\ Authority\ population}{National\ population} * Activity\ data\ at\ national\ level$$

<u>Bottom-up approach</u>: The method is based on the survey of the households within the local authority, and it can be relatively simple to apply. This approach requires more data collection and analysis than the scaling method, but also provides far more useful information to guide local policy and planning. There are relatively simple to more sophisticated ways to apply to this method, but all are usually based on the following parameters:

- The shares of energy carriers used (fuelwood, charcoal, electricity, etc.) per type of end-use services (i.e. cooking, lighting and heating & cooling);
- The fuel consumption (actual in-use or alternatively national statistics) of each type of energy carrier (e. amount of charcoal sales [kg/year] or electricity sales [kWh/year]).
- The Net Calorific Value (NCV) of the fuel [e.g. in kWh/kg] (conversion factor) are available as default values (IPCC, 2006).

In order to ensure the overall consistency of the GCoM methodology, it is suggested using the equation below, which can be applied with limited effort by all GCoM signatories, as a basic approach to assess the energy consumption by type of energy carrier:

Box 15. How to estimate the activity data?

Equation 2.

Activity data = % share of energy carrier per end use service **X** fuel consumption **X** NCV

<u>Example of calculation of energy consumption in the stationary energy sector</u>

Where data is missing, fuel sales data could be used by cities. However, this proxy should always be completed with local data or estimates, in order to better allow identifying local mitigation actions.

Population of the local authority: 1,127,900 inhabitants;

Number of households (population divided per 5): 225,380 households;

The shares of energy carriers used (fuelwood, charcoal, electricity, etc.) per type of end-use services (i.e. cooking, lighting and heating & cooling), can be derived from national statistics, or from local authority surveys.

Share of energy carriers in the residential sector (in %)	Cooking	Lighting and appliances	Heating & cooling	Total
fuelwood	21%	0%	2%	23%
charcoal	43%	0%	5%	48%
other (LPG, kerosene)	13.5%	0%	1.5%	15%
electricity	3%	10%	1%	14%
All fuels	80%	10%	10%	100%

The amount of the energy intensity can be derived from national statistics or fuel sales in the local territory from market operators.

Amount of energy carriers used in the residential sector	Cooking	Lighting and appliances	Heating & cooling	Net Calorific Value (kWh/kg)
fuelwood (kg/household)	223	-	25	4.33368
charcoal (kg/household)	246	-	27	8.1951
other (LPG, kerosene) (kg/household)	48	-	5.3	13.14
electricity (kWh/household)	140	466	65	

Assessment of the total amount of the energy consumption per type of fuel.

Estimated energy consumption per energy carrier	Assessment	Total (MWh/year)
fuelwood (kg/household)	= fuelwood (kg/household) x NCV x number of households	241,543
charcoal (kg/household)	= charcoal (kg/household) x NCV x number of households	504,091
other (LPG, kerosene) (kg/household)	= other (kg/household) x NCV x number of households	157,528
electricity (kWh/household)	= electricity (kWh/household) x number of households	46,208
Total		949,371

4.2.2.2.2 Emission factors

Local authorities can use country specific emission factors or develop own emission factors, based on the detailed properties of the fuels used within the local territory when calculating their local CO_2 or GHG emissions as long as such local data are available and reliable.

Reporting weighted EFs ([57]) is needed to allow the automatic calculation of CO_2 or $CO_{2\text{-eq}}$ emissions, that are as close as possible to the ones estimated in the BEI as published in their CAP official document, for each key sector. The local authorities shall also update these factors during the monitoring phase in case of changes in the composition/properties of the energy carriers consumed locally. This is particularly important for municipal wastes, for which both the supply chain and combustion process are often under the direct control or responsibility of the municipality. In such cases, it is important to account for the changes in the composition and treatment (plant) phases of the waste management process.

Grid wise Emission Factors are released by Central Electricity Authority of India and are updated time to time, mostly Year to Year. Currently, national CO_2 emission factor is 820 Kg CO_2 per Mega Watt Hour e.g. 0.82 KG CO_2 per KWh. However, it may vary Year to Year depending on certain factors like:

- National energy mix for the year,
- Power grid being referred,
- Plant or grid level emission factors,
- Local emission factors,
- Market emission factors.

Further guidance on emission factors that better reflect the fuels used in their territory or on estimating GHG emissions using activity-based and LCA approaches, are available from:

([57]) In some cases the local authority shall calculate weighted emission factors for reporting. This is the case when: a) The same energy carrier has different emission factors in different activity sectors or b) An energy carrier included in the final energy consumption section of the inventory includes aggregated data for two or more local energy carriers with different emission factors, the shares of which vary across activity sectors.

— IPCC (IPCC, 2006) default emissions factors, which can be used when country-specific data are unavailable (Annex 5).

— IPCC (IPCC, 2006) report, which provides general guidance for acquiring and compiling information from different sources and for applying the default emission factors. (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html)

— EFBD Emission Factor Database (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php), which is a recognised library, where users can find additional emission factors and other parameters with background documentation or technical references.

— The JRC ILCD Handbook (Wolf et al., 2012).

The estimation of the local emissions may significantly vary according to the i) methodological approach, ii) the emission factors and iii) the greenhouse gases selected.

i. The local authority can choose between the activity-based approach (recommended), in line with IPCC principles (e.g. only including the emission occurring during fuel combustion), or the LCA approach (including the emissions from both fuel combustion and the supply chain).

ii. After selecting the emission inventory approach, the local authority can either use default emission factors or choose emission factors that are considered more appropriate.

The activity-based emission factors depend on the carbon content of the fuels and therefore do not vary significantly from case to case. In the case the LA would prefer to use its own factors, it should ensure that they are in line with the recommendations provided in IPCC (2006) guidelines on energy (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html). EFs and GWP values for the fossil fuels are expected to remain constant over the monitoring period (e.g. the same reference should be used for both base year and progress monitoring years).

In order to calculate the indirect CO_2 emissions to be attributed to grid supplied energy, Covenant developed a specific methodology of estimating the local emission factor for electricity (EFE) taking into account the following components: the National emission factor for electricity consumption (NEFE); the indirect emissions from local electricity production (LPE) and the purchase and sale of Certified Electricity (CE) (see for further details in the Annex 3).

iii. The local authority has to account for CO_2 emissions and include CH4 and N_2O GHG emissions in the BEI/MEI. For CH4 and N_2O, it is recommended to apply the IPCC Fourth Assessment Report (IPCC, 2007), Global Warming Potential (GWP) values (also used for the national inventory reporting in the so-called *Annex I countries* under the UNFCCC (2013)) in order to convert emissions of these GHGs into CO_2 equivalent ($CO_{2\text{-eq}}$). However, the LA may decide to use other IPCC GWP values.

4.2.2.3 *Transport*

This section aims to provide practical approaches to build emission inventories for the transport macro-sector focusing on CO_2 and where possible CH4 and N_2O. Different resources and capabilities of local authorities are taken into account and options are provided that are considered to be feasible to be implemented in mid-sized and even smaller local authorities. Measuring transport emissions and collecting associated data is vital to guide climate change mitigation actions, but can also guide wider transport policy and planning. While this Guidebook focuses on greenhouse gas emissions, insights gained from the data collection and analysis described in this chapter can also inform urban planning, the provision of transport services, air quality measures and other actions.

The Global Covenant of Mayors defines the transport activity sectors, according to ownership and functionality criteria, as follows (**Table 9**):

Table 9. Mobile sources in emission inventory under Transport sector

Sector: *Transport*	
Subsector	**Description**

<table>
<tr><th colspan="2">Sector: Transport</th></tr>
<tr><th>Subsector</th><th>Description</th></tr>
<tr><td>Municipal fleet</td><td rowspan="3">All GHG emissions from fuel combustion and use of grid-supplied energy for transportation within the city boundary shall be reported and disaggregated by mode: on-road, rail, waterborne navigation, aviation and off-road:
- on-road transportation: urban street network under the competence of the local authority;
- on-road transportation serving a larger area and/or not under the competence of local authority (e.g. highways) may be included if mitigations actions are planned in that area
- off-road transport: off road traffic of vehicles/mobile machinery in any activity sector
- rail transportation: local transport (metro, tram and local trains); long-distance trains, intercity trains, regional and cargo rail transportation may be included if mitigations actions are planned in that area
- waterborne navigation: local ferries in public and private transport acting on the local territory
- aviation: local governments may choose to report GHG emissions from the inboundary component of domestic and/or international aviation (such as the landing and take-off cycle for aviation), or assume these are all out of boundary emissions and use the notation key “Included Elsewhere”</td></tr>
<tr><td>Public transport</td></tr>
<tr><td>Private and commercial transport</td></tr>
</table>

Source: JRC own elaboration.

It is not required (but recommended when possible) to provide energy data for each individual fleet type (municipal fleet, public transport, private and commercial transport) but only at the macro-sector level, meaning road and rail travel.

The data to be collected mainly concerns the road and rail transport:

— Road and rail transport should be included if it is serving mainly the local territory and/or is regulated by the local authority, e.g. the highways and regional trains could be excluded if emissions are not significant and no actions are included in the CAP.

— The off-road transportation should be reported under the activity sector it serves, i.e. municipal, public, or private/commercial transport, and be included only if emissions are significant and related actions are included in the CAP.

Where data is not available and cannot be estimated, notation keys shall be used.

There are relatively simple to more sophisticated ways to estimate transport emissions, but all are usually based on the following (**Figure 12**):

— The Vehicle-Kilometres Travelled (VKT) as a measure of traffic flow, determined by multiplying the number of vehicles on a given road or traffic network by the average length of their trips measured in kilometres; it can be measured as passenger-kilometre (a unit of measure = 1 passenger transported a distance of 1 kilometre) and tonne-kilometre (a unit of measure: 1 tonne transported a distance of 1 kilometre). There are three different methodological approaches to determine traffic activity ([58]):

  - Vehicle approach, determined as: (vehicle stocks x annual average mileage);
  - User approach, determined as: (trips number by mode x the average trip distance / load factor);
  - infrastructure approach, determined as: (traffics accounts (by vehicle type) x infrastructure link length)

([58]) http://mobiliseyourcity.net/

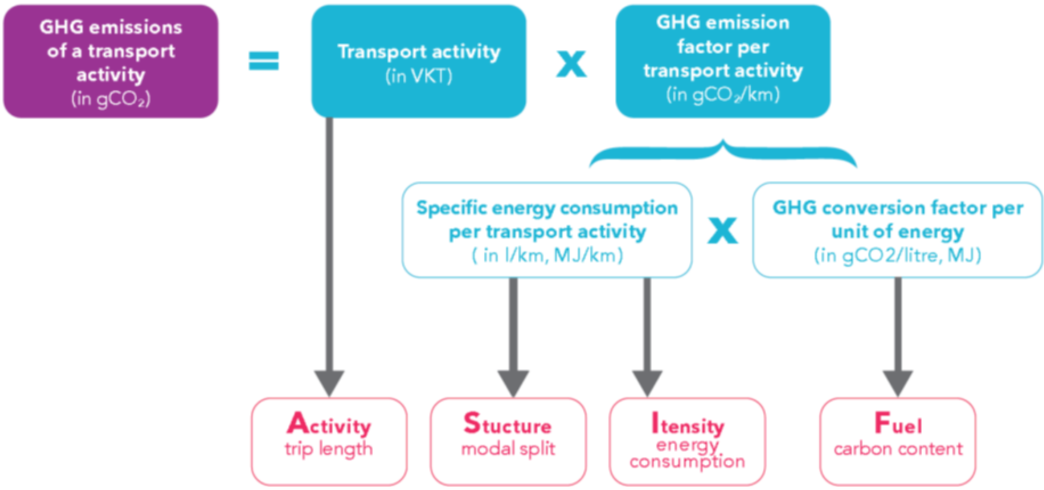
— The modal share and distribution of trips to different types of vehicles (fleet distribution), describing the portion of trips by different modes: road (passengers and freight transport); rail, inland-waterways; air and maritime. In urban areas the most important mode relates to road passenger, which can be further disaggregated into vehicle types (e.g. passenger, light-duty or heavy-duty for road vehicles);
— Energy intensity as a measure of the fuel consumption (actual in-use or alternatively average) assessed as the product of the average fuel consumption of vehicle the type [l fuel/km] and the Net Calorific Value (NCV) of the fuel [Wh/l]. This is often affected by the age of vehicle, especially in the region where the average vehicle life is sometimes over 10 years;
— Fuel carbon intensity relates to the emission factors of the fuels (e.g. diesel, motor gasoline/petrol, electricity, hydrogen etc.).

In order to ensure the overall consistency of the GCoM methodology, it is suggested using the below equation (Equation 3):

$$GHG\ emissions = \sum_{MODES} \sum_{FUELS} (Activity\ trip\ length\ x\ modal\ split\ x\ intensity\ x\ fuel\ carbon\ content)$$

One of the specificities of calculating the energy consumption/GHG emissions in urban transport is related to the potential high share of sources moving across the border of the urban territory, which makes it difficult to allocate the energy consumption to a certain territory.

Figure 12: ASIF framework to calculate GHG emissions from the transport sector



Source: MobiliseYourCity, 2017

4.2.2.3.1 Road transportation

It can be challenging to account for road transport activity sector emissions in urban areas, given the nature of the road transport, which contains numerous mobile sources moving within but also across the boundaries of the urban territory, according to various patterns.

Several approaches and methods for accounting the energy consumption from transport have been developed, which differ greatly in their level of effort required to collect and analyse data and in their level of information they provide, but can be distinguished with two main top-down and bottom-up approaches (see for instance Dünnebeil et al., 2012; EEA, 2016):

The top-down approach to assess transport activity sector GHG emissions is primarily relevant for the national level and only offers very basic information for the local level. It is commonly based on the so-called "Fuel sales method". This territorial method calculates on-road transportation emissions based on the total fuel sold within the city boundaries. The fuel sold on the territory is used as a proxy for transportation activity occurring in the same territory. For the GCoM cities of Surat, Vadodara, Bhavnagar, Gandhinagar, Gangtok and

Panaji the top-down approach was used after consolidating sales figures of fuels sold in the city. Fuel data was obtained in these cities mainly by approaching local petroleum dealers' association.

This approach treats the quantity of transport fuels sold as a proxy for transportation activities. Cities may assume that all fuels sold within the boundary are used for journeys within the boundary. It is also possible to use surveys or other methods to determine the portion of fuels sold that are attributable to journeys within the boundary. Fuel sales data can be obtained from fuel dispensing facilities and/or distributors, or fuel sales tax receipts.

Bottom-up methodologies to assess emissions from transport require more data collection and analysis, but also provide far more useful information to guide local policy and planning. Unlike the fuel sales method, these bottom-up methods, based on travel patterns, can help identifying priority areas for policy intervention. For many cities, the method is indeed already integrated into the local plans (e.g. Sustainable Urban Mobility Plans, Air and Noise Pollution Mitigation Plans). The main disadvantage of these methods is that they might require significant resources with regard to data collection and analysis. According to the way energy consumption/emissions is allocated to the local territory, three main methods exist:

- Territorial method (also called geographic method): This method, which is the one recommended in the frame of this initiative, quantifies emissions from transportation activity occurring solely within local boundaries, regardless of the trip's origin or destination and whatever the driver is a resident of the municipality or not. Basic traffic counts are required to estimate the number of vehicles traveling, including the average trip length and potentially also the type of vehicle.

- Resident activity method: This method quantifies emissions from transportation activity undertaken by city residents only, considering all their trips, within or across the city borders. It requires information on resident Vehicle Kilometre Travelled (VKT) from vehicle registration records and surveys on travel behaviour of residents. Modest efforts are required to get relatively solid estimates with a combination of vehicle fleet registration data and surveys among residents and basic travel behaviour.

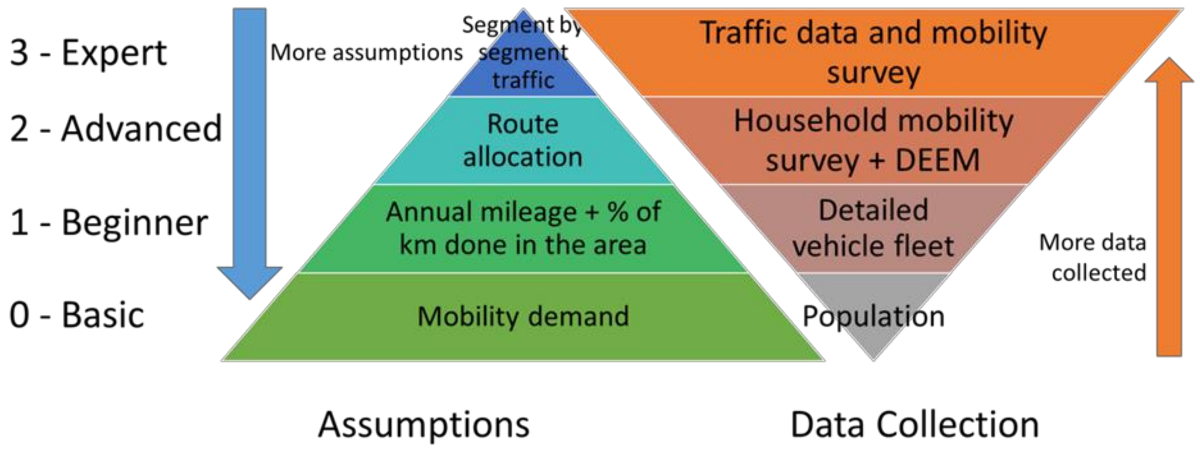
- Induced activity method: With regard to urban planning and future projections, this approach is the most sophisticated methodology as it identifies the underlying travel dynamics in the region, which can be relevant for local, regional and national policy making. It requires a substantial amount of data from city residents and other travellers, which can be gathered through different sources, including data collection at major routes, Big Data (e.g. from smart phones) and satellite data. Computer modelling allows analysing the effects/trade-off of various scenarios in transport policy and urban planning.

To develop a CO_2 emission inventory for the transport sector and to assess the direct and indirect CO_2 emission reduction potential from bottom up methods, there are a number of tools that require only minimal data and no modelling efforts, as the ones provided in the GPC Greenhouse Gas Protocol Tools (GHG Emissions from Transport): http://www.ghgprotocol.org/calculation-tools or as described in MobiliseYourCity project, that provides guidance for the cities involved in the initiative on urban transportation GHG-MRV approaches.

(http://mobiliseyourcity.net/wp-content/uploads/sites/2/2017/09/MobiliseYourCity_MRV_Approach.pdf).

The level and quality of data needed can be adapted to the city situation and resources, as explained in the **Figure 13** below:

Figure 13: Four methodological approaches to get VKT



Source: MobiliseYourCity, 2017

Example of calculation of energy consumption from road transportation

An example of the application of the Eq. 3, using IPCC (2006) net calorific value for the most typical gasoline (9.2 kWh/l) and diesel fuels (10.0 kWh/l) is given in Box 16. Where the mileage (VKT) and/or fleet (type of vehicles) data is missing, fuel sales data could be used by cities in which the number of vehicle trips over the city borders is small compared with the number of trips within the city. However, this proxy should always be completed with local traffic/fleet data or estimates, in order to better allow identifying local mitigation actions.

Box 16. Calculation of energy consumption from road transportation

Input data:
1) Total mileage VKT = 4 500 million km and fleet type distribution (in % of VKT)
2) Average fuel consumption; Net Calorific Values and Emission factors

Input data: Fleet type distribution (in % of VKT)

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
All fuels	**67%**	**15%**	**2%**	**3%**	**13%**	**100%**
- Gasoline/petrol	25%	1%	-	-	13%	39%
- Diesel	37%	14%	2%	3%	-	56%
- Electric cars	5%	-	-	-	-	5%

Input data: Average fuel consumption, NCV and Emission factors

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Net Calorific value (NCV)	Emission factors (EF)
	(l/km)	(l/km)	(l/km)	(l/km)	(l/km)	(Wh/l)	(tCO_2-eq/MWh)
- Gasoline	0.0768	0.13	-	-	0.04	9,200	0.249
- Diesel	0.0658	0.098	0.298	0.292	-	10,000	0.267
- Electricity	-	-	-	-	-	-	0.46

Calculation of the energy consumption and GHG emission related

Step 1. *Estimated activity/mileage per fleet type [million km]=*
Total VKT [million km] ***x*** *Fleet type distribution (in % of VKT)*

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	1139	40.5	-	-	580.5	1,760
- Diesel	1661	639	104	113	-	2,516
- Electric cars	225	-	-	-	-	225
Step 2. *Energy intensity per fleet type [Wh/km]= Average fuel consumption [l/km] x Net calorific value [Wh/l]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	707	1196	-	-	368	
- Diesel	658	980	2980	2920	-	
- Electric cars	186	-	-	-	-	
Step 3. *Estimated Final energy consumption per fleet type [MWh]= Estimated mileage per fleet type [million km]* ***x*** *Energy intensity [Wh/km]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	804,419	48,438	-	-	213,624	1,066,481
- Diesel	1,092,609	626,220	308,430	328,500	-	2,355,759
- Electric cars	41,850	-	-	-	-	41,850
Total final energy consumption	1,938,878	674,658	308,430	328,500	213,624	**3,464,090**
Step 4. *Estimated GHG emissions per fleet type [tCO_2-eq]= Estimated Final energy consumption [MWh]* ***x*** *Emission factors [in tCO_2-eq/MWh]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	200,300	12,061	-	-	53,192	265,554
- Diesel	291,727	167,201	82,351	87,710	-	628,988
- Electric cars	19,251	-	-	-	-	19,251
Total GHG emissions	511,278	179,262	82,351	87,710	53,192	**913,792**

4.2.2.3.2 Rail transportation

Like for road transportation, the rail transportation in the local territory can be divided into two parts:

- Urban rail transportation, for example tram, metro and local trains. The inclusion of this urban rail transportation in the "public transport" activity sector in the BEI is strongly recommended.
- Other rail transportation, which covers the long-distance, intercity and regional rail transportation that occurs in the local territory. Other rail transportation does not only serve the local territory, but a larger area. Other rail transportation includes also freight transport. These emissions can be included in the BEI if the local authority aims to include measures to reduce these emissions in the CAP.

There are two types of activity data for rail transportation: consumption of electricity and consumption of fuel in diesel locomotives. Use of diesel locomotives in urban rail transportation is less common for local services. Number of providers of rail transport in the local territory is usually low. The LA is recommended to ask the annual electricity and fuel use data directly from the service providers. If such data are not available, the LA can estimate the emissions based on mileage travelled and average electricity or fuel consumption.

4.2.2.4 *Waste*

The local authority shall report all GHG emissions from disposal and treatment of waste including solid waste and wastewater) ([59]) generated within the city boundaries and disaggregated by the following subsectors . Further definitions and guidance on subsectors are provided below:

Table 10. Non-energy related activity sectors/data

Sector: *Waste*	
Subsector	**Description**
Solid waste disposal	All emissions from solid waste that are disposed of at managed sites (e.g. sanitary landfill and managed dumps), and unmanaged sites (e.g. open dumps, including above-ground piles, holes in the ground, and dumping into natural features such as ravines).
Biological treatment	All emissions from biological treatment of waste, including composting and anaerobic digestion of organic waste.
Incineration and open burning	All emissions from waste that are burned either in a controlled, industrial, process or in an uncontrolled, often illicit, process. The former is often referred to as incineration, and the latter as open burning. Note that this excludes emissions from waste incineration for the purposes of energy generation, also known as energy recovery.
Wastewater treatment & discharge	All emissions from the treatment process of wastewater, either aerobically or anaerobically, and direct discharge of wastewater into an open body of water.

Source: JRC own elaboration based on the GCoM common reporting framework

The quantification of GHG emissions from disposal and treatment of waste should include the following steps:

Activity data: Local authority should identify the quantity of waste generated in the inventory year, categorised by different types of generation and treatment pathways where possible. How waste is generated affects the composition of waste, which determines the emission factors that need to be used. How waste is treated determines what GHGs are emitted as well as the emission factors. Guidance on collecting this information is available in IPCC Guidelines ([60]). As per Chapter 6 of IPCC Guidelines for National Greenhouse Gas Inventories (revised 1996), CH_4 emissions from MSW are estimated based on waste management practices in pilot cities in India Further, the estimated CH_4 emission is converted to CO_2e based on the conversion factor: 1 kg of CH_4 emission is equivalent to 25 kg of CO_2e.

The emission factor: Guidance for calculating emission factors from different waste disposal and treatment pathways, including equations and default data that local authorities may use in absence of local or regional/national data, is available within the IPCC Guidelines and the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories ([Error! Bookmark not defined.]). If the local authority has chosen to use the LCA approach, emission factors for landfills are available from the ELCD (2015) database ('Landfilling' class) ([61]).

For the end-life management of Photovoltaic systems and the end-of-life management of batteries in the off-grid solar sector please refer to the Annex 7 ([62]).

([59]) Water access: GWOPA Global Water Operator Partnership Alliance www.unhabitat.org; - Solid waste treatment: IRRC Integrated Resource Recovery Centre – A low cost municipal solid waste management system in South East Asia- ESCAP

([60]) The 2006 IPCC Guidelines focus on emission inventories at national level. The specific volume that is relevant for GCoM local authorities regarding non-energy related emissions is Volume 5, "Waste". The GPC is available at http://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf and contains a detailed methodology, based on the IPCC one, on how to assess, at city level, the emissions from waste and wastewater (Chapter 8 "Waste").

([61]) http://eplca.jrc.ec.europa.eu/

([62]) GIZ document: "END-OF-LIFE MANAGEMENT OF BATTERIES IN THE OFF-GRID SOLAR SECTOR - How to deal with hazardous battery waste from solar power projects in developing countries?" available at: https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf

4.2.2.5 *Energy supply*

Additionally, to the emissions generated through energy consumption, local governments shall report GHG emissions from energy generation activities. To avoid double counting, these shall not form part of the GHG emissions inventory total, and will be reported under an "Energy Generation" or "Energy Supply" sector, as follows:

- All GHG emissions from generation of grid-supplied energy within the city boundaries, and all GHG emissions from generation of grid-supplied energy by facilities owned (full or partial) by the local government outside the city boundaries shall be reported and disaggregated by electricity-only, combined heat and power (CHP), and heat/cold production plants.
- GHG emissions from sources covered by a regional or national emissions trading scheme (ETS), or similar, should be identified, if existing.
- In addition, local governments should report all activity data for distributed local renewable energy generation.

The local production of energy and associated direct emissions are not part of the activity sectors included in the emission inventory but are considered in the calculation of the local emission factors to be applied to the local consumption of electricity and heat/cold. The principle is to allow signatories to reduce their emissions associated with the consumption of distributed energy, by encouraging both energy saving measures and measures related to the implementation of local energy production. JRC specific methodology for indirect CO_2 emissions calculation can be found in Annex 3 of Global Covenant of Mayors Common Reporting Framework.

Table 11. Energy supply activity sectors/data

Sector: *Energy supply*	
Subsector	**Description**
Electricity-only generation	All activity data and GHG emissions from energy (both renewable and non-renewable) consumption for the purpose of generating grid-supplied electricity in power plants that solely generate electricity.
CHP generation	In the case of CHP plants, which generate heat and electricity simultaneously, or any other plants not listed, the amount of electricity produced (in MWh), both from renewable and non-renewable energy sources shall be reported.
District heating/cooling generation	All activity data and GHG emissions from energy (both renewable and non-renewable) consumption for the purpose of generating thermal energy in district heating/cooling plants
Distributed local renewable energy generation	All activity data and GHG emissions from local energy generation (electricity, heat, etc.) facilities not grid-connected.

Source: JRC own elaboration based on the GCoM common reporting framework

4.3 Adaptation pillar assessment: Prepare Risk & Vulnerability Assessment (RVA)

The Climate Change Risk and Vulnerability Assessment (RVA) enables local authorities to identify their exposure to current and future climate hazards, vulnerabilities, risks and potential climate change impacts, as well as understand the main city specificities that contribute to aggravating the consequences of a specific climate hazard.

Similarly to the Baseline Emission Inventory, the RVA defines the basis for setting the priorities of adaptation action and investment and monitoring the effectiveness of implemented adaptation measures for a specific region or sector. To this end, an assessment of climate vulnerability and risks has to be undertaken - on the basis of available data - and regularly monitored and evaluated versus a baseline scenario.

In the following sections, the main concepts around climate risk as proposed by the IPCC are included as well as the requirements outlined in the GCoM CRF; followed by recommendations on how to prepare a RVA together with potential sources of information.

4.3.1 Introduction

Collection of data for RVA is through onsite assessments and combines it with national threat and vulnerability information for an organization with actionable remediation recommendations prioritised by risk. RVA is designed to identify vulnerabilities arising out of climate change.

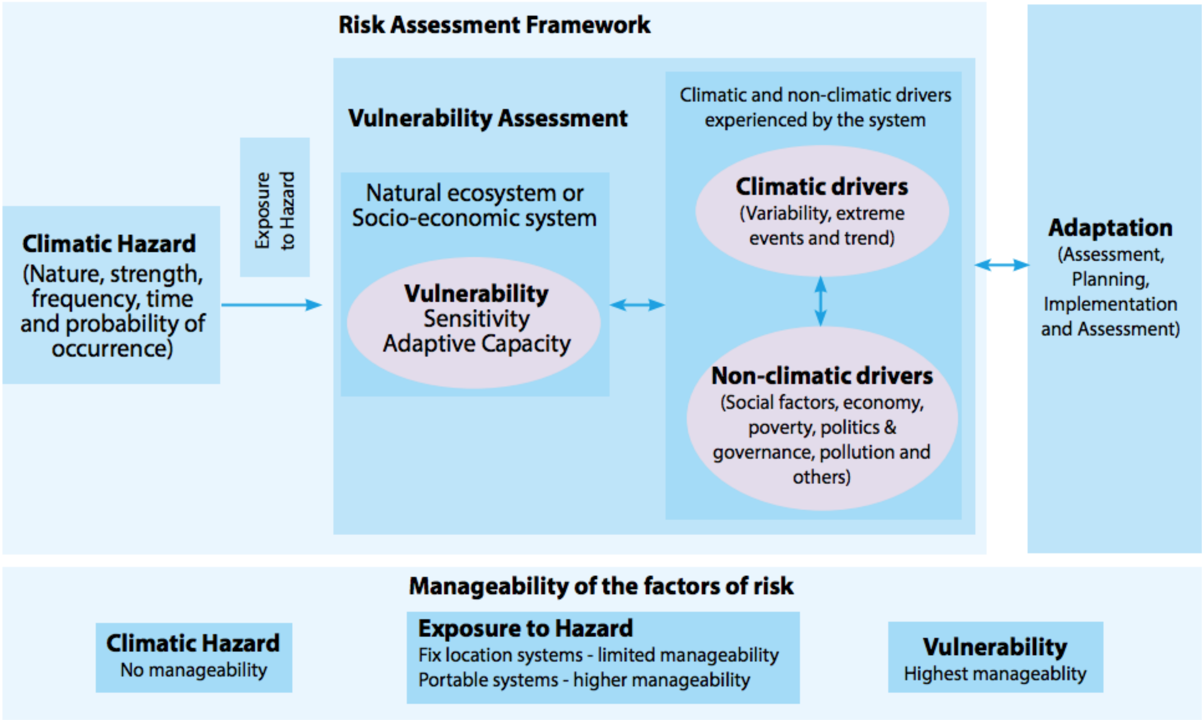
Vulnerability assessment is required for multiple purposes, particularly for adaptation planning. Vulnerability assessment would assist in ([63]):

1. Adaptation planning of developmental programmes and projects.
2. Prioritisation of adaptation interventions and investment at national, state, district and city levels.
3. Developing adaptation proposals for Green Climate Fund, World Bank, Asian Development Bank, Adaptation Fund, bilateral agencies, etc.
4. Meeting the requirements of Paris Agreement, Article 9 that requires assessment of the impact and vulnerability.
5. Designing and implementing the 'Nationally Determined Contributions' component which aims to better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change.
6. Revision of the State Action Plan on Climate Change for assessing the vulnerability and prioritising adaptation programmes and projects.

RVA framework assesses the vulnerability profile and helps to address this by raising awareness of the vulnerabilities within a city **(Figure 14)**. It will enhance the city administrations' knowledge and hence their ability to plan for climate-induced hazards. It gives an overview of current status of the city which needs to be continuously updated at regular interval in order to keep a check. Cities can never be fully risk or hazard proof, but can be resilient, and one can minimize the effect of such risks. Policies, guidelines and most importantly awareness will help to make cities sustainable and liveable.

Figure 14: Common framework for management of Vulnerability and Risk

([63]) https://www.weadapt.org/placemarks/maps/view/47336



Source: Manual- Common framework for assessment and reduction of vulnerability and risk ([64])

In-depth understanding of key vulnerabilities is essential for evidence-based adaptation planning towards the risks of climate change impacts.

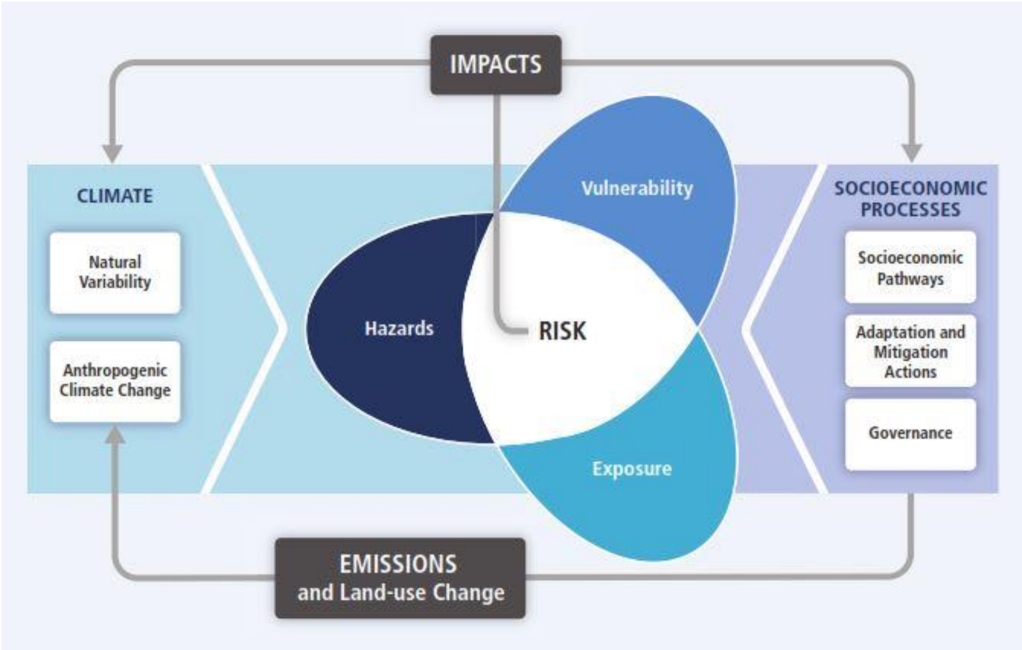
4.3.2 Main concepts

The last Assessment Report of the IPCC (AR5) focuses on the concept of climate risk and proposes a new framework for its assessment (**Error! Reference source not found.** in this guidebook follows this framework). Risk is defined as a function of the expected potential hazards of climate extremes, system vulnerability, and exposure.

Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes - including adaptation and mitigation (right) - are drivers of hazards, exposure, and vulnerability.

Figure 15: Illustration of the core concepts of the WGII AR5

([64]) https://www.weadapt.org/placemarks/maps/view/47336



Source: Field and et al., 2014

Box 17. Key risks from climate change in India

To better understand the risks of climate change to development, the World Bank Group commissioned the Potsdam Institute for Climate Impact Research and Climate Analytics to look at the likely impacts of temperature increases from 2ºC to 4ºC in three regions. The scientists used the best available evidence and supplemented it with advanced computer simulations to arrive at likely impacts on agriculture, water resources, cities and coastal ecosystems in South Asia, South-East Asia and Sub-Saharan Africa. The proposed measures mentioned below are not the only possible solutions to the identified impacts, but just examples of solutions. Some of their findings for India include ([65]):

1. **Extreme Heat**

   India is already experiencing a warming climate. Unusual and unprecedented spells of hot weather are expected to occur far more frequently and cover much larger areas. Under 4°C warming, the west coast and southern India are projected to shift to new, high-temperature climatic regimes with significant impacts on agriculture.

   What can be done?

   With built-up urban areas rapidly becoming "heat-islands", urban planners will need to adopt measures to counteract this effect.

2. **Changing Rainfall Patterns**

   A decline in monsoon rainfall since the 1950s has already been observed. The frequency of heavy rainfall events has also increased. A 2°C rise in the world's average temperatures will make India's summer monsoon highly unpredictable.

   At 4°C warming, an extremely wet monsoon that currently has a chance of occurring only once in 100 years is projected to occur every 10 years by the end of the century. An abrupt change in the monsoon could precipitate a major crisis, triggering more frequent droughts as well as greater flooding in large parts of India. India's northwest coast to the south-eastern coastal region could see higher than average rainfall. Dry years are expected to be drier and wet years wetter. **What can be done?**

   Improvements in hydro-meteorological systems for weather forecasting and the installation of flood warning systems can help people move out of harm's way before a weather-related disaster strikes.

([65]) https://www.worldbank.org/en/news/feature/2013/06/19/india-climate-change-impacts

Building codes will need to be enforced to ensure that homes and infrastructure are not at risk.

3. Droughts

Evidence indicates that parts of South Asia have become drier since the 1970s with an increase in the number of droughts. Droughts have major consequences. In 1987 and 2002-2003, droughts affected more than half of India's crop area and led to a huge fall in crop production. Droughts are expected to be more frequent in some areas, especially in north-western India, Jharkhand, Orissa and Chhattisgarh. Crop yields are expected to fall significantly because of extreme heat by the 2040s.

What can be done?

Investments in R&D for the development of drought-resistant crops can help reduce some of the negative impacts.

4. Groundwater

More than 60% of India's agriculture is rain-fed, making the country highly dependent on groundwater. Even without climate change, 15% of India's groundwater resources are overexploited. Although it is difficult to predict future ground water levels, falling water tables can be expected to reduce further on account of increasing demand for water from a growing population, more affluent lifestyles, as well as from the services sector and industry.

What can be done?

The efficient use of ground water resources will need to be incentivized.

5. Glacier Melt

Glaciers in the north-western Himalayas and in the Karakoram range - where westerly winter winds are the major source of moisture - have remained stable or even advanced. On the other hand, majority of Himalayan glaciers of Uttrakhand - where a substantial part of the moisture is supplied by the summer monsoon - have been retreating over the past century. At 2.5°C warming, melting glaciers and the loss of snow cover over the Himalayas are expected to threaten the stability and reliability of northern India's primarily glacier-fed rivers, particularly the Indus and the Brahmaputra. The Ganges will be less dependent on melt water due to high annual rainfall downstream during the monsoon season.

The Indus and Brahmaputra are expected to see increased flows in spring when the snows melt, with flows reducing subsequently in late spring and summer. Alterations in the flows of the Indus, Ganges, and Brahmaputra rivers could significantly impact irrigation, affecting the amount of food that can be produced in their basins as well as the livelihoods of millions of people (209 million in the Indus basin, 478 million in the Ganges basin, and 62 million in the Brahmaputra basin in the year 2005).

What can be done?

Major investments in water storage capacity would be needed to benefit from increased river flows in spring and compensate for lower flows later on.

6. Sea Level Rise

Mumbai has the world's largest population exposed to coastal flooding, with large parts of the city built on reclaimed land, below the high-tide mark. Rapid and unplanned urbanisation further increases the risks of sea water intrusion. With India close to the equator, the sub-continent would see much higher rises in sea levels than higher latitudes.

Sea-level rise and storm surges would lead to saltwater intrusion in the coastal areas, impacting agriculture, degrading groundwater quality, contaminating drinking water, and possibly causing a rise in diarrhea cases and cholera outbreaks, as the cholera bacterium survives longer in saline water.

Kolkata and Mumbai, both densely populated cities, are particularly vulnerable to the impacts of sea-level rise, tropical cyclones, and riverine flooding.

What can be done?

Building codes will need to be strictly enforced and urban planning will need to prepare for climate-related disasters. Coastal embankments will need to be built where necessary and Coastal Regulation

Zone codes enforced strictly.

7. Agriculture and Food Security

Even without climate change, world food prices are expected to increase due to growing populations and rising incomes, as well as a greater demand for biofuels.

Rice: While overall rice yields have increased, rising temperatures with lower rainfall at the end of the growing season have caused a significant loss in India's rice production. Without climate change, average rice yields could have been almost 6% higher (75 million tons in absolute terms).

Wheat: Recent studies show that wheat yields peaked in India and Bangladesh around 2001 and have not increased since despite increasing fertilizer applications. Observations show that extremely high temperatures in northern India - above 34°C - have had a substantial negative effect on wheat yields, and rising temperatures can only aggravate the situation.

Seasonal water scarcity, rising temperatures, and intrusion of sea water would threaten crop yields, jeopardising the country's food security. Should current trends persist, substantial yield reductions in both rice and wheat can be expected in the near and medium term. Under 2°C warming by the 2050s, the country may need to import more than twice the amount of food-grain than would be required without climate change.

What can be done?

Crop diversification, more efficient water use, and improved soil management practices, together with the development of drought-resistant crops can help reduce some of the negative impacts.

8. Energy Security

Climate-related impacts on water resources can undermine the two dominant forms of power generation in India - hydropower and thermal power generation - both of which depend on adequate water supplies to function effectively.

To function at full efficiency, thermal power plants need a constant supply of fresh cool water to maintain their cooling systems. The increasing variability and long-term decreases in river flows can pose a major challenge to hydropower plants and increase the risk of physical damage from landslides, flash floods, glacial lake outbursts, and other climate-related natural disasters. Decreases in the availability of water and increases in temperature will pose major risk factors to thermal power generation.

What can be done?

Projects will need to be planned taking into account climatic risks.

9. Water Security

Many parts of India are already experiencing water stress. Even without climate change, satisfying future demand for water will be a major challenge. Urbanisation, population growth, economic development, and increasing demand for water from agriculture and industry are likely to aggravate the situation further.

An increase in variability of monsoon rainfall is expected to increase water shortages in some areas. Studies have found that the threat to water security is very high over central India, along the mountain ranges of the Western Ghats, and in India's north-eastern states.

What can be done?

Improvements in irrigation systems, water harvesting techniques, and more-efficient agricultural water management can offset some of these risks.

10. Health

Climate change is expected to have major health impacts in India- increasing malnutrition and related health disorders such as child stunting - with the poor likely to be affected most severely. Child stunting is projected to increase by 35% by 2050 compared to a scenario without climate change.

Malaria and other vector-borne diseases, along with and diarrheal infections which are a major cause of child mortality, are likely to spread into areas where colder temperatures had previously limited transmission. Heat waves are likely to result in a very substantial rise in mortality and death, and injuries from extreme weather events are likely to increase. Health systems will need to be strengthened in identified hotspots.

What can be done?

Improvements in hydro-meteorological systems for weather forecasting and the installation of flood warning systems can help people move out of harm's way before a weather-related disaster strikes. Building codes will need to be enforced to ensure that homes and infrastructure are not at risk.

11. Migration and Conflict

South Asia is a hotspot for the migration of people from disaster-affected or degraded areas to other national and international regions. The Indus and the Ganges-Brahmaputra-Meghna Basins are major trans boundary rivers, and increasing demand for water is already leading to tensions among countries over water sharing. Climate change impacts on agriculture and livelihoods can increase the number of climate refugees.

What can be done?

Regional cooperation on water issues will be needed.

Box 18. Definitions

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Impacts: Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (see **Error! Reference source not found.**). In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Maladaptation: Interventions and investments in a specific location or sector that could increase the vulnerability of another location or sector, or increase the vulnerability of the target group to future climate change. Maladaptation arises not only from inadvertent badly planned actions, but also from deliberate decisions focused on short-term benefits ahead of longer-term threats, or that fail to consider the full range of interactions, feedbacks and trade-offs between systems and sectors arising from planned actions.

Source: IPCC, 2014b

Box 2 Sources of information for the adaptation pillar in India

Climate data and future projections

For policy makers in India, it is important to have a clear comprehensive view on the possible future climate change projections. Climate models are often used to project how our world will change under a future scenario. Climate models have proven remarkably accurate in simulating the climate change we have experienced to date. Global climate models project a continuation of human-induced climate change during the twenty-first century and beyond. Climate change projections, however, may have large uncertainties. The largest uncertainty in climate change projections is the level of greenhouse gas emissions in the future. The need for a comprehensive assessment report on climate change was felt for a long time. Ministry of Earth Sciences (MoES), Government of India produced report on 'Assessment of Climate Change over the Indian Region'

This is the first-ever climate change assessment report for India. The report consists of details describing the observed changes and future projections of precipitation, temperature, monsoon, drought, sea level, tropical cyclones, and extreme weather events, etc. This report will be very useful for policy makers, researchers, social scientists, economists, and students ([66]). Other relevant climate change details are enumerated as under:

1. World Bank Group Climate Change Knowledge Portal

(https://climateknowledgeportal.worldbank.org/country/india/climate-data-projections)

The Climate Change Knowledge Portal (CCKP) of World Bank supports the analysis of climate impacts on India using multi-model ensembles, as they represent the range and distribution of the most plausible projected outcomes when representing expected changes.

2. Future changes in rainfall, temperature and reference evapotranspiration in the central India by least square support vector machine

(https://www.sciencedirect.com/science/article/pii/S1674987116300561)

Climate change affects the environment and natural resources immensely. Rainfall, temperature and evapotranspiration are major parameters of climate affecting changes in the environment. Evapotranspiration plays a key role in crop production and water balance of a region, one of the major parameters affected by climate change.

3. Historical and Projected Surface Temperature over India during the 20th and 21st century

(https://www.nature.com/articles/s41598-017-02130-3)

Surface Temperature (ST) over India has increased by ~0.055 K/decade during 1860–2005 and follows the global warming trend. Here, the natural and external forcings (e.g., natural and anthropogenic) responsible for ST variability are studied from Coupled Model Inter-comparison phase 5 (CMIP5) models during the 20th century and projections during the 21st century along with seasonal variability.

4. India: The Impact of Climate Change to 2030

(https://www.dni.gov/files/documents/climate2030_india.pdf)

This assessment identifies and summarizes the latest peer-reviewed research related to the impact of

([66]) https://cordex.org/2020/07/03/new-book-on-assessment-of-climate-change-over-the-indian-region/

climate change on India, drawing on both the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports and on other peer reviewed research literature and relevant reporting.

5. High-resolution climate change scenarios for India for the 21st century

(https://www.jstor.org/stable/24091867)

A state-of-art regional climate modelling system, known as PRECIS (Providing Regional Climates for Impacts Studies) developed by the Hadley Centre for Climate Prediction and Research, is applied for India to develop high-resolution climate change scenarios.

6. Projection of seasonal summer precipitation over Indian sub-continent with a high-resolution AGCM based on the RCP scenarios

(https://link.springer.com/article/10.1007/s00703-018-0612-7)

Seasonal changes in precipitation characteristics over India were projected using a high-resolution (40-km) atmospheric general circulation model (AGCM) during the near- (2010–2039), mid- (2040–2069), and far- (2070–2099) futures.

Disasters, disasters losses and disaster resilience

1. Global Assessment Report Risk Data Platform (http://risk.preventionweb.net)

This interactive Risk Viewer provides the global risk data from the Global Assessment Reports, presented in an easily accessible manner. Risk and exposure indicators can be overlaid with hazard data from earthquakes, cyclones, surges, floods, tsunamis and volcanoes. Other country-specific data can also be downloaded, including future projections of return periods, etc.

2. EM-DAT: The International Disaster Database (http://www.emdat.be)

EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, nongovernmental organisations, insurance companies, research institutes and press agencies. Users can download data and create their own tables and figures by selecting from among the data sets.

3. PREVIEW Global Risk Data Platform (http://preview.grid.unep.ch)

The PREVIEW Global Risk Data Platform contains spatial data information on global risk from natural hazards. Users can visualise, download or extract data on past hazardous events, human and economical hazard exposure and risk from natural hazards. It covers tropical cyclones and related storm surges, drought, earthquakes, biomass fires, floods, landslides, tsunamis and volcanic eruptions.

4.Disaster Resilience Scorecard for Cities (https://www.unisdr.org/campaign/resilientcities/home/toolkit)

The Scorecard provides a set of assessments that will allow local governments to assess their disaster resilience, structured around UNISDR's Ten Essentials for Making Cities Resilient. It also helps to monitor and review progress and challenges in the implementation of the Sendai Framework for DR: 2015-2030. This tool for disaster resilience planning can be used as a stand-alone tool, it does require you to consider your city's hazards and risks. Specifically, the Scorecard prompts you to identify "most probable" and "most severe" risk scenarios for each of your identified city hazards, or for a potential multi-hazard event.

5. Oasis Hub (https://oasishub.co/)

Oasis Hub is an aggregator for catastrophe, extreme weather and environmental risk data, tools & services. It also provides data set enhancement, development and data aggregation services. It is an open, transparent, data platform that would inevitably help provide environmental, climate change and catastrophe risk information to business and wider society, whilst providing everyone with a platform that encourages collaboration and crossover around data and services

4.3.3 Climate Change Risk and Vulnerability Assessment

A Risk and Vulnerability Assessment (RVA) determines the nature and extent of a risk by analysing potential hazards and assessing the vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (IPCC, 2014b). This can take the form of a single assessment or various assessments undertaken per sector.

RVAs is the first and crucial step in adaptation cycle. RVAs are the most commonly used tools for identifying, quantifying and prioritising key risks of a system to climate change. However, before giving more details on how to prepare a RVA as well as its indicators and objectives to be included in the CAP, it is worth noting that not all issues that emerge from vulnerability assessments can be addressed, mainly due to budgetary limitations (World Bank, 2010). Therefore, to identify the optimal level of adaptation it is required to assess the trade-off between the costs of investment in resilience and the expected benefits in terms of reduced losses and damages, versus a scenario of inaction. This cost-benefit analysis is a crucial step in developing adaptation plans, and cities are encouraged to undertake robust estimations of costs, benefits and uncertainties to the extent possible.

Box 20. Reporting element: RVA.

All signatories shall prepare a RVA within two years after committing to the GCoM;

It is mandatory to include:

— Boundary of assessment equal to or greater than the city boundaries;

— Year of approval from local government;

— Data sources;

— A glossary of key terms and definitions;

— Leading/coordinating team in the city;

— Terminologies and definitions used in the reports shall be consistent with those in the IPCC Fifth Assessment Report or update thereof as well as with national frameworks/requirements.

— At least one hazard and one vulnerable sector shall be reported

Source: GCoM Common Reporting Framework (see Annex 2(1))

Usually there is one more step at the end, which is monitoring and evaluation, which then feeds back into the cycle, as monitoring is part of GCoM commitment

Many tools and methods exist for undertaking vulnerability and adaptation assessments, both qualitative and quantitative (Mukheibir and Ziervogel, 2007). The choice should be based on the purpose of the assessment, the spatial scale of assessment and the resources available, including data, tools, budget and technical skills. **Error! Reference source not found.** summarises strengths and weaknesses of three different methodological approaches: indicator-based, model and GIS based and participatory approach.

Table 12. Strengths, weaknesses of vulnerability assessment methodologies.

Type	Description	Strengths	Weaknesses
Indicator based	Indicator-based methodologies use a specific set or combination of proxy indicators in order to produce measurable outputs across various spatial scales. Examples of indicators include the Livelihood Vulnerability Index (LVI) (Hahn et al., 2009), Household Adaptive Capacity Index (HACI), Well-being Index (HWI), Index of Social Vulnerability to Climate Change for Africa (SVA).	Produce measurable outputs across various spatial scales that can be easily used by policy-makers Valuable for monitoring trends and exploring the implementation of adaptation responses	Limited by lack of reliable data, particularly socioeconomic sources, at the scale required for assessment Challenges associated with testing and validating the metrics used, such as good governance.
Model- and GIS-based	Model- and GIS-based methods incorporate biophysical and socioeconomic modelling, and display vulnerability spatially through mapping. These methods commonly focus on a specific driver of change or sector and apply statistical measures and mapping techniques to display vulnerability as well as measures of adaptive capacity and resilience.	Mapping of climate change vulnerability provides an insight into the vulnerability of place, and may have some value in identifying vulnerable places and people	Typically, a snapshot of vulnerability, failing to encapsulate spatial and temporal drivers of structural inequalities
Participatory approaches	Participatory approaches focus on including stakeholders in the assessment process, and this can be done in a variety of ways and to various extents. A range of tools for participatory vulnerability assessments exist, including cognitive mapping, interviews, surveys, vulnerability matrices, stakeholder engagement workshops and expert-based inputs.	Recognise the local or context-specific knowledge that exists within a system, and the fact that many aspects are best known by those individuals operating within that system	The perception and understanding shared by participants should ideally be complemented with supporting socio-economic and biophysical data Challenges associated with identification of the appropriate target group, and ensuring that all voices are heard and equally included in the process

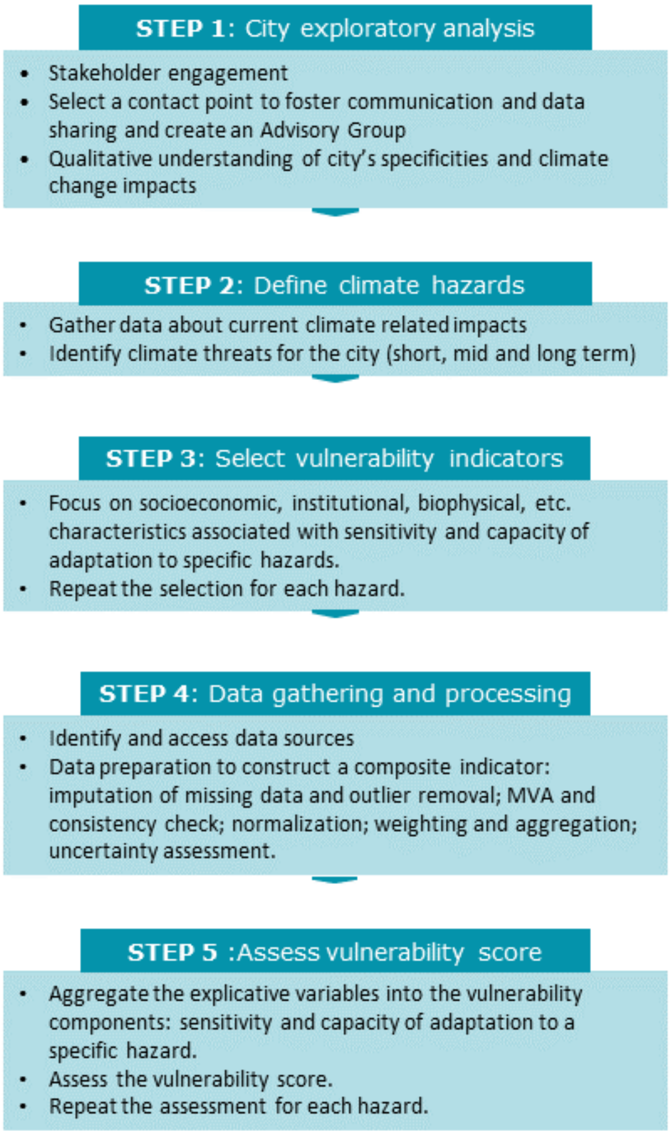
Source: (Davis and Vincent, 2017)

The Model- and GIS-based approach typically requires advanced technical skills and robust geo-referenced datasets, which makes it more accessible to big cities that have the necessary resources and capacities.

The indicator-based approach requires less resources and technical skills which makes this type of vulnerability assessment a viable option for small and medium cities. The approach is described in more details in the following paragraph.

4.3.3.1 *Indicator-based vulnerability assessment*

Figure 16: Steps and main activities for indicator-based vulnerability assessment.



Source: JRC own elaboration.

STEP 1: City exploratory analysis. This step includes a kick-off meeting with city stakeholders in order to contextualise the assessment, understand needs and expectations, identify instances of climate change impacts, select a contact point in the LA (for example from the environment or planning department), and clearly explain the RVA approach and the required data. Weber *et al.* (2015) suggest creating an Advisory Group of relevant experts from academia, NGOs, city government and private sector, to help construct sound and policy-relevant indicators and selecting the best scale of analysis (e.g., neighbourhood or settlements). Input from city decision makers and local institutions steers the project towards actionable results. The main sources of information – such as city departments/agencies, civil protection, utility companies, and universities, among others – should be mapped. The contact point at the LA should be entrusted with facilitating the communication between the parties and fostering data sharing.

STEP 2: Define climate hazards. **Error! Reference source not found.** proposes a regional assessment of expected climate-change impacts in India. This coarse assessment or any other hazard maps can help drive the discussion with key-stakeholders (STEP 1) about expected climate hazards by localising the city within a specific risk zone. The macro-scale information should be calibrated through observed instances of climate-related impacts within the city. This information should be derived from data on the most relevant climate threats faced by the region. Also, according to the GCoM common reporting framework (see Annex 2(1)), local governments shall identify the most significant climate hazards faced by the community. For each hazard identified, the local authority shall collect the following information:

- current risk level (probability x consequence) of the hazard;
- description of expected future impacts;
- expected intensity, frequency, and timescale ([67]) of the hazard;
- all relevant sectors, assets, and services that are expected to be most impacted by the hazard in future and the magnitude of the impact for each of them ([68]).

It is further recommended to identify the vulnerability for each hazard: Information on vulnerable population groups (e.g. poor, elderly, youth, people with chronic disease, unemployed, etc.) that are expected to be most affected by future hazards. This information can help the local government in having a better understanding of the vulnerability dimension of risks and in prioritising their adaptation actions.

Besides the assessment of future hazards, the local government shall also assess the following information about major hazards that occurred in the past years:

- Scale of the hazard, including loss of human lives, economic losses (direct and indirect, if possible), environmental and other impacts;
- Current risk level of the hazards (probability X consequence);
- Intensity and frequency of the hazard;
- All relevant sectors, assets, or services most impacted by the hazard and the magnitude of impact for each of them;
- Vulnerable population groups most affected by the hazard (if available).

STEP 3: Select vulnerability indicators. In this step, it is necessary to correctly identify the indicators that drive urban vulnerability to the selected climate hazards, through literature review with the Advisory Group. Exposure is included in vulnerability, which include the people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

STEP 4: Data gathering and processing. In this step, it is important to extract city socioeconomic indicators and information about the built environment and biophysical attributes from existing databases at local, regional and national level.

STEP 5: Assess vulnerability score. In this step, it is critical to calculate the sensitivity ([69]) as well as the adaptation capacity for specific climate threats through different equations and aggregation approaches.

The GCoM common reporting framework asks cities to identify factors that will most affect its own and the city's adaptive capacity and enhance climate resilience. For each factor, the local government shall report the following information:

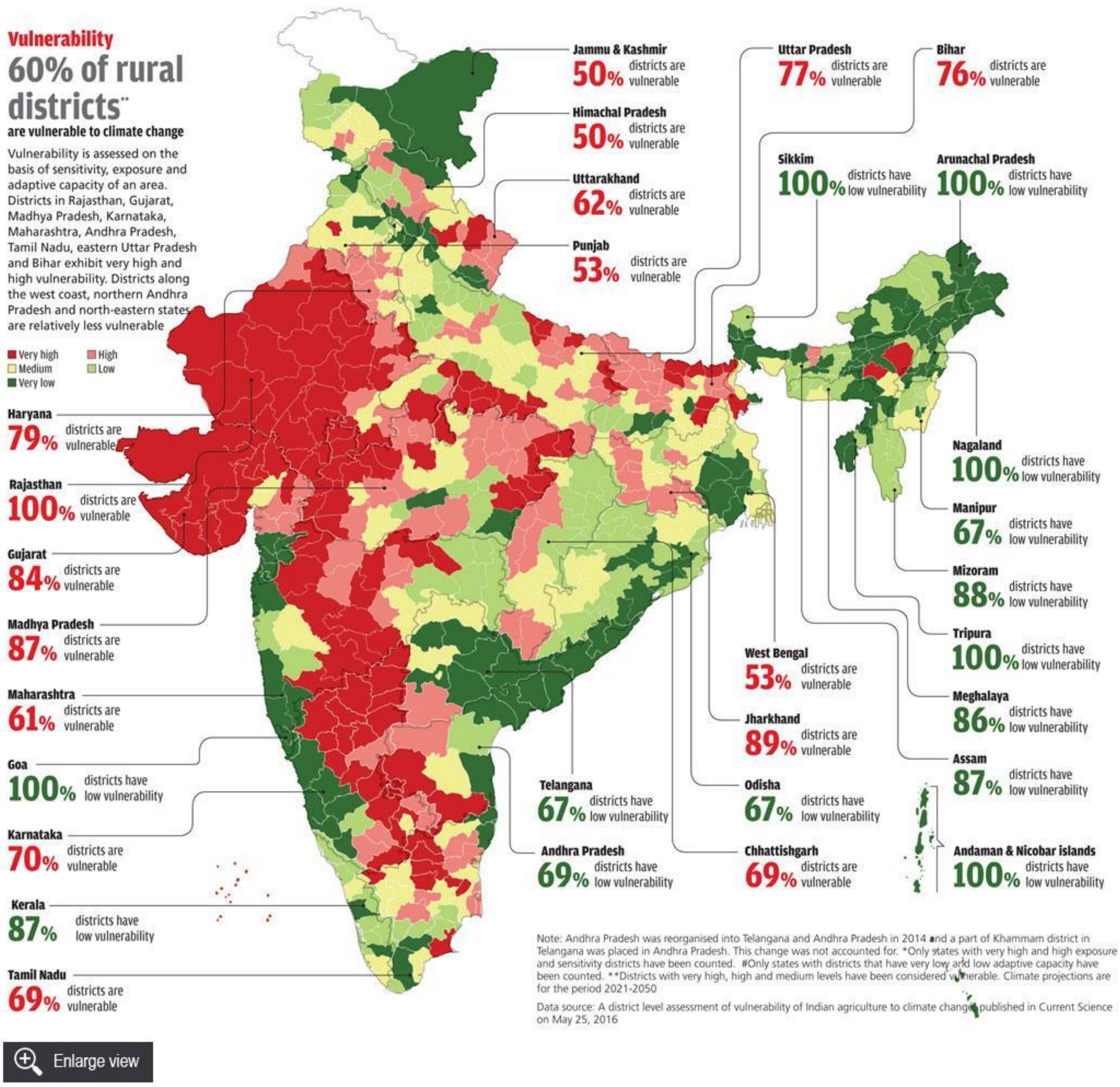
- Description of the factor as it relates to (supporting or challenging) the adaptive capacity
- Degree to which the factor challenges (as opposed to supports) the adaptive capacity and obstructs enhanced climate resilience

([67]) A qualitative description of time-scales (short term – less than 10 years; near term 2030 - 2040 and long term 2080- 2100) of the expected impacts should be provided in order to correctly prioritize investments.

([68]) The exposed/vulnerable sectors – such as buildings, transport, energy, water, waste, food & agriculture, environment, forestry, biodiversity, health, among others – may be possibly impacted with different levels of severity (low, moderate, high) and over different time periods (e.g.: short-term, medium-term, long-term).

([69]) IPCC defines as sensitivity the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Figure 17: Current, possible impacts & vulnerability associated with climate change



Source: (Current Science, 2016).

The anticipated future impacts of climate change, identified by the Government of India (GOI) in its Initial National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) include (GOI, 2004) ([70]):

- Decreased snow cover, affecting snow-fed and glacial systems such as the Ganges and Brahmaputra; 70 per cent of the summer flow of the Ganges comes from snowmelt;
- Erratic monsoons with serious effects on rain-fed agriculture, peninsular rivers, water and power supply;
- Decline in wheat production by 4-5 million tonnes with as little as a 1ºC rise in temperature;
- Rising sea levels causing displacement along one of the most densely populated coastlines in the world and threatening freshwater sources and mangrove ecosystems;
- Increased frequency and intensity of floods; increased vulnerability of people in coastal, arid and semi-arid zones of the country; and

([70]) https://www.adaptation-undp.org/explore/india

- Over 50 per cent of India's forests are likely to experience a shift in forest types, adversely impacting associated biodiversity and regional climate dynamics, as well as livelihoods based on forest products.

As per 15th edition of the Global Climate Risk Index 2020 prepared by Bonn-based think-tank Germanwatch, India is the fifth most vulnerable of 181 countries to the effects of climate change, with its poorest being the most at risk.

India had the most (2,081) deaths in 2018 due to extreme weather events caused by climate change--cyclones, heavy rainfall, floods and landslides.

Overall, India's economic losses due to climate change were the second highest in the world with a loss of Rs 2.7 lakh crore ($37 billion) - nearly as much as its defence budget in 2018. This translates to losing about 0.36% per unit of gross domestic product.

The index does not take into account the slower processes of rising sea levels, glacier melting or more acidic and warmer seas due to climate change.

India also suffered from one of the longest ever recorded heatwaves in 2018, with temperatures rising to 48 degrees Celsius, resulting in hundreds of deaths. This, compounded with a water shortage, led to prolonged drought, widespread crop failures, violent riots and increased migration. The worst-hit regions in the central, northern and western parts of the country, were also among India's poorest. Since 2004, India has experienced 11 of its 15 warmest recorded years (since record-keeping began in 1901), and an estimated 25,000 Indians have died as a result of heatwaves since 1992.

India is particularly vulnerable to extreme heat due to low per capita income, social inequality and a heavy reliance on agriculture. India would lose 5.8% of its working hours due to heat stress by 2050, which is equivalent to 34 million full-time jobs out of a total of 80 million worldwide. In India, agriculture and construction, the two biggest employers, will bear the brunt of this loss in productivity.

4.3.4 Adaptation indicators

There are no single and unanimously adopted criteria to quantify vulnerability. For example, Eriksen and Kelly (2007) provide an assessment of the different types of vulnerability indicators developed for climate policy assessments, and highlight the fact that some approaches emphasize the physical more than the social aspects and vice versa. Error! Reference source not found. serves the purpose of providing signatories with some examples of vulnerability indicators.

Table 13. Examples of Adaptation Indicators.

Vulnerability Type	Vulnerability- related indicator
Climatic	Number of days/nights with extreme temperature (compared to ref. annual/seasonal temperatures at day/night times)
Climatic	Frequency of heat/cold waves
Climatic	Number of days/nights with extreme precipitation (compared to ref. annual/seasonal precipitation at day/night times for each season)
Climatic	Number of consecutive days/nights without rainfall
Socio-economic	Current population vs. projections 2020/2030/2050
Socio-economic	Population density (compared to national/regional average in year X in country/region X)
Socio-economic	% share of sensitive population groups (e.g. elderly (65+)/young (25-) people, lonely pensioner households, low-income/unemployed households) - compared to national average in year X in country X
Socio-economic	% of population living in areas at risk (e.g. flood/drought/heat wave/forest or land fire)

Socio-economic	% of areas non-accessible for emergency / firefighting services
Physical & environmental	% change in average annual/monthly temperature
Physical & environmental	% change in average annual/monthly precipitation
Physical & environmental	Length of transport network (e.g. road/rail) located in areas at risk (e.g. flood/drought/heat wave/ forest or land fire)
Physical & environmental	Length of coastline / river(s) affected by extreme weather conditions / soil erosion (without adaptation)
Physical & environmental	% of low-lying or at altitude areas
Physical & environmental	% of areas at coasts or rivers
Physical & environmental	% of protected (ecologically and/or culturally sensitive) areas / % of forest cover
Physical & environmental	% of (e.g. residential/commercial/agricultural/industrial/touristic) areas at risk (e.g. flood/drought/heat wave/ forest or land fire)
Physical & environmental	Current energy consumption per capita vs. projections 2020/2030/2050
Physical & environmental	Current water consumption per capita vs. projections 2020/2030/2050

Source: JRC own elaboration.

4.4 State of access to energy

Energy is a key input for meeting basic needs and for achieving socio-economic development goals: access to energy, fuel for cooking, heating and lighting in households, power for industry, and petroleum products for transportation. The growth of the information and communications technology sector relies on the access to energy in general and access to electricity specifically. Energy access is linked to other basic services such as water and sanitation The use of energy, the types of energy used and the lack of access to sufficient energy have far reaching implications for a city's economic development, its environmental health and for social cohesion. Access to energy is one of the factors that bring together human development, economic growth and sustainability. Energy planning and energy policy are tackled across different levels of government.

In over two decades, India has made significant progress in providing universal electricity access to its population. Its electrification rate has increased very rapidly. The rate of national access has grown from 43% in 2000 to more than 95% in 2019 ([71]). After reaching 100% village electrification in 2018, within just a year, in March 2019, the GoI declared it had achieved the full electrification of all households (except those that refused access). In 2000 there was a spread of 41 percentage points between urban and rural (urban 88%, rural 47%), electrification efforts lead to a reduction of this spread to only 7 percentage points (urban 99%, rural 92%) in 2018.

The government supports the strengthening of distribution networks and increasing village and household connections by co-funding network upgrades and extensions. It provides grants through the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) scheme in rural areas, the Saubhagya scheme to ensure last-mile connectivity through mini-grid and stand-alone solar home systems, and the integrated power development scheme (IPDS) (in urban areas), building on the Restructured Accelerated Power Development and Reforms Programme. These efforts also supported the modernisation of the grid, including adoption of technology for data collection and monitoring, capacity building and customer care service. Besides providing access, these schemes have reinforced the transmission and distribution grids and driven the reduction in losses. After

([71]) https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf implementing the programme for the electrification of villages and households, the GoI is now working to further improve access to clean and secure energy and to ensure full reliable access to electricity (with solar PV or batteries, notably in rural areas) and reach the remaining population. Despite good progress in electrification, there are still around 100 million people without access ([72]).

4.4.1 Introduction

4.4.1.1 *Access to electricity*

With a population of 1.4 billion and one of the world's fastest-growing major economies, India will be vital for the future of the global energy markets. The Government of India has made impressive progress in recent years in increasing citizens' access to electricity and clean cooking. It has also successfully implemented a range of energy market reforms and carried out a huge amount of renewable electricity deployment, notably in solar energy. Looking ahead, the government has laid out an ambitious vision to bring secure, affordable and sustainable energy to all its citizens. Government is focusing on energy system transformation, energy security and energy affordability.

India's security of electricity supply has improved markedly through the creation of a single national power system and major investments in thermal and renewable capacity. India's power system is currently experiencing a major shift to higher shares of variable renewable energy, which is making system integration and flexibility priority issues.

India has taken significant steps to improve energy efficiency, which have avoided an additional 15% of annual energy demand and 300 million tonnes of CO_2 emissions over the period 2000-2018, according to IEA analysis. The major programmes target industry and business, relying on large-scale public procurement of efficient products such as LEDs and the use of tradable energy efficiency certificates. The government's LED programme has radically pushed down the price of the products in the global market and helped create local manufacturing jobs to meet the demand for energy-efficient lighting ([73]). Table 14 and Table 15 show India's installed power capacity in terms of Governance and fuel.

Table 14 Total Installed Power Capacity (Government wise) as on 31st Dec 2020

Sector	MW	% of Total
Central	93,927	25.10
State	103,617	27.70
Private	176,655	47.20
Total	**3,74,199**	**100.00**

Source: JRC own elaboration.

Table 15 Total Installed Power Capacity (Fuel wise) as on 31st Dec 2020

Fuel		MW	MW	% of Total	% of Total

([72]) Electrification rate can be measured in different ways. India has dual electrification targets that focus on both electrifying villages (a village is considered electrified if 10% of households and community services have access) and households. IEA methodology, however, focuses on the share of the population with access to electricity in line with the UN SDG tracking framework.

([73]) India 2020 Energy Review Policy

Fuel		MW	MW	% of Total	% of Total
Thermal			2,31,321		61.80
	Coal	1,99,595		53.30	
	Lignite	6,260		1.70	
	Gas	24,957		6.70	
	Diesel	510		0.10	
Hydro			45,699		12.20
Nuclear			6,780		1.80
RES(1)			90,399		24.20
Total			**3,74,199**		**100.00**

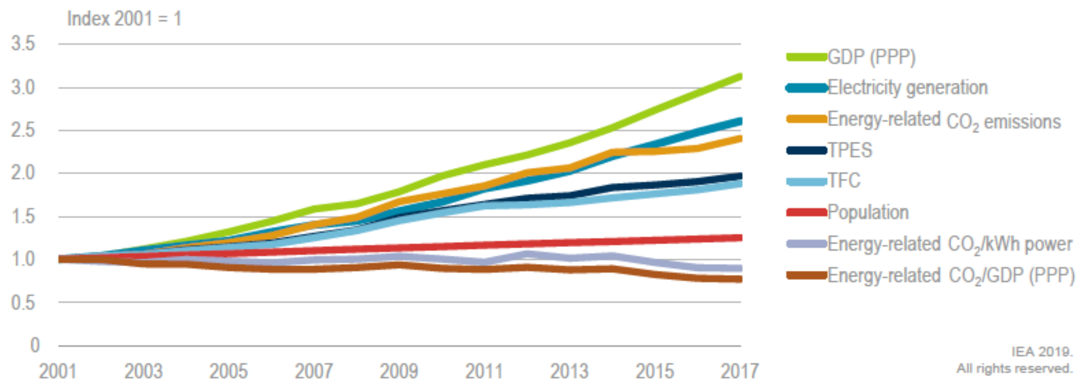
(1)RES (Renewable Energy Sources) include Small Hydro Project, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy.

4.4.1.2 *Electricity consumption*

India has been able to meet the gap between demand for and domestic supply of energy while addressing the environmental externalities associated with energy use.

In financial year 2020-2021, India's overall power supply position has only a marginal gap of about 0.5% and the peak power deficit stood at 0.7% between energy requirement and the energy supplied, according to the union coal ministry. Despite high growth rates experienced in energy-intensive sectors, energy consumption and carbon dioxide (CO_2) emissions have not grown as rapidly as gross domestic product (GDP). Electricity supply is growing in line with economic growth, while its carbon intensity is in decline thanks to the increase in the share of renewables and declining utilisation of coal power plants (**Figure 18**). Between year 2001 and 2017 India's energy demand and emissions steadily grew, driven by its strong growth in GDP. India has seen a reduction of around 13% in the emissions intensity of its economy (energy-related CO_2 emitted/GDP in PPP) during the past decade, while total final energy consumption and electricity generation continue to rise. The growth in CO_2 emissions has slowed and a minor decoupling of GDP growth from emissions has emerged since 2013.

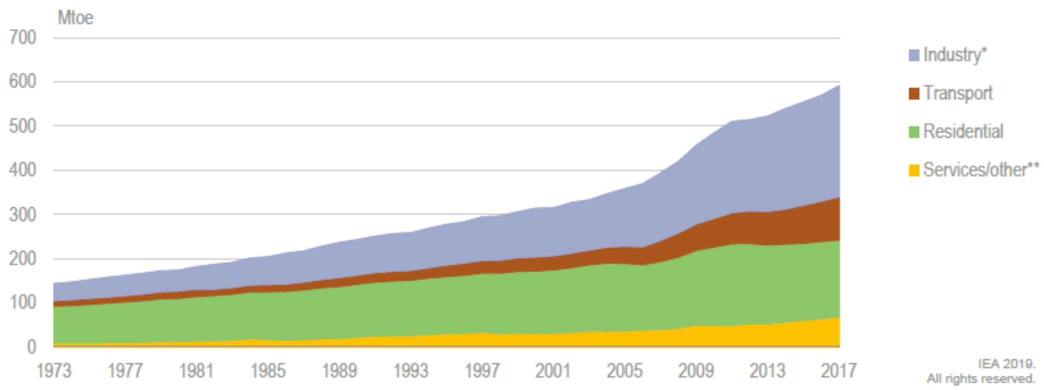
Figure 18: Trends in the growth of the economy, population and energy indicators



Source: IEA (2019a) World Energy Balance 2019, www.iea.org/statistics/

India's Total Fuel Consumption (TFC) increased by 50% in the decade from 2007 to 2017, with significant growth across all sectors (**Figure 19**.). Half of the growth came from the industrial sector, which accounted for 42% of TFC in 2017, including non-energy consumption.

Figure 19: India's Total Fuel Consumption



Source : IEA (2019a) World Energy Balance 2019, www.iea.org/statistics/

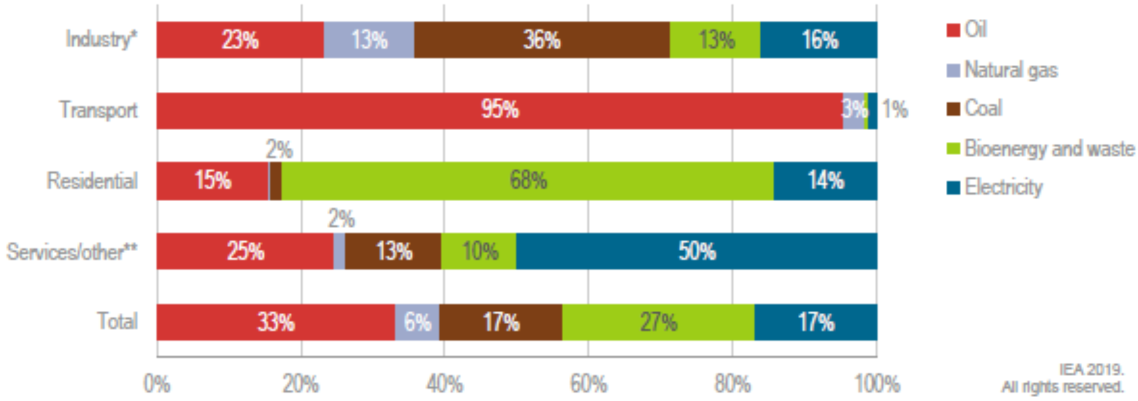
* industry includes non-energy consumption

** Services/others includes commercial and public services, agriculture and forestry

India's TFC has increased by 50% in the past decade, with growth across all sectors, but the largest increase is in industry and transport. Years run in India from 1 April to 31 March (**Figure 19)**.

Industry consumes a mix of coal, oil, natural gas, electricity and biofuels, with fossil fuels together representing 56% of total consumption (not counting electricity production) **(Figure 20**). India's sectors show large variations in energy source, with clear dominance of oil in transport, bioenergy in the residential sector and electricity in commercial consumption.

Figure 20: Total Fuel Consumption by Source and Sector, 2017



Source : IEA (2019a) World Energy Balance 2019, www.iea.org/statistics/

* industry includes non-energy consumption
** Services/others includes commercial and public services, agriculture and forestry

The residential sector is the second biggest energy consumer at 29% of TFC in 2017. Traditional use of biomass for heating and cooking accounts for the largest share of residential energy consumption, although the lack of sufficient data collection makes the numbers uncertain. The transport sector is the third-largest energy consumer at 17% of TFC in 2017, dominated by oil fuels. Transport energy demand has more than doubled in a decade, accounting for one-quarter of TFC growth. Finally, the service sector including agriculture consumed 12% of TFC in 2017, with electricity accounting for more than half.

4.4.1.3 *Electricity Access*

The GoI has been supporting the expansion of distribution grid infrastructure across India to foster electricity access in villages. It provides budgetary support (grants) to state government DISCOMs under the Deendayal Upadhyaya Gram Jyoti Yojana (in rural areas), the Saubhagya scheme (last-mile connectivity to households) and the Integrated Power Development Scheme (IPDS) (in urban areas). The co-ordinated cross-government schemes focus on strengthening distribution networks and increasing village and household connections by co-funding network upgrades and extensions by the DISCOMs. The GoI announced that India had achieved its goal of providing electricity to every village in India in April 2018. A village is considered to be electrified when 10% of households and all public buildings are connected to the grid. The final 600 000 villages (and a further 26 million households) had gained access to electricity, according to the latest government data in April 2019([74]). IISD-CEEW expects consumption subsidies to increase as a greater share of the population now have access to electricity, but not the financial capacity.

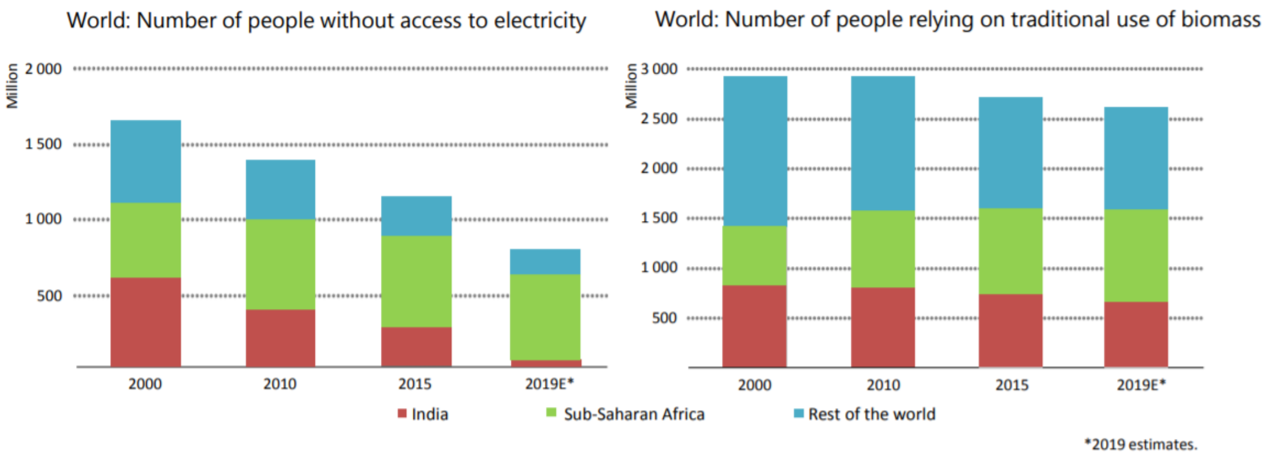
The electricity access is shared responsibility between the central and state governments, with states having considerable freedom to set electricity prices, the average subsidy level and the beneficiaries of the cross-subsidisation. To provide inclusive electricity access, under the National Electricity Policy, electricity is subsidised for the agricultural sector and domestic consumers below the poverty line (BPL). Households with a total annual income of ₹ 1.8 lakh, equivalent to USD 2,600, are included in the below-poverty-line category families.

Ministry of Power, GoI launched Ujwal DISCOM Assurance Yojana (UDAY) scheme in 2015 for state governments for improvements in operational targets.

Several support programmes for universal electricity access have included reforms to reduce and better target the subsidy. The Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) programme, with a total budget of USD 10.8 billion, also required the separation of household and agricultural feeders to avoid the overcompensation of agriculture. The Saubhagya scheme allocated a total budget of USD 1.8 billion to

([74]) India's central online tracking of electricity access can be found at: http://garv.gov.in/dashboard support the provision of electricity to individual households. One of the major reform efforts is the GoI work with states towards tariffs progressively reflecting the cost of supply of electricity, based on roadmaps for the reduction of cross-subsidies, established by the SERCs. Tariffs for all consumer categories are to be brought within ± 20% of the average cost of supply and cross-subsidies reduced. Subsidy to any category of consumers has to be provided through Direct Benefit Transfer (75). India has achieved electricity access for all and is tackling air pollution and clean cooking (76).

Figure 21: Electricity Access and Reliance on Biomass



Source: IEA (2019a) World Energy Balance 2019, www.iea.org/statistics/

Almost 750 million people gained access to electricity in India since 2000, while vigorous programmes have helped replace biomass use in cooking. India can offer good experience to Africa and the world **(Figure 21)**.

4.4.1.4 *Clean Cooking*

To promote clean cooking, the GoI subsidises the provision of LPG (also known as cooking gas) in order to reduce the exposure to indoor air pollution from burning wood or dung and the time needed for collecting fuelwood or unsustainable biomass. By the end of 2019 around 95% of the population had access to clean cooking (77). LPG is heavily subsidised and the sharp increase in LPG consumption from hitting 80 million connections in 2019 is also a substantial fiscal burden on the GoI budget. The 2018 budget allocated INR 197698 million (USD 2.78 billion) to LPG subsidy, but it will need to increase in the 2019 budget to INR 323 150 million (USD 4.54 billion).

Several major initiatives have been introduced to better target the subsidies and avoid commercial use of LPG, notably through the Pratyaksh Hanstantrit Labh (PAHAL), Pradhan Mantri Ujjwala Yojana (PMUY) and "#GiveItUp" schemes.

PAHAL, also known as the Direct Benefit Transfer of LPG scheme, sends the subsidy for the LPG purchased directly to a citizen's bank account. Key to the scheme's success has been the Aadhaar identity system, which links subsidy payments to bank accounts, and the better targeting of subsidies directly to women, which has increased women's financial inclusion and access to clean cooking. As of June 2019, 247 million LPG consumers have joined the PAHAL. By using PAHAL scheme, the GoI saved around USD 8.8 billion during 2013-20.

(75) The GoI introduced the direct benefit transfer in 2013 to provide subsidies directly to the people through their bank accounts, thus reducing leakages or delays. The subsidy on LPG cylinders will be credited directly to consumers' Aadhaar-linked bank accounts, as an advance in their bank account as soon as they book the first subsidized cylinder before delivery, so they can purchase the next cylinder at market rate until the cap of 12 cylinders per year is reached. Aadhaar is a 12-digit unique identity number that can be obtained voluntarily by residents of India, based on their biometric and demographic data.

(76) https://iea.blob.core.windows.net/assets/2bb811d9-2de6-4e7e-84e8-546111762f21/India-2020-Launch-Presentation.pdf

(77) https://www.pmuy.gov.in/about

Under the PMUY, women and BPL families receive a subsidy. Initially targeting 50 million LPG connections, the scheme reached 80 million in September 2019. PMUY had a total budget of USD 1.2 billion, which was committed by the central government. Individuals with an annual income over INR 1 million are excluded (800 000 people). The 2019 budget also confirms the goal to extend the PMUY to provide every single rural family with an electricity and a clean cooking facility.

The GoI launched the "#GiveItUp" campaign in which wealthier consumers with higher incomes are asked to volunteer to forego or "transfer" their LPG subsidy to a lower-income household. Middle-class LPG users are donating about USD 250 million annually to the effort. As of June 2019, over 10 million customers had voluntarily given it up.

4.4.1.5 *Energy in urban areas*

More than 50% of the world population (7 billion) lives in cities. By 2050, 70% of the world population will be in cities; close to 90% of the population growth is expected in cities. The pressure in sustainability is huge: challenges in terms of housing, infrastructure, basic services, food security, health, education, decent jobs, safety and natural resources, among others. Energy related challenges have grown tremendously already during the last century in cities all around the globe, in all countries, regardless the level of development. While cities acquire an increasingly dominant role in the global economy as centers of production and consumption, this rapid urban growth throughout the developing world is overtaking their capacity to provide adequate services for their citizens (ICLEI - Local Goverments for Sustainability et al., 2009)

In-depth review by IEA([78]) on India aims to assist the government in meeting its energy policy objectives by setting out a range of recommendations in each area, with a focus on energy system transformation, energy security and energy affordability. The review also highlights a number of important lessons from the rapid development of India's energy sector that could help inform the plans of other countries around the world. The India Residential Energy Consumption Survey (IRES) is the first-ever pan-India survey on the state of energy access, consumption, and energy efficiency in Indian homes. Conducted in 2019 in collaboration with the Initiative for Sustainable Energy Policy (ISEP), the survey indicates that 99.2% urban households have access to energy.

According to UN Habitat, cities consume 78 per cent of the world's energy and produce more than 60 per cent of greenhouse gas emissions, a reality that places cities at the forefront of the climate change and sustainability agenda([79]). In terms of energy consumption, cities generally account for about 60-80% of a country's demand, either directly or indirectly. Consequently, the way cities are planned, financed and managed has a determining effect on sustainability outcomes and on the lives and livelihoods of city residents. Cities, with high population densities, tend to concentrate environmental problems, air pollution, whose impacts can be felt both inside (may affect the health of the urban residents) and outside (affecting crops of near rural areas). Cities are typically more vulnerable to specific climate risks, such as increased temperatures and heat waves due to heat island effects, as well as to flooding resulting in increased surface run-off. On the other hand, it makes it easier to plan the provision of basic services (water and sanitation, electricity, waste collection and treatment, health, public transport, infrastructure) to citizens. As a result, urban areas tend to offer better social and economic opportunities than rural areas.

Differences in opportunities are found also within the city. Urban societies in developing countries are dual in nature: in some segments of the society, incomes are quite high, and their energy-consumption patterns are similar to those of industrialized countries, with increasing demand for high-intensity energy-consuming services, such as refrigeration, air-conditioning and personal transport. For the remaining segments of society, which constitute the overwhelming majority of the population, consumption patterns are similar to those in rural areas. Indeed, almost a billion urban residents live in informal settlements in developing country cities. In India, as in many other developing countries, urban population growth and the shortage of planned affordable housing have led to 26–37 million households (33–47 per cent of the urban population) living in informal housing (slums and unauthorised housing)([80]).

Energy is used in urban areas for transportation, industrial production, in households and in office activities or services. In households, energy is mainly used for cooking, heating, cooling and lighting, being household income and climate the most influencing factors in the source of energy used and in the pattern. In some

([78]) India 2020 Energy Policy Review IEA
([79]) https://www.un.org/en/climatechange/climate-solutions/cities-pollution
([80]) https://www.fsg.org/sites/default/files/publications/Informal%20Housing%20Inadequate%20Property%20Rights.pdf

cases, it is also used for productive uses. In most low-income countries, a high proportion (up to 90 per cent) of the energy used in residential building is for cooking. In poor urban communities, firewood alone often meets nearly all the energy needs of households. Traditional food processing and cooking are too time-consuming for most women who have to seek paid work to earn money: thus, an increasingly important activity in urban agglomerations is the street food products – often utilising highly energy inefficient cooking appliances.

In India out of the total population of 1,210.2 million as on 1st March, 2011, about 377.1 million lived in urban areas. The percentage of urban population to the total population of the country stands at 31.6.. The provisional results of Census 2011 reveals that there was an increase of 2,774 towns comprising 242 Statutory and 2,532 Census towns over the decade 2001-2011. Growth rate of population in urban areas was 31.8% ([81]). Nowadays approximately a third of the total population in India lived in cities ([82]).

4.4.2 Definitions and data

The IEA defines energy access as *"a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average*". A basic bundle of energy services means, at a minimum, several lightbulbs, task lighting (such as a flashlight), phone charging and a radio. Access to clean cooking facilities means "*access to (and primary use of) modern fuels and technologies, including natural gas, liquefied petroleum gas (LPG), electricity and biogas, or improved biomass cook stoves (ICS), as opposed to the basic biomass cook stoves and three-stone fires used in developing countries*". This energy access definition serves as a benchmark to measure progress towards SDGs (International Energy Agency, 2017).

More recently, however, there have been efforts in the context of the Sustainable Energy for All (SE4All) initiative to broaden understanding of access to energy in various dimensions (Bhatia and Angelou, 2015). The World Bank's Energy Sector Management Assistance Program is undertaking surveys in 15 countries to measure energy access according to the "**Multi-Tier Framework**", a methodology which measures multiple attributes of the supplied electricity and cooking fuel. It seeks to understand electricity access not in binary terms. The approach excludes illegal connections.

- From a focus on households to encompass businesses and public and community facilities;
- From electricity supply to encompass modern fuels for cooking and (where needed) heating;
- From access to energy to technologies for its use (particularly improved and energy-efficient stoves);
- From a binary definition (of having or not having access) to a continuum, reflected in several tiers of access;
- From physical connection or availability to include attributes of supply, including quantity, reliability, continuity and safety;
- From physical supply to affordability;
- From access at a point in time to a progressive upgrading in access over time.

In the same report (Bhatia and Angelou, 2015), the definition of access to energy services highlights the ability of the end user to utilize energy services (such as lighting, phone charging, cooking, air circulation, refrigeration, air conditioning, heating, communication, entertainment, computation, motive power, etc.) that require an energy appliance and suitable energy supply.

In practice, the attributes of the energy supply will influence its usability for various energy services. Up to eight key attributes could be used with the purpose of defining and measuring energy access: capacity, affordability, availability, reliability, quality, health and safety, legality, and convenience (United Nations Conference on Trade and Development, 2017). Yet, SDG7 specifically mentions four: *affordable, reliable, sustainable and modern.*

([81]) https://www.mohua.gov.in/cms/urban-growth.php
([82]) https://www.statista.com/statistics/271312/urbanization-in-india/

4.4.2.1 ***Secure energy***

As per IEA report on 'India Energy Outlook 2021', changing global energy dynamics and pathways for India point strongly towards the need for a broader concept of energy security that encompasses new and evolving risks to energy supply. To take one example, changes in India's electricity sector are dramatically increasing the need for flexibility in power system operation.Hour-to-hour ramping requirements are set to more than double in India over the next decade, and the pace of transformation would be even more rapid.

India needs to ensure that institutional and regulatory changes in the power sector keep pace with the speed of technological change if it is to safeguard the security of its electricity supply

Managing the risks and geopolitical hazards associated with these increasingly important value chains will be an important task for India's policy makers and one where – as with other aspects of energy security – international collaboration can play a vitally important role.

Table 16. *Total Generation and growth over previous year 2009 to 2020*

Year	Total Generation (Including Renewable Sources) (BU)	% of growth
2009-10	808.498	7.56
2010-11	850.387	5.59
2011-12	928.113	9.14
2012-13	969.506	4.46
2013-14	1,020.200	5.23
2014-15	1,110.392	8.84
2015-16	1,173.603	5.69
2016-17	1,241.689	5.80
2017-18	1,308.146	5.35
2018-19	1,376.095	5.19
2019-20	1,389.102	0.95
2020-21 *	901.035	-4.75

* Upto November 2020 (Provisional), Source : CEA

In India the electricity generation target of conventional sources for the year 2020-21 has been fixed as 1,330 Billion Unit (BU). i.e. growth of around 6.33% over actual conventional generation of 1,250 BU. The total generation, including renewable, during 2019-20 was 1389. **(Table 16)**

The electricity generation target of conventional sources for the year 2020-21 was fixed at 1330 BU comprising of 1138.533 BU thermal; 140.357 BU hydro; 43.880 nuclear; and 7.230 BU import from Bhutan.

The power supply position in the country during 2009-2010 to 2020-2021 (**Table 17**):

Table 17. *Power Supply Position in India during 2009 to 2020*

Year	Energy				Peak			
	Requirement	Availability	Surplus(+)/Deficts(-)		Peak Demand	Peak Met	Surplus(+) / Deficts(-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009-10	8,30,594	7,46,644	-83,950	-10.1	1,19,166	1,04,009	-15,157	-12.7
2010-11	8,61,591	7,88,355	-73,236	-8.5	1,22,287	1,10,256	-12,031	-9.8
2011-12	9,37,199	8,57,886	-79,313	-8.5	1,30,006	1,16,191	-13,815	-10.6
2012-13	9,95,557	9,08,652	-86,905	-8.7	1,35,453	1,23,294	-12,159	-9.0
2013-14	10,02,257	9,59,829	-42,428	-4.2	1,35,918	1,29,815	-6,103	-4.5
2014-15	10,68,923	10,30,785	-38,138	-3.6	1,48,166	1,41,160	-7,006	-4.7
2015-16	11,14,408	10,90,850	-23,558	-2.1	1,53,366	1,48,463	-4,903	-3.2
2016-17	11,42,929	11,35,334	-7,595	-0.7	1,59,542	1,56,934	-2,608	-1.6
2017-18	12,13,326	12,04,697	-8,629	-0.7	1,64,066	1,60,752	-3,314	-2.0
2018-19	12,74,595	12,67,526	-7,070	-0.6	1,77,022	1,75,528	-1,494	-0.8
2019-20	12,91,010	12,84,444	-6,566	-0.5	1,83,804	1,82,533	-1,271	-0.7
2020-21*	8,34,672	8,31,937	-2,735	-0.3	1,77,019	1,76,413	-605	-0.3

* Upto November 2020 (Provisional), Source : CEA

4.4.2.2 *Sustainable energy*

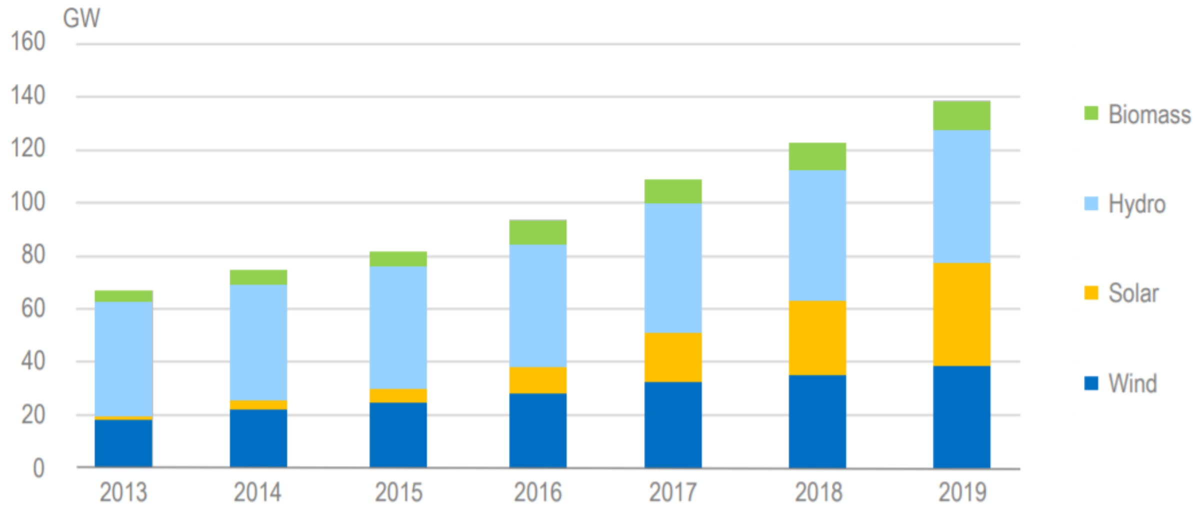
Local renewable energy sources such as biomass, solar radiation, hydropower and wind are all abundant in India. Energy recovery from waste can play a role in minimising the impact of Municipal Solid Waste (MSW) on the environment with the additional benefit of providing a local source of energy (Scarlat et al., 2015).

The government has embarked on an ambitious policy to boost renewable electricity, with a target of 175 GW capacity by 2022. Under its NDC, India targets a share of non fossil-based capacity in the electricity mix of more than 40% by 2030 and a reduction in the emissions intensity of its GDP of 33-35% by 2030 over 2005. Recently the GoI has indicated ambitious new targets for renewables capacity in the region of 450 GW. In addition, the GoI is promoting hydropower as a source of flexibility and grid stability (it is now categorised as renewable energy and can be supported under hydro purchase obligations). The GoI expects 21 GW of new hydropower projects to be developed by 2030, requiring an investment of about USD 31 billion.

India's energy sector is transitioning to greater sustainability. As a result of the country's proactive and sustained actions on climate change mitigation, the emissions intensity of India's GDP has reduced by around 13% in the past decade.

Figure 22 depicts India's renewable power generation capacity, 2013-19([83]):

Figure 22: India's renewable power generation capacity



Source : IEA (2019a) World Energy Balance 2019, www.iea.org/statistics/

Solar PV and onshore wind have seen strong growth, overtaking for the first-time investment in thermal power generation in 2018. To reach 175 GW by 2022 and 450 GW, system integration becomes a priority.

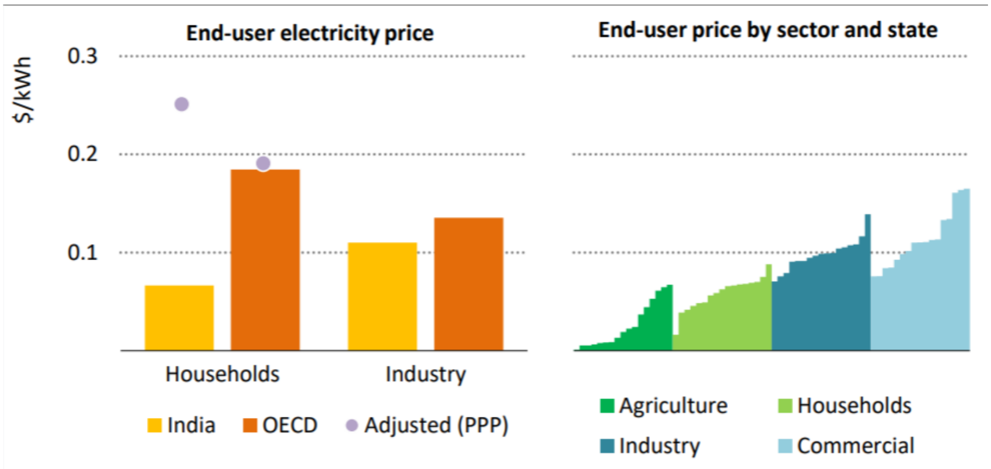
Energy efficiency is receiving more attention, with standards and codes being set for industry, buildings and appliances. Renewables are already providing a rising share of the electricity mix. India has vast renewable resources, which are great assets for building a sustainable energy future.

4.4.2.3 *Affordable energy*

Electricity prices in India in nominal terms are lower than the average among member countries of the Organisation for Economic Co-operation and Development (OECD). However, after adjusting for purchasing power, so as to reflect spending on electricity as a share of Indian household income, prices are higher than the OECD average. This is despite the fact that India has higher end-user prices for more energy-intensive industrial consumers in order to cross-subsidise the lower tariffs paid by vulnerable users in the household and agricultural segment. Prices also vary not just among end users, but also between states, where a complex patchwork of different taxes and subsidy regimes can leave consumers in some states paying five times more for their electricity than their counterparts in neighbouring states as shown in **Figure 23**.

([83]) IEA India Policy Review 2020

Figure 23: Comparison of electricity prices paid by different end users in India, 2018



Source: India Energy Outlook 2021

(Households' electricity tariffs in India are higher than the OECD average, adjusted for purchasing power, despite being subsidised by commercial and industrial consumers. End-user prices (stacked by state) calculate each state's DISCOM revenue per megawatt-hour for each category of consumer.)

The degree to which electricity becomes affordable is primarily a consequence of macroeconomic conditions, particularly the purchasing power of wages and the level of wage growth, but there are also issues endemic to the power sector that create additional challenges, such as high levels of technical and commercial losses and poor billing practices and collection rates. Tariffs sometimes end up four times higher than the purchase cost of power, and some low-income households pay a significant portion of their monthly income to meet electricity bills.

Looking ahead, the rise of renewables is likely to add to the complexity of electricity tariffs because it likely to lead to billing based on the time of use becoming a more important part of cost-effective system balancing. There is already a case for ensuring that the complex and varied tariffs in place do not disadvantage low-income households, and this further projected increase in the variation in tariffs adds to it.

Achieving universal energy access at affordable prices and on a 24/7 basis by 2022 is a top priority for the GoI and the states. Over recent decades India has made significant progress in village electrification and providing electricity connections to households.

4.4.2.4 *Data on energy access*

Official databases on access to electricity with global coverage show important discrepancies. The difference between IEA (estimates based on utility connections, reports higher figures) and World Bank (estimates based on household surveys) for figures on electricity access for 2014 is approximately 200 million (World Bank, 2015). IEA 2017 provides access data for 2016.

The IEA Energy Data Centre and the GoI are collaborating closely, through Ministry of Statistics and Policy Implementation (MoSPI), on annual energy statistics to establish the country's energy balance and improve India energy data collection and dissemination. The IEA supports MoSPI's work to help centralise data collection and to improve templates used to collect data from ministries to establish the country's energy balance. The IEA and Ministry of Science & Technology (MoST) collaborate under a memorandum of understanding to improve the availability and collection of data on energy RD&D.

The IEA defines energy access as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average". This energy access definition serves as a benchmark to measure progress towards goal SDG 7.1 and as a metric for our forward-looking analysis([84]).

([84]) IEA Defining energy access: 2020 methodology

4.4.2.5 *Indicators*

Monitoring energy access is a challenging task. If no survey is conducted regularly in the national/regional/ local level including questions on the issue, it could become very demanding since it generally requires conducting surveys and interviews. Energy Access Indicators are the quantitative and/or qualitative measures derived from a series of observed facts that can reveal a country, community or person's relative status in modern energy access (OECD, 2008). Energy access indicators can be single (one-dimensional), a set of individual non-aggregated indicators (dashboards), or composite (multidimensional). Some examples are listed below:

- Number/percentage of population with electricity access.
- Electricity consumption per capita.
- The Multidimensional Energy Poverty Index (MEPI) developed by a team at UNIDO.
- The Energy Development Index (EDI) used by the International Energy Agency.
- The Energy Access Index proposed by the UK Charity, Practical Action.

4.4.3 Energy access implications

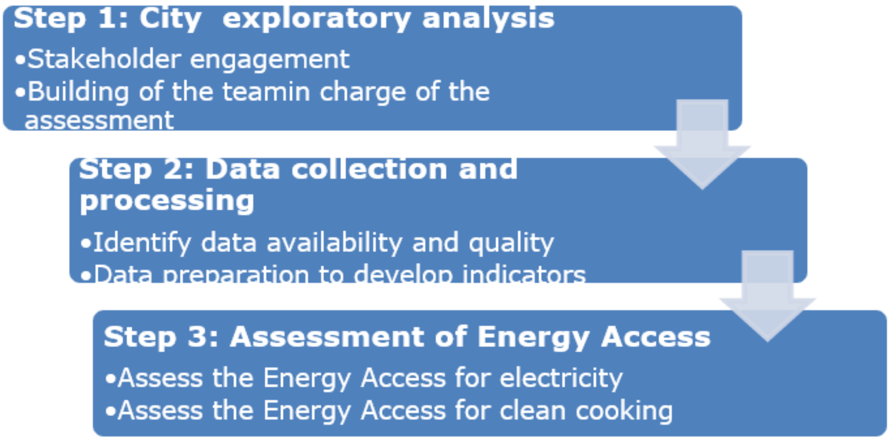
This calls for a strategic engagement of different stakeholders that may participate actively in the decisions regarding the provision of the energy services.

Against this background, the energy access approach includes the attributes of secure, sustainable and affordable energy, which have been already presented through the present document. As a consequence, any assessment of Access to Energy shall take into consideration these attributes. In the following paragraphs, how these attributes are assessed in the AEA framework is further developed.

4.4.4 Access to Energy Assessment (AEA)

The Access to Energy Assessment (AEA) is developed as a dashboard of multiple indicators that help to figure out a clear picture of the current condition of the local authority. The first step of the procedure consists in building the team responsible for the assessment. For effective results, suitable skills and knowledge of both the topic and the territory should be important requirements for the team members. Moreover, the involvement of stakeholders may be essential for the following step. The second step regards the collection of data necessary for developing the indicators. In the third step, the indicators are used to assess the energy access in the key fields proposed within the GCoM framework (**Error! Reference source not found.**). Detailed assessment of the current condition can support decision making process regarding policies and investments.

Figure 24: Procedure for the Energy Access Assessment



Source: JRC own elaboration

It must be noted that at the date of the preparation of the present document, the recommendations of the GCoM TWG on energy access and energy poverty are not yet available.

A. India's power system transformation

B. Ensure power system Reliability

Most recently, the Ministry of Power issued the Electricity Right of Power Consumers Rules, 2020, with the aim to ensure a minimum standard of service for the supply of electricity to end consumers. This rule requires state electricity regulatory commissions to develop clear guidelines for discoms to follow for maintaining a 24/7 reliable distribution network. It also directs SERCs to prescribe detailed mechanisms for performance measurement of discoms and suitable compensation for consumers in case of non-performance ([85]).

While these directives and regulatory oversight have improved reliability on the bulk power system, the same is not true for the distribution network. What it means is that, although the incidence of regional, large-scale blackouts is rare, the end consumers (especially from rural and peri-urban areas) are nevertheless subject to intermittent and frequent power outages.

4.4.4.1 *Data collection*

The collection of data to develop the assessment is a key step of the process. However, data is not always available. It also may vary in terms of detail, scale, aggregation, and typology. For this reason, several options of data collection can be considered and a combination of the different opportunities may allow filling the gaps. Modelling outcomes are a resource, as well. As previously mentioned, data regarding local territories is ideal, but in case this is not accessible, integration with more aggregated data at regional or country level may be feasible. In this perspective, National data from public institutions may represent a key starting point. Statistical Services may conduct periodic national population and housing census that may include household energy usage data. There may also be initiatives led by central governments or international institutions focusing on particular regions or areas. In these cases, comparisons or modelling methodologies based on these data, if transparent and well-explained, may lead to acceptable results and estimations. As an example, the International Energy Agency has historical values since 1971, by country and regions, including actual consumption levels and share of households relying on traditional fuels as primary source for cooking. Food and Agriculture Organization (FAO) is working on the area of fuel and energy for cooking, heating, lighting and powering. Resources on this topic are publicly available on the website (http://www.fao.org).

Other options for data collection can be online platforms from research centres or universities that collect and publish data and analysis related to climate change. Collaborations with universities may be a strong point in the fact that specific courses, master thesis and PhD researches can focus on specific topics in areas within the local authority territory and produce useful results. This underlines the importance of collaboration and stakeholders' involvement.

Moreover, local authorities should have a clear picture of the financial institutions (FI) to be partnered with. FI should be contacted at the beginning of the CAP process (see chapter 8 on financing), since their support may deal with numerous options in addition to funds. As an example, scholarships may be funded allowing students and researchers to work on projects that are able to provide key data. Energy surveys are an essential data-collection tool. The preparation of the survey is a crucial step. Questions should be focused in order to gather useful data for building the indicators and samples must be chosen accurately. Moreover, the same survey could be used to establish energy access and household fuel use for inventory purposes. In this context, it is also important to keep track of the categories and the samples surveyed. This tool could be useful in the case of off-grid areas and households. Survey results can then be used for example to determine the expected monthly electricity bills and customers' ability and willingness to pay.

4.4.4.2 *Key variables and indicators*

Access to energy has a multi-dimensional nature which makes its assessment challenging. As previously stated, binary definitions of energy access – 'having access' or 'not having access' – are unable to catch important differences in terms of energy technologies and communities' needs. On the contrary, the use of multiple indicators allows evaluating energy access with the aim of supporting decision making, and clearly

([85]) https://pib.gov.in/pressreleasepage.aspx?prid=1682384 monitoring progress made. In literature numerous types of energy access indicators exist. This guidebook introduces the list of indicators identified by the Global Covenant of Mayors for its Energy Access and Poverty Pillar. The indicators are divided between global and regional relevance and structured over three attributes of secure, sustainable and affordable energy.

Global indicators

Secure energy indicators

- Percentage of municipality population or households with access to electricity
- Average duration of available electricity
- Average yearly energy consumption per capita
- Estimated share of electricity consumed within the municipality but not billed (non-technical losses, illegal connections) For the section Sustainable Energy
- Average number of electric supply interruptions in a typical month (or year)
- % energy consumption per capita from i) electricity, ii) gas, iii) other sources

Sustainable energy indicators

- Installed capacity of renewable energy sources within local boundaries
- Total energy generated from renewable energy source within local boundaries
- Energy consumption from renewable energy sources
- Source mix of thermal energy (heating and cooling) consumed within local boundaries
- Percentage of households within the municipality with access to clean cooking fuels and technologies
- Total installed energy capacity within local boundaries
- Number of local energy efficiency programs
- Number of local renewable energy programs

Affordable energy

- Percentage of households or population within the city boundaries that spending up to X% of income on energy service
- Percentage of households within the municipality experiencing heating or cooling discomfort
- Percentage of clean energy investment at local level going to low- and moderate-income househo
- Price of green electricity

Regional indicators

- MW of installed rooftop and community solar in your jurisdiction
- Percentage of population employed in non-renewable energy sectors
- Number of essential services that would take more than one (1) hour to access by walking, cycling and public transport
- % of population employed in non-renewable energy sectors
- Number of essential services that would take more than one (1) hour to access by walking, cycling and public transport
- % of population living less than 1600 m from nearest mass transit station/stop
- % of public building expenditure on energy
- Average percentage of revenue spent in energy generation for: i) industries, ii) commercial, iii) tertiary, of the municipality

- Percentage of population/households relying on the traditional use of biomass for cooking
- Time spent and distance covered gathering fuelwood
- Number of improved cookstoves being used
- Percentage of household income spent on cooking
- Electricity bill collection rate

A detailed description of the indicators, including units, what the indicator measures and possible data sources, is provided in the updated version of the Common Reporting Framework expected to be published in 2022.

5 Climate Action Plan (CAP) process: development of the plan / moving forward

Plan elaboration – that is, breaking the targets down into actions the local authority will undertake in the sectors addressed – serves several functions as well as translates the city's vision into practical actions assigning deadlines and a budget for each of them. It outlines what the city will look like in the future in terms of energy, mobility, resilience, infrastructure and land use, population, consumption patterns and climate projections while also communicating the plan to stakeholders. In addition to generating a roadmap of specific, scheduled, budgeted actions, roles and responsibilities, the CAP serves as a reference during implementation and monitoring. The following characteristics may be useful to develop sound CAP actions:

- **Measurable**: Design actions based on the indicators used for the BEI and the RVA.
- **Thorough**: Elucidate actions in depth to get a clear and realistic sense of requirements and results (resources, budget, timeframe, policy integration, etc.). All actions adopted in the CAP should be carefully designed and properly described, including timing, budget, responsibilities and sources of financing.
- **Realistic**: Assess action implementation requirements against available capacity and resources.
- **Appropriate**: Actions depend on the specific context of each local authority and the quality of the assessment of the existing local, regional and national policy framework.

For each action explored, consider also where chief responsibility lies (whether or not they are addressed by the local administration and/or require coordination with higher or national authorities), what instruments will be used (regulation, financial support, communication and information, demonstration, etc.) and the impact on energy production and consumption patterns (energy efficiency of equipment, buildings, cars; behavioural change such as turning off lights, using public transportation; cleaner energy such as renewable energies, biofuels) and or vulnerable sectors. More specifically, for each action included in the action plan, the local government should provide the following:

- Brief description of the action/action area/sector
- Assessment of energy saving, renewable energy production, and GHG emissions reduction by action, action area or sector (only applicable to mitigation actions).
- Financial strategy for implementing the action/action area/sector
- Implementation status, cost and timeframe
- Implementing agency(ies)
- Stakeholders involved in planning and implementation
- Prioritisation of actions
- Policy instrument(s) to implement the actions

Most local authority activity concerns buildings and transport, the use of renewable energy sources to produce energy locally, urban and land-use policies, and public procurement. In most countries, however, these policies are decided at regional and national levels and local authorities are not always part of the decision-making. In assessing existing policies, concentrate on the local authorities' capacity to go beyond national policies in the territory under their responsibility and to ensure resources and financing for the proposed actions.

Box 21. CAP actions: best practices

- Catalogue existing activity/policy;
- Analyse best practices;
- Set priorities based on the results of the pre-assessment;
- Carry out risk analysis;
- Specify timing, responsibilities, budget and financing;
- Seek approval and funding;
- Review/Update and communicate CAP regularly.

It is worth noting that continuous monitoring and evaluation is needed to follow CAP implementation and progresses towards the defined targets and eventually to make corrections. Regular monitoring followed by adequate adaptations of the plan allows initiating a continuous improvement cycle. This is the "loop" principle of the project management cycle: *Plan, Do, Check, Act*. It is important that progress is reported to the political leadership.

5.1 Setting objectives and targets

5.1.1 Long-term vision

Local authorities should establish a long-term vision with clear SMART([86]) objectives. The vision shall be tackled as the guiding principle of the CAP work, pointing out the direction that the municipality wants to follow. A comparison between the vision and the local authority's current situation is the basis for identifying which action is needed to reach the desired objectives. The CAP work is a systematic approach to gradually get closer to the vision.

The vision should be elaborated with the local communities through citizen participation and discussion groups in order to allow for the unification of all the stakeholders.

Despite the fact that the vision needs to be compatible with the GCoM commitments, it could also be more ambitious than that. Some cities already plan to become carbon neutral in the long run. Setting a longer-term target is considered a key success factor of CAPs as it clearly shows the local authority's political commitment and gives a strong message to citizens and stakeholders on how the local authority wants to develop in the future, paving the way for more substantial investment in sustainable infrastructure (Rivas et al., 2015). The vision should be realistic but still ambitious and aligned with the national and international policy landscape. It should describe the desired future of the city and be expressed in visual terms to make it more understandable for citizens and stakeholders.

5.1.2 Setting mitigation targets

Once the vision is well established, it is necessary to translate it into more specific objectives and targets.

With regards to mitigation, all GCoM local governments and cities are required to set and report city-wide emissions reduction targets. The GCoM defines eight categories of requirements for target setting, as explained below:

- Boundary (geographic coverage, sectors, and GHGs): The target boundary shall be consistent with all emissions sources included in the GHG emissions inventory, with the possibility to exclude sources that are not controlled by the local government. In case that the target boundary does not align with the inventory boundary, any additions or exclusions shall be specified and justified.
- Target type: Local governments shall use one of the following four target types: base year emissions target, base year intensity target, baseline scenario target, or fixed level target (**Error! Reference source not found.**). For a baseline scenario target, the modelling methodologies, and parameters shall be transparently described.
- Target year: The target year shall be the same as the target year adopted in the Nationally Determined Contribution (NDC). Cities that set a target year beyond 2030 shall include an interim target before 2030.
- Base year (for base year target and base year intensity targets only): The base year shall be the same as the base year used in the NDC. Where the base year is different from the NDC (e.g. due to a lack of data availability), this shall be justified.
- Ambition: At a minimum, the target shall be as ambitious as the unconditional components of the NDC. Local governments should set targets that are more ambitious than the NDC.
- Units: Targets shall be reported as a percentage (%) reduction from the base year or scenario year. The absolute emissions in the target year(s) in metric tonnes $CO_{2\text{-eq}}$ shall also be reported.
- The use of transferable emissions units is only permissible when a city's target ambition exceeds the NDC. Where this is the case, the local government shall report the target, with and without the transferable emissions units, as well as identify the source of the transferable emissions units.

([86]) The principles of the SMART acronym: Specific, Measurable, Achievable, Realistic, and Time-bound

- Any conditional components included in the target shall be identified. Where possible the conditional components should also to be quantified. Conditional components include where cities set a stretch target, or where actions are identified for other key stakeholders beyond that which they have committed to themselves (for example, where a local government assumes a more ambitious reduction in the carbon-intensity of the national electricity grid than that committed to in the NDC or official government policy), if possible.

Box 22. Target type ([87])

Base year emissions target: Reduce, or control the increase of, emissions by a specified quantity relative to a base year. For example, a 25% reduction from 1990 levels by 2030.

Base year intensity target: Reduce emissions intensity (emissions per unit of another variable, typically GDP or capital Gross Domestic Product – GDP or per capita) by a specified quantity relative to a base year. For example, a 40% reduction from 1990 base year intensity by 2030.

Baseline scenario target: Reduce emissions by a specified quantity relative to a projected emissions baseline scenario. A Business as Usual (BaU) baseline scenario is a reference case that represents future events or conditions most likely to occur in the absence of activities taken to meet the mitigation target. For example, a 30% reduction from baseline scenario emissions in 2030.

Fixed-level target: Reduce, or control the increase of, emissions to an absolute emissions level in a target year. One type of fixed-level target is carbon neutrality

5.1.3 Setting adaptation goals

Though climate change is perceived as a global threat little attention is paid to the ways in which it affects local populations and settlements in cities. This means little attention to the importance of locally driven adaptation, both to reduce risks and to be better prepared to cope with consequences. In cities many initiatives are underway in India that respond to climate change and to mainstream effective adaptation. Adaptation has to be mainstreamed within urban development and urban governance. Many local authorities in India are grappling with large deficits in infrastructure and services and do not see climate change adaptation as a priority. However, their attention may be engaged if they can see the co-benefits between adaptation and measures to address development and environmental health concerns.

Adaptation action is defined as "policies, programs, and projects designed and implemented specifically to address the current and projected impacts of climate change." Therefore, the goals are focused on examining policies, programs, and projects in which specific reference has been made to supporting adaptation to climate change or climate risk reduction. Niti Ayog([88]) has identified several adaptation goals for India.

One way to set adaptation goals is to integrate adaptation into the everyday functioning of sectors so that their efforts are protected against the negative impacts of climate change. While this concept of 'mainstreaming' is not new, it is not taking place at the scale that is required. In some instances, adaptation is integrated into the policies and planning documents, but not implemented in action. Evidence-based research on what can enable implementation can help accelerate the uptake of mainstreaming.

Climate change is a complex issue that integrates many scientific fields to explain and estimate the immediate and potential long-term impacts. The impacts include effects of GHGs on the climatic system, energy balance, and ecosystems as well as social and economic systems. A complex issue garners a complex response to tackle it, both, at the temporal and spatial scales. The Assessment of Climate Change over the Indian Region report published by the Ministry of Earth Sciences gives the latest data on climate change observed in the Indian subcontinent. The report launched by the Global Commission on Adaptation in 2019

([87]) See also the Global Protocol for Community Scale Greenhouse Gas Inventory (GPC) available at: https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
([88]) https://niti.gov.in/writereaddata/files/Strategy_for_New_India.pdf

enumerates the imperative for climate adaptation on three fronts: the human imperative; the environmental imperative; and the economic imperative. The development pathway of India is marked by the dependence on climate-sensitive sectors agriculture, water, health, infrastructure, natural ecosystems and forestry and energy. This makes the socio-economic system of the country highly vulnerable to climate change and its impacts. For the purpose of the guiding framework, the following 6 systems are identified for developing a Long-term Strategy- agriculture, water, urban, rural, health, and natural environment. Disaster risk management and resilient infrastructure are cross-cutting issues across the systems mentioned above ([89]).

5.1.4 Setting the targets for energy access and energy poverty

Energy poverty is lack of access to adequate, high-quality, clean, and affordable forms of energy or energy systems. It is a prominent risk factor for global burden of disease and has severe environmental, social, and economic implications. The India Residential Energy Consumption Survey of year 2019 (IRES) is the first-ever pan-India survey on the state of energy access, consumption, and energy efficiency in Indian homes. It covers nearly 15,000 households in 1,210 villages and 614 wards in 152 districts across 21 states ([90]).

Key finding of the survey include :

- 96.7 per cent of Indian households are now connected to the grid, with another 0.33 per cent relying on off-grid electricity sources.
- 2.4 per cent of Indian households still remain unelectrified. Most of them are concentrated in the rural areas of Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar.
- A majority of the unelectrified households cited their inability to afford grid-connection as the reason for not having a connection.
- An average Indian household receives 20.6 hours of power supply from the grid per day. The average daily supply in urban areas (22 hours) is longer by a couple of hours than in rural areas (20 hours).
- The power supply situation has significantly improved in rural India since 2015, especially in the six ACCESS states (Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal). Daily power supply to rural households in these states is around 18.5 hours in 2020 compared to 15 hours in 2018 and 12.5 hours in 2015.
- This improvement in the power supply situation is also reflected in the improved satisfaction rates among the households. In the six ACCESS states alone, the satisfaction levels among rural consumers from electricity supply situation in their homes increased from 23 per cent in 2015 to 55 per cent in 2018 to 73 per cent in 2020.

Under the GCoM framework, the local authorities commit to improving the access to energy and reduce the level of energy poverty within the area of their responsibility. The set of global and regional energy access and poverty indicators developed by the GCoM serves as a foundation for the development of an energy access and poverty assessment. Indicators are determinants, along with the assessment of the current status, to allow to monitor the progresses of energy access and energy poverty related actions. On the basis of the indicators and requirement previously described, LAs can choose and declare their energy access and energy poverty goal. The Common Reporting Framework update to be published in 2022 provides further description and guidance over requirements for setting an energy access and poverty goal. This approach enables to keep a high level of flexibility which supports the consideration of local peculiarities. On the other side, the process to improve the energy access selected by local authorities will be clearly showed by the progresses in each indicator. The following box reports the SDG7 main goal and targets.

Box 23. Sustainable Development Goal 7 (SDG7)

SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all. The targets are:

— By 2030, ensure universal access to affordable, reliable, and modern energy services

— Increase substantially the share of renewable energy in the global energy mix by 2030

— double the global rate of improvement in energy efficiency by 2030

([89]) https://www.teriin.org/sites/default/files/2020-09/guiding-gramework-LTS-adaptation.pdf
([90]) https://www.ceew.in/publications/state-electricity-access-india

— By 2030, enhance international cooperation to facilitate access to clean energy research and technologies, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technologies, and promote investment in energy infrastructure and clean energy technologies

— By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, particularly least developed countries (LDCs) and small island developing states (SIDS).

5.1.5 Actions with co-benefits

The benefits of policies that are implemented for various reasons at the same time are numerous. Most including climate change mitigation policies, designed to address greenhouse gas mitigation, also have other, often at least equally important, rationales (e.g. related to objectives of development, sustainability and equity).

Immediate needs (such as high levels of unemployment, poverty, high crime rates, and infrastructural backlogs) compete with climate change for political attention and resources, so any action must have development co-benefits.

The following sections provide a short overview of the policies and measures usually implemented by local authorities to reduce their energy consumption and CO_2 emissions in the mandatory and non-mandatory sectors on one hand and to enhance climate vulnerability and risk reduction on the other hand.

5.2 Elaboration of the plan: Mitigation actions

5.2.1 Local policies to support Climate Action Plans

Strengthening the multilevel governance allows addressing more effectively the issues of climate change in cities. The transition towards a more sustainable urban environment at the local level includes a common understanding of the importance of curbing the city's CO_2 emissions. This understanding provides a basis upon which political leadership instigates a process of exploring possibilities and discussing different options with a wide range of stakeholders towards selecting, detailing, implementing and monitoring local action.

Climate change policies and preparedness strategies are most effective, and draw the most support from residents and community groups, if they are designed through inclusive processes and address the intersecting problems of racial, income, and environmental inequalities. In addition, climate solutions are the most successful when city leaders partner with community groups to set priorities and shape those solutions. By embracing strategies that support pathways to a just economy while reducing GHG emissions, extreme weather, flooding, and other climate change risks, city officials can expand access to living wages and safe jobs, quality schools and affordable housing, and safe and sustainable neighborhoods.

To achieve the above goals, Covenant teams may consider the following nine principles while elaborating the city's Climate Action Plan (CAP):

- Make equity, racial justice, and a just economy core goals of city resilience and climate action plans.
- Collaborate with community groups and build neighborhood capacity to shape and implement climate change solutions.
- Expand economic opportunities and the availability of affordable housing.
- Increase access to affordable and clean energy.
- Ensure access to affordable and clean transportation.
- Invest in resilient infrastructure and nature-based solutions.
- Support emergency preparedness and resilient disaster recovery.
- Support social cohesion and deeply connected communities.
- Use innovative financing to strengthen community resilience and livability.

For successful climate and energy policies there are two main different forms of collaboration: horizontal and vertical. Both of them are crucial to bridge the gaps of knowledge, skills and authority. In this process, local authorities play a key role in facing climate change issues and have the capacity to support and mobilise action for local energy generation investments through several modes of urban climate governance. In the following, four modes of urban energy and climate governance are investigated and a policy matrix that summarises the scope of each mode along with the main tools, the barrier that requires being addressed and exemplary actions to support local energy sustainability is provided. The modes of urban energy and climate governance ([91]) can be mainly summarised as:

- Municipal self-governing
- Municipal enabling (governing through enabling)
- Governing through provision
- Regulation and planning (governing by authority)

Overall, the barriers that can be addressed with each main tool under these modes of governance are different. For this reason, it is often necessary to combine multiple modes of governance to reinforce and align incentives for particular objectives. This must be supported by an analysis of the legal, physical, social and economic barriers hindering local energy generation prior to considering corrective actions and measures.

5.2.1.1 *Municipal self-governing*

Local Authorities have the capacity to govern their own activities and undertake strategic investments in municipality-owned assets (Kern and Alber, 2009), which include investments in energy efficiency and local energy generation based on renewable energy sources. The main tools that are used by local authorities in this capacity are energy audits, demonstration projects in public facilities and public procurement, which can be used to better manage the local authority estate. Through these tools, local authority can provide technical validation and stimulate energy efficiency and demand for renewable energy and/or its purchase from district networks (**Table 18**). Moreover, this mode of governance also relies on reorganisation and institutional innovation. Awareness raising among public servants and transversal communication among different departments are key measure to implement CAPs and progress towards sustainability.

Table 18. Municipal self-governing mode of urban climate governance

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
Municipal self-governing: **Strategic investments in municipality-owned assets to increase local energy generation**	Energy management of local authority estate	Lack of transparent and consistent monitoring and control of energy use; Disincentive for energy efficiency efforts in budget; Difficulty for public entities to contract and manage energy service providers.	Establish standards for monitoring and management of energy to improve efficiency in a systematic and sustainable way; Adopt high energy efficiency performance standard for public buildings.
	Demonstration projects in public facilities	Need for technical validation and demonstration of performances.	Town halls or municipal buildings with solar energy façades and PV powered schools Counter of emission avoided publicly shown; Showcases of obtained results to raise citizen

([91]) Modes of urban climate governance are based on definitions in Kern and Alber, OECD and IEA

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
			awareness.
	Green public procurement	Need to stimulate demand for energy efficiency renewable energy and/or the purchase of district heating/cooling; Need for National implementation of core criteria as a reference for green public procurement procedures; Deficiency in national and regional platform of public procurement.	Green public procurement for purchasing energy efficient appliances and clean vehicles; Low-carbon, distributed energy supply in public buildings and schools; Municipal purchases of certified green electricity; Clean and sustainable procurement of the LA fleet.
	Institutional reorganisation	Allocation of competencies split in different departments.	Allocation of competencies split in different departments.

Source: JRC own elaboration.

5.2.1.2 *Municipal enabling (governing through enabling)*

As a facilitator, the local authority has an active role in enabling cooperation between community actors, including those that lead to the launch of public-private partnerships to promote local energy generation ([92]). Moreover, the involvement of a range of different partners increases the democracy of the processes. The LA also has a crucial role in engaging in awareness and capacity building campaigns that promote energy efficiency in buildings, sustainable transport and behaviour, utilisation of renewable energy sources and the deployment of local energy generation technologies. These tools can be actively used within the capacity of local authorities to overcome any lack of business models to leverage financial resources as well as inadequate knowledge and skills (**Table 19**).

Table 19. Municipal enabling mode of urban climate governance

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
Governing through enabling: Facilitating co-operation among stakeholders and awareness building	Labels and certificates in the building sector	Lack of reliable and credible advice on the building performance and awareness of energy savings potential.	Implement all national and/or statal provisions; Promote the adoption of additional voluntary schemes.

([92]) "The state of European Cities 2016".EU, UN-Habitat 2016.

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
	Partnership with transport service providers	Fragmentation of modes	Integrated ticketing and charging.
	Public-private partnerships	Lack of business models to leverage financial resources; Budget constraints in LA.	Public-private partnership for anaerobic digestion of bio-waste; Co-financing between local and regional authorities and private investors for public energy upgrading.
	Awareness raising/training	Inadequate knowledge and skills that may hinder undertaking renewable energy projects. Need for capacity building of LA staff.	Promotional and Communication campaigns to promote behavioural changes; Effective communication on public transport; Promote competitions, awards and contests for climate protection and GHG reduction efforts; Provide guidelines for energy efficiency improvement; Networking with other LA, state / national authorities, universities to ease the access to funding opportunities; Showcases of obtained results; Appropriate training activities for LA staff.
	Community cooperatives for local energy projects	Need to overcome perceptions of risk as a barrier to citizen involvement.	Supporting tools and information sessions for citizen empowerment

Source: JRC own elaboration.

5.2.1.3 *Governing through provision*

The Local Authority is a provider of urban services and as such, has control or influence over infrastructure development. Within this capacity, the LA can effectively guide development in a way that increases energy efficiency in all urban sectors, support transition to sustainable transport and promote local energy production (**Table 20**).

Table 20. Governing through provision mode of urban climate governance

Mode of urban climate governance [91]	Tools	Barrier addressed	Action examples
Governing through provision: Providing services and financial resources	Public sector financial management and procurement policies	Split incentives and difficulties to access them; Fragmentation in processes and actors of the building trade; Budget constraints.	Revise budgetary rules to allow retention of energy cost savings for other justified public spending; Revise public procurement rules (GPP) to allow for contracting of energy service providers and adopt EE purchase requirements.
	Direct infrastructure investments for transport	Congestion and high energy consumptions and related emissions due to private transport modes; Low density territories.	Reliable and affordable public transport infrastructure (light rail system and bus rapid transit); Fine tune public transport to the characteristics of the territory (density, type of fluxes).
	Financial incentives in transport	High cost and low financial sustainability of electric mobility ;	LA incentives for purchasing clean electric vehicles and electric bikes.
	Direct energy infrastructure investments	Insufficient energy infrastructure to provide access to renewable energy;	Investments in electric networks; Minimum quotas for renewable energy supply or co-generation provided by LA owned utilities; Renewable energy sources in public housing.
	Incentives and grants to local energy generation	Insufficient financial incentive; Constrains of local budget; Competition with other investment priorities;	Use public funds (also national) to leverage private and commercial investments; Third party financing; ESCOs;

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
		Presence of market failures for related technological options.	Municipal subsidies for renewable energy.

Source: JRC own elaboration.

5.2.1.4 *Regulation and planning (governing by authority)*

In addition to capacities as implementer, enabler, and provider, local authorities govern by authority through setting regulations and putting forth urban planning principles ([93]).

Among other tools, local authorities can revise building codes to promote the improvement of energy efficiency in buildings, impose road charging to reduce congestion as well as incentive the use of renewable energy in the building stock for distributed generation. In the context of local energy generation, this mode of governing involves setting requirements on the mandatory use of renewable energy and ruling on strategic energy planning decisions. Based on such tools as ordinances and strategic energy planning, local authorities can assist in addressing certain shortcomings for supporting niche markets and emerging technologies as well as insufficient guidance to inform decision-making for local energy generation (**Table 21**).

Table 21. Policy matrix for local energy generation and urban climate governance

Mode of urban climate governance ([91])	Tools	Barrier addressed	Action examples
Regulation and planning: Requirements and guidance in support of energy efficiency and local energy generation	Mandatory standards and building codes Regulation, controls and sanctions	Fragmentation and gaps in the regulatory action of public planning; Urban planners lacking of skills to include energy and climate issues in their work.	Prepare a comprehensive plan to improve energy efficiency in buildings; Introduce Indian Building Code that addresses energy efficient buildings with minimum energy requirements; Introduce subsidies and bonus; Establish a supporting program to assist in the retrofitting of buildings; Capacity building on climate and energy for urban planners.
	Zoning, urban regeneration and mixed used	Sprawl and brownfields.	Creating mixed-use developments; Review the public

([93]) OECD (2010), Cities and Climate Change, OECD Publishing, Paris, https://doi.org/10.1787/9789264091375-en.

	developments		transport considering mobility patterns of different types of users; Smart intermodal mobility planning; Encourage renovation of existing buildings.
	Regulation and pricing in the transport sector	Difficulty in promoting the use of public and collective transport; Congestion.	Road pricing and congestion charges; Parking management;
	Ordinances on the mandatory use of renewable energy	Lack of support for niche markets or emerging technologies.	Incentivise the installation of solar water heating/solar PV systems in new buildings; Construction of nearly or net-zero-energy buildings.
	Revision of administrative procedures for energy projects	Uncertainty of administrative procedures.	Advantageous conditions to projects in the "Public Interest".
	Strategic energy planning to support local energy generation	Insufficient guidance and access to data to better inform decision-making.	Local maps with industrial waste heat; Land use planning for large-scale solar plants and wind turbines.

Source: JRC own elaboration.

5.2.1.5 ***Public Procurement***

Public procurement refers to the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies. Public procurement and the way procurement processes are shaped and priorities are set in the procurement decisions, offer a significant opportunity for local authorities to improve their overall energy efficiency.

Green public procurement is the process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured. This means that public contracting authorities take environmental considerations into account when procuring goods, services or works. Sustainable public procurement goes even further and means that the contracting authorities take into account the three pillars of sustainable development – the effects on environment, society and economy - when procuring goods, services or works.

Energy efficient public procurement allows improving energy efficiency by setting it as relevant criteria in the tendering and decision-making processes related to goods, services or works. It applies to the design, construction and management of buildings, the procurement of energy consuming equipment, such as HVAC systems, vehicles and electrical equipment, and also to the direct purchase of energy, e.g. electricity, gas. It includes practices such as life-cycle costing, the setting of minimum energy-efficiency standards, the use of energy efficient criteria in the tendering process, and measures to promote energy efficiency across organisations.Energy-efficient procurement offers public authorities, and their communities, social, economic and environmental benefits:

– By using less energy, public authorities will reduce unnecessary costs, and save money;

– Some energy-efficient goods, such as light bulbs, have a longer lifespan and are of higher quality than their cheaper alternatives. Purchasing them will reduce valuable time and effort involved in frequently replacing equipment;

– Reducing CO_2 emissions as a result of energy-efficient procurement will help public authorities to decrease their carbon footprint;

– Through leading by example, public authorities help to convince the general public and private businesses of the importance of energy efficiency and support the development of green economy.

The interest in developing Green Public Procurement regards not only its impact in terms of CO_2 emission reduction, but also in terms of its financial impact. Here are some examples of energy-efficient measures proposed in high-priority product groups (**Table 22**). In the transport sector, a public procurement may require environmental specifications for the LA fleet.

Table 22. Energy-efficient measures proposed in high-priority product groups

Product group	Examples of Public procurement requirement
Public transport	Purchase low-emission buses and public fleet vehicles. The buses have to be equipped with driving-style meters to monitor fuel usage.
Electricity	Increase the share of electricity from renewable sources going beyond national support schemes.
IT products	Purchase of environmentally friendly IT goods that meet the highest standards for energy performance, such as Energy Start. Provide training to users on how to save energy using their IT devices.
Building construction/ renovation	Use of localised renewable energy sources (RES) Impose high efficiency standards that reduce the building's energy consumption. Energy efficient lighting. Using energy efficient cooling equipment or making use of natural ventilation instead of expensive cooling systems.

Source: JRC own elaboration.

Green, sustainable or energy-efficient public procurements are highly recommended. However, in the context of the Covenant of Mayors SSA, only measures related to energy-efficient public procurement will be reflected in the CO_2 emission inventories. Nevertheless, a comprehensive GPP policy will be considered as a good way to enhance sustainable governance dealing also with the resources used in cities (support the reuse or refurbishment of goods and materials).

Green Electricity Purchasing: In order to ensure that the electricity supplied comes from a renewable energy source, consumers have the possibility to request guarantees of origin certificates of the electricity. The supplier has also the possibility to provide independent proof of the fact that a corresponding quantity of electricity has been generated from renewable sources, or produced by means of high-efficiency cogeneration ([94]). Price differences between conventional and green electricity depend on the status of liberalisation, the features of the national support schemes and the existence of green electricity suppliers. Green electricity has proven to be a product group which is available for public procurement on a competitive basis.

([94]) Further information on www.procuraplus.org

India's Green Power Market Development Group (GPMDG), led by WRI and the Confederation of Indian Industries (CII), brings together government, utilities, regulators, companies and energy developers to scale up renewable energy purchasing in the private sector. So far, the group has worked with over 30 leading businesses in India to facilitate 200 megawatts (MW) of renewable energy transactions across several states, including Karnataka, Tamil Nadu and Maharashtra. GPMDG aims to bring 1,000 MW of additional clean energy online by 2020, enough power to energize 200,000 typical two-bedroom apartments.

5.2.2 Information measures and public awareness

Public awareness and social engaging play a pivotal role for successful climate action. Measures to induce behaviour change and to provide education significantly contribute to the decrease of energy consumption through social and non-technological approaches that must be included in policies that support energy efficiency and energy savings. Local authorities are encouraged to integrate policies aiming at increasing public awareness (such as information and benefit campaigns) towards a behavioural change in energy use in their territories.

Climate change is one of the major challenges that India is facing in the present century. Many factors have been attributed to contribute to global climate change. As such, numerous efforts are being made by stakeholders to combat climate change. However, we are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. At this juncture climate change poses additional threat to the vulnerability of human sustenance. Hopes are high on effective integration of environment and development concerns and greater attention to climate change for a more prosperous future. Therefore, developing necessary Climate Change Information and promoting Education, raising of public awareness through proper channel, which makes public to understand the importance of Climate Change are linked to virtually all areas and even more closely to the ones on meeting basic needs, capacity building, data and information, science, and the role of major groups. The role of Interactive Multimedia Framework for disseminating climate change information right from the individual level targeted groups like school children, community level illiterate people, regional level population like a State and National level initiatives to spread the message of climate change vulnerabilities and ways to adapt to or mitigate climate change.

This chapter aims at guiding local authorities in the preparation and successful implementation of this kind of measures that allow improving the impact of their information and training campaigns.

5.2.2.1 *Type of measure*

Measures targeting different groups and covering several sectors are frequently selected from local authorities in their Sustainable Energy and Climate Actions Plans. The most common tools which the measures rely on include:

- web based platforms, whose popularity is growing;
- mass info campaigns: In general the scope and messages to be communicated are extremely varied. There is a need to tailor-made targeted messages for specific audiences. However, they must target specific areas of society, and the message need to be repeated to be effective
- based on active communication on-line tools: to calculate CO_2 reduction or energy savings estimations.
- database containing examples of energy efficiency applications: illustrated examples of energy renovated houses, energy efficient expert list. These kinds of measures targeting users with previous knowledge on the topic may be very effective.
- energy days, dedicated moments and spots to specific topics enable to raise the attention of public on themes that may be daily neglected (helpdesk and info points).
- "Training measures" may have a great impact on community since they target more enthusiastic or empathic audience (students, energy related workers). However, these measures are not very common, because they are more difficult to set and organize, requiring specific skills. Three most common training measures are:
  - General training to adults, targeting sectors or general ones
  - Education and awareness raising at schools

- Ecodriving, general (adults, students) or professional (drivers, energy related workers) ones.

5.2.2.2 *Planning implementing and monitoring an information measure*

5.2.2.2.1 Planning

Literature and experience show the relevance of an optimal planning of information measures to be implemented. A carefully designed strategic plan to develop measures improves effectiveness ([95]).

The recommended planning steps are:

- setting the measure/program goals in line with policy goals;
- analysis the determinants of desired behavioural change;
- analysis market segmentation and choice of target groups;
- choice of instruments;
- planning the organization and management;
- risk analysis and backup plan;
- programmer testing and pilot campaigning;
- planning the resources;
- planning the monitoring and evaluation.

One of the most important factors to be considered in the planning phase is the selection of the communication channel.

This is based on:

- cost-efficiency;
- media brands;
- media coverage and access;
- cultural factors;
- long-term view and repetition.

In particular, the repetition is a frequently underestimated factor, which is on the contrary, a key to initiate the process for a change in the behaviour. Repetition or further development of the campaign is recommended in order to keep the message in the minds of the target group. However, pure information doesn't necessarily result in behavioural changes: information materials must be accompanied by actions allowing people reproducing a new behaviour.

Finally, the suitability of the selected communication tools is another important element. Often it is much more effective to write a personal letter than to use anonymous direct mailing. Face-to-face contacts are more appropriate than telephone calls. Pictures and films are livelier than brochures and texts and leave a more lasting impression.

5.2.2.2.2 Implementing

The effectiveness of information campaign relies mostly on the effectiveness of delivered messages. They must be simple, adequate to the targeted group, easy to understand and inspiring. Three main aspects need to be considered ([96]):

([95]) Case studies on innovative communication campaign packages on EE Global CCS institute study. Available at: https://hub.globalccsinstitute.com/publications/energy-efficiency-recipe-success/case-studies-innovative-communication-campaign-packages-energy-efficiency

([96]) Stewart Barr et al.(2005).The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. Energy Policy 33 pp. 1425–1444

Emotions and rational arguments: Emotions are a very appropriate way to raise awareness. Once the target group is aware of the problem (e.g. motorised transport) and also of their own role, it makes sense to provide also rational arguments that support a change of behaviour.

Tone: pessimistic and catastrophic messages are not translated in a positive behavioural change. Experience shows that the message needs to be funny and must engage the audience. It needs to be tailored, positive and based on principles of cooperation and self-responsibility. The main pillars of this type of communication are: information, consultation, cooperation and self-responsibility. Moreover, the message must clearly reach the audience, so it might have to be disseminated in local languages.

Feasibility: Maybe the most important aspect to be addressed to ensure the effectiveness of measures. Citizens need to be informed and motivated, but they absolutely need to be able to adopt the measures. The role of the authorities is to provide opportunities for feasible actions. It should also be considered that only reliable information can enable the implementation of effective solutions.

5.2.2.2.3 Monitoring and evaluation

The monitoring and evaluation phase of any kind of measure is crucial. It must be integrated in the planning phase, especially when trying to adapt or modify human behaviour.

The evaluation of the effectiveness of the measure needs to:

- choose an evaluation method. A current challenge is to find better ways to evaluate measures effectiveness, to develop new indicators for societal progress allowing to measure if higher awareness is translated into more energy efficient individual behaviours;
- collect the data;
- conduct the evaluation and report results and disseminate the results to improve the effectiveness of future programs.

Even if there is still not an harmonised world-wide method for comparing energy behavioural measures, literature gives several examples that can easily be adopted by local authorities: "comparison before the program and after"; the use of statistical analysis like the *Difference in differences* (DDI) "comparing the average change over time in the outcome variable for the treatment group, compared to the average change over time for the control group" or the *Randomized control trial* (RCT) "the people being studied are randomly allocated one or other of the different treatments under study" Schulz K.F. et al. (2010). **Table 23** shows strengths emerged from information measures implemented in the CoM framework.

Table 23. Strengths/ tips on information campaign Covenant signatories

Strengths:
✓ unifying information in web pages (information hubs)
✓ the development of active communication tools is growing
✓ generation of datasets targeting audience with energy knowledge
✓ easier and more engaging access to energy information through energy days and info-points

Source: JRC own elaboration.

5.2.2.3 *Overall recommendations*

There is still a lack of knowledge among end-consumers of the existing economic and health potential associated with energy savings and solutions available. Furthermore, the low level of knowledge is not due to the inadequacy of available information. On the contrary, it depends on the way the information is provided. It might be deduced that previous approaches such as the price-based approach (save money) and the environmental approach (save the planet) were not completely successful. Based on the fact that human behaviour and decision making are the core of the Climate Change problem, and that solutions should come from that, *the social* approach could succeed where other approaches failed. The social approach may drive information and awareness measures for changing the energy behaviour towards sustainable practices. Improvements are still necessary: people need to be inspired, to be engaged, to have fun when receiving the message. This must be carefully selected and keep as simple as possible. **Table 24** summarises these considerations.

Table 24. Overall recommendations

City planners should consider
✓ emphasise energy use/Climate Change as a real, actual local and personal risk
✓ facilitate more affective and experiential engagement (personal stories)
✓ leverage relevant social group norms
✓ frame policy solutions on what can be gained from immediate action
✓ appeal to intrinsically valued long-term goals and outcomes

Source: JRC own elaboration.

5.2.3 Buildings

Buildings and transport are among the most energy intensive sectors at local level. However, they are also fields where local authorities can take action to reduce energy consumption and carbon emissions in the framework of the GCoM. The reduction of final energy consumption in the building sector contributes to climate change mitigation and to reducing the dependence on fossil energy sources.

The actions planned will together allow achieving the targets set in the CAP. First and foremost, the local authority itself assumes an exemplary role in the implementation of these actions. Committing to highly efficient buildings in their own facilities is a way local authorities can reduce emissions and lead by example, showing the community how to deal with the issue and results achieved. Public buildings represent a field where large reductions in energy consumption can be achieved. By developing energy efficiency projects in their buildings, local authorities set an example to the local community, inspiring citizens to adopt sustainable and low-carbon practices.

Moreover, local authorities empowered with the jurisdiction to build upon national efficiency policies in the building sector, can implement codes and regulation with more stringent requirements than national ones. Through these regulations, integrated actions to improve energy efficiency in the buildings are provided and the use of renewable sources for space heating and cooling is fostered.

To achieve the carbon reduction goals, local authorities must work with national and regional/provincial governments, as well as with other stakeholders (e.g. building owners, energy utilities, energy service traders and banks) and design specific measures in the action plan that are also able to remove and addresses the main common barriers in the building sector.

These may include: regulatory and institutional barriers, financial challenges, market inefficiencies, and, lastly, the lack of knowledge and know-how.

This chapter aims at providing an overview of the key municipal policies and strategies to improve the energy performance of the buildings stock. It also gives broader insights on specific potential measures that may be implemented either for existing buildings or for new constructions and provides a collection of best practices that highlights the role of the local authority in steering the changes in the building sector.

To address the major barriers and to scale up energy efficiency in existing buildings, it is important for a local authority to outline a clear and comprehensive overview of the main issues, opportunities, and options available. A key first step is to carry out a sectorial assessment that can cover either the entire building sector or a certain specific segment.

An overview of the most common policies and related tools available to increase energy efficiency in buildings is shown in **Table 25** which also includes indications of the barriers that the measures intend to address, and the potential role of the local authority in their implementation.

In a bid to boost eco-friendly construction, the World Bank Group member IFC and Green Business Certification Inc (GBCI) have partnered with realty developers' body The Confederation of Real Estate Developers` Association of India (CREDAI) to launch EDGE green building certification system in India. Green Business Certification Inc is a third-party agency recognising excellence in the green building industry.

EDGE (Excellence in Design for Greater Efficiencies) is a free, easy-to-use software that suggests practical solutions for energy and water savings, improving operational performance at little or no extra cost. (https://edgebuildings.com/)

Set up by Confederation of Indian Industries, services of Green Business Centre include- Energy Management, Green Buildings, Green Companies, Renewable Energy, GHG Inventorisation, Green Product Certification, Waste Management and Cleaner Production Process. CII-Godrej GBC works closely with the stakeholders in facilitating India emerge as one of the global leaders in Green Business by the year 2022. (http://www.greenbusinesscentre.com/site/ciigbc/aboutus.jsp)

The Global Alliance for Buildings and Construction, as part of the Global Climate Action Agenda initiative, promotes a zero-emission, efficient and resilient buildings and construction sector. More recommendations can be found on its website (https://www.globalabc.org/) and in their annual status report (link to the 2017 GABC Global Status report:
https://www.globalabc.org/uploads/media/default/0001/01/35860b0b1bb31a8bcf2f6b0acd18841d8d00e1f6.pdf).

Table 25. Policy matrix for energy efficiency in buildings

Mode of urban climate governance ([91])	Policies and tools	Addressed Barrier	Illustrative Measures	Local potentials (What local authority can do)
Municipal self-governing: Strategies for municipality-owned assets to reduce final energy consumption and to inspire community engagement	Energy management of local authority estate Demonstration projects in public facilities Green Public procurement Institutional reorganisation	Lack of transparent and consistent monitoring and control of energy use; Disincentive for energy efficiency efforts in budget supported public entities; Difficulty for public entities to contract energy service providers; Need for technical validation and demonstration; Allocation of competencies split in different departments.	Undertaking of cost-effective energy efficient investment in public buildings and LA's facilities (town-hall, schools...) such as: - energy audits; - energy management systems; - retrofit facilities for energy efficiency improvement; Energy services companies (ESCO); Integration of tasks into interdepartmental units.	Establish standards for monitoring and management of energy to improve efficiency in a systematic and sustainable way; Adopt high energy efficiency performance standard for new buildings; Procurement of energy efficient appliances; Showcases of obtained results to raise citizen awareness.
Regulation and planning: Requirements and guidance in support of energy efficiency in buildings	Mandatory standards and codes Regulation, controls and sanctions	Fragmentation and gaps in the regulatory action of public planning; Disincentive for energy utilities to invest in demand-side activities to lost sales.	Minimal environmental criteria; Minimum performance standard for buildings and appliances; Decouple energy utility revenue from sales.	Prepare a comprehensive plan to improve energy efficiency in the buildings; Develop building codes that addresses energy efficient buildings with minimum energy requirements (stricter than national ones); Introduce subsidies and bonus (e.g. reduction in development fees, expedited permit process or allowances for extra building floor/volume) for building with high energy performance; Establish a supporting program to assist in the retrofitting of old

				buildings.
Governing through enabling: Facilitating co-operation among stakeholders and awareness raising	Labels and certificates	Lack of reliable and credible advice on the building performance and awareness of energy savings potential	Energy Performance Certificates (EPCs); Energy label for appliances and materials; Voluntary certification schemes.	Implement all national and/or regional provisions; Promote the adoption of additional voluntary schemes.
	Public-private Partnerships	Segmentation of knowledge , skills and actions	Organize working groups that bring together companies and investors with the necessary expertise to develop strategies for energy saving in buildings.	The involvement of a range of different partners increases the democracy of the processes.
	Capacity building, education and awareness raising	Inadequate knowledge and skills for standards and building codes compliance. Lack of internal competencies in small LA.	Institution of local energy/environmental agencies; Energy efficiency training to design, engineering, building operations and maintenance staff; Public campaign to promote efficient use of energy; Dissemination of best practices and achieved results.	Ensures that municipal staff receive appropriate training; Promote competitions, awards and contests for climate protection and GHG reduction efforts; Provide guidelines for energy efficiency improvement in buildings.
Governing through provision: Providing services and financial resources for buildings energy efficiency projects	Public sector financial management and procurement policies	Split incentives; Fragmentation of the building trade.	Use Revise budgetary rules to allow retention of energy cost savings for other justified public spending; Revise public procurement rules to allow for contracting of energy service providers and adopt EE purchase requirements;	Make adjustments based on the local peculiarities to address energy efficiency in buildings.
	Financial facilitation	Insufficient financial incentive for citizens; Constrains of local budget; Competition with other investment	Subsidies for energy efficiency investments; Develop a dedicated energy efficiency fund and/or credit-line;	Use public funds (also national) to leverage private and commercial investments; Third party financing;

		priorities.	Establish a partial risk guarantee.	Energy services companies (ESCO)

Source: JRC own elaboration.

5.2.3.1 *Specific considerations related to different kinds of buildings*

The demand for energy in buildings is linked to a significant number of parameters related to constructive design and the usage of the facilities. The main variables on which it is convenient to undertake actions to reduce the energy consumption are:

- Geometry, orientation, urban design and functional design of the building, including bioclimatic design and natural ventilation;
- Usage patterns and levels of indoor comfort;
- Building envelope, such as insulation, windows and solar protections;
- Equipment and systems, such as type of heat boilers, air conditioners and lighting;
- On-site energy production and renewable energy sources (RES), such as photovoltaic (PV) and thermal collectors;
- Building automation and control systems, able to continuously monitor, analyse and adjust the energy usage.

For each of these domains, both the current design capacity and the available technology options allow applying the energy efficiency principle, the importance of which is indisputable at global level. In addition to cutting emissions and energy bills, energy efficiency brings relevant additional benefits (i.e. better and healthier comfort conditions, new jobs and greater energy security). Moreover, according to the types of buildings and their conditions, the identified variables differently influence the energy performance, therefore, implying specific energy efficiency measures. However, although the benefits of efficient buildings are obvious, time and resources to be allocated are frequently significant barriers for the local administrations. At this level, it is crucial to find potential common allies, able to share policy best practices and exemplary applications.

Energy, environment and architecture are closely related, the more is the energy consumption the worse is the environmental degradation. With rapid economic growth and improvement in people's living standard, the building sector will continue to be the key energy end-user. Hence energy conservation becomes a necessity rather than an option in both commercial and residential buildings and hence it becomes desirable to design climate responsive buildings by incorporating appropriate solar passive features. Climate responsive building design is a concept that integrates the micro-climate and architecture with human thermal comfort conditions. Bioclimatic building design charts for each climatic zones is developed and different design potentials is determined for both summer and winter months separately. ([97])

In the following paragraphs, an insight on status, strategies and tools for specific kinds of buildings, namely new buildings, existing buildings and public buildings, is provided.

New buildings: Newly constructed buildings represent the best opportunity to reach very low energy consumptions (or even positive levels, where energy production exceeds consumption), introducing energy efficiency technologies that can result very cost-effective over the course of their life cycle (also 30-50 years). These results can most effectively be achieved by introducing regulatory policies (minimum energy performance standards) at national, regional or local level (i.e. building energy efficiency codes). Another valuable option in this framework is incentivising owners, investors and developers to exceed the current minimum energy performance standards. To this aim, the current energy certification scheme (or other voluntary rating systems) can be used to apply incentives whether financial (e.g. tax discounts) or not (e.g. volumetric increments).

Whether a well-designed and constructed new building achieves expected energy savings will largely depend also on user behaviour and operational management. As a consequence, the use of information and communication technologies (ICT) should be recommended in large new buildings, particularly the non-residential ones. 'Smart buildings' refer to more efficient buildings whose design, construction and operation is integrating ICT techniques like "Building Management Systems" (BMS) that run heating, cooling, ventilation or lighting systems according to the occupants' needs, or software that switches off all PCs and monitors after everyone has gone home. BMSs can be used to collect data allowing the identification of additional opportunities for efficiency improvements.

([97]) https://www.researchgate.net/publication/265092917_Climate-responsive_Building_Design_in_North-East_India

Existing buildings undergoing major refurbishments: The retrofitting of existing structures and the replacement of old energy-consuming systems is often considered one of the most valuable strategies to achieve high energy savings. The most common strategy for the energy refurbishment consists in minimising thermal losses through the envelope, but the control of the solar heat gains and the reduction of cooling loads are also beneficial.

Encouraging retrofits of buildings in the residential sector is generally more challenging than in other sectors because of the highly disaggregated nature of home ownership and the small size of individual investments and returns. In the past, most efforts have focused on equipment replacement (such as incandescent lamps and refrigerators), encouraging or requiring the energy utilities to carry out demand-side management programs. Frequently, local authorities provide forms of incentives and subsidies to boost the implementation of energy measures and retrofit of buildings among citizens.

Social housing is included in the building sector and it is crucial for the overall improvement of energy efficiency al local level. The retrofitting of existing buildings within the social housing stock allows reaching an important reduction of consumption due to an old building stock in many countries. Furthermore, the social housing refurbishment may address also fuel poverty and energy access issues. As a consequence, the refurbishment of Social Housing building stock is an integrated policy that while dealing with Climate Change achieves other policy objectives.

Larger margins for the local authorities to intervene are possible in the sector of the private-owned commercial buildings. Here the use of a combination of regulatory and incentive instruments can help to overcome financing barriers and scale up investments. For instance, national financial incentives could be used to encourage comprehensive retrofit projects, preventing the sporadic implementation of partial retrofit projects by market participants.

Public Buildings: The buildings owned, controlled or managed by the local authority itself are those on which the local authority has the greatest control. Therefore, it is expected that the local authority should lead by example by testing new policy measures and initiating cost-effective activities that increase the efficiency of its own buildings.

Focusing on the existing ones, a retrofit programme of public building should be set up, defining the scope and depth of a retrofit scheme, the delivery mechanism of the retrofit program, and the financing and repayment arrangements for the project. The choice of which retrofit option to apply is based on the local climatic conditions and on detailed energy audits. Depending on the complexity of the programme and the financing arrangements, the local administrators may follow several commonly used contracting models. The guaranteed-savings contracts are an interesting option. They only require Energy Services Companies (ESCOs) to implement the retrofit projects, and can guarantee a stable stream of annual energy cost savings to repay the financers. In India Bureau of Energy Efficiency (BEE) of Government of India has been organising facilitation program by bringing together end-users, ESCOs, Technology providers, Financial Institutions, DISCOMs, Government agencies etc. on a single platform to accelerate uptake of Energy Efficiency Projects through ESCO route. ([98])

5.2.3.2 *Measures for energy efficient buildings*

All the processes that are involved in the energy efficiency of buildings, from the design and the construction, to the renovation and operation, recognise the provision of healthy and comfortable environments to its occupants as the main purpose of any buildings. The 'sustainable comfort' can be defined as achieving good comfort conditions with no or limited use of resource energy and through the use of environmentally non-harmful materials.

In this framework, ten steps are suggested to improve the energy efficiency of buildings, which implies also adopting measures on both thermal and electric energy (e.g. through reducing the wall transmittance in the former and using efficient appliances in the latter). This approach leaves ample freedom to designers while supporting them in adopting solutions that also take into consideration local specificities of climate, culture andlocally available materials:

1. Define explicitly the building objectives, with particular focus on the thermal comfort.
2. Assess the microclimatic factors and intervene on the site layout and features which can affect the comfort indoor.

([98]) https://beeindia.gov.in/content/escos-0

3. Control the heat gains at the external surface of the building envelope.
4. Control and modulate heat transfer through the building envelope.
5. Control the internal gains from appliances and lighting.
6. Allow for local and individual adaptation.
7. Use passive means and strategies ([99]) to deliver and remove thermal energy to/from the building.
8. Use HVAC systems assisted by natural (and renewable) energy sources.
9. Use high efficiency active conventional heating and cooling plants, if still necessary.
10. Train building managers and occupants on how to use, monitor the performance of and adequately operate and maintain the building.

The first two points refer to the comfort requirements and the multiple interactions between indoor and outdoor environments. Steps 3 and 4 include all technologies and strategies associated to the building envelope from which the net thermal energy needs for heating and cooling ([100]) depend. Steps 5 and 6 have to do with the way a building is used and occupied. Points 7, 8 and 9 provide sustainable approach to reach low levels of delivered (or final) energy consumption ([101]) implementing appropriate system solutions. The last step includes all strategies needed to verify and adapt the building performance during the real-life operation.

The 2017 National Energy Efficient Buildings programme aims to retrofit 20,000 large public and private buildings with more efficient appliances and equipment by 2020. As part of the programme, buildings are equipped with advanced building management systems to track power consumption in real time and identify options to reduce energy waste. The system also provides data-driven insights to optimise energy management strategies and minimise operational costs. It can give facility managers a comparative snapshot of energy use and energy cost, and provide an overall energy sustainability report (EESL, 2019a).

A National Energy-Efficient Building Dashboard provides information on results (www.eeslbeep.com). To date almost 10,000 buildings have been retrofitted. The programme has enabled annual savings of 85.6 gigawatt hours (GWh) and reduced buildings' operating costs by USD 11.3 million. Guidance, tools, capacity building and peer-to-peer learning are delivered by the Building Energy Efficiency Project set up by the MoP and the Swiss Federal Department of Foreign Affairs (www.beepindia.org). The Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE), which is a risk-sharing mechanism, has been used for projects in government buildings and private buildings (commercial and multi-storey residential buildings).

India is also progressing energy efficiency through green building rating schemes. These are voluntary schemes promoting sustainable new projects and retrofits. Rated projects comply with national building codes and standards including the ECBC. Rated buildings typically use 30-40% less energy than those that are non-rated. With a green building rated floor space of around 600 million m^2, India has the second-largest green building footprint in the world (IGBC, 2019a). The MoEFCC and several state governments provide incentives for green building projects (IGBC, 2019b).

The tables below provide an overview of the prevailing technologies and strategies which could be considered for intermediate/warm climates (**Table 26**) in accordance to the methodological step (introduced above) and the building type.

([99]) This does not exclude the use of a fan or a pump when their application might enhance the performance.
([100]) Energy needed for heating and cooling means heat to be delivered to or extracted from a conditioned space to maintain intended temperature conditions during a given period of time.
([101]) Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances, etc.).

Table 26. Building technologies and strategies for warm and intermediate climates.

Warm and intermediate Climate (Heating degree days < 3 350)	
New building	**Renovation**
- Summer Adaptive comfort - Optimised distribution of internal spaces	
- Main building axis oriented east-west - Cool materials and finishing for urban surfaces - Inclusion of greening strategies in the design (vegetation and surface water)	- Cool materials and finishing for urban surfaces - Inclusion of greening strategies in the design
- Architectural shading - Reflective (cool) roof - Ventilated roof, double-skin façades - Double-glazed low-e or windows with low g-value - Exterior window shading/blinds and dynamic shading - Finishing material - Low heat conductivity building materials	- Reflective (cool) roof - Double-glazed windows with low g-value - Exterior window shading/blinds and dynamic shading - Window film reducing g-value - Finishing material - Low heat conductivity building materials
- Medium-highly insulated roof and external walls - Optimised thermal mass inertia	- Medium insulated roof and external walls - phase-change materials
- Daylighting solutions - Very efficient lighting sources and systems - Very efficient appliances and equipment - Smart shutdown logics	- Very efficient lighting sources and systems - Very efficient appliances and equipment - Smart shutdown logics
- Openable windows - Ceiling fan - Low thermal insulation furniture - Flexible dressing code	- Openable windows - Ceiling fan - Low thermal insulation furniture - Flexible dressing code
- Architectural features - Dynamic glass/shades - Comfort daytime and night ventilation - Ground heat exchanger - Direct or indirect evaporative cooling - Radiative cooling - Open groundwater or surface water systems	- Dynamic glass/shades - Comfort daytime and night ventilation
- Ground source heat pump - Solar cooling systems	- Ground source heat pump - Solar cooling systems
- Very efficient HVAC systems - Condensing boiler - Insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps	- Very efficient HVAC systems - Condensing boiler - Insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps
- Clear and exhaustive building manuals - Monitoring plan - Maintenance plan	- Clear and exhaustive building manuals - Monitoring plan - Maintenance plan

Source: JRC own elaboration.

5.2.3.3 *Improvement of the envelope and other aspects*

One of the most common strategies for energy retrofit of buildings usually consists in reducing both thermal losses through the envelope and cooling loads and in controlling the solar heat gains.

The losses of energy through the envelope may be reduced through the implementation of several measures that affects glazing and frames and the walls and roofs characteristics.

- Gains and losses of energy through windows are four to five times higher than the rest of the surfaces. Both daylight provision and gaining or protecting from solar radiation penetration must be taken into account in the choice of appropriate glazing. New technologies with decreased values of transmittance for glazing are available.
- Either internal or external thermal insulation of walls reduces their transmittance values according to specific needs and location of the buildings. Commonly used types of insulation in building construction include: Fibreglass, Polyurethane foam, Polystyrene foam, Cellulose insulation and Rock wool. These materials also contribute to reduce the effect of thermal bridge and to improve sound insulation and thermal inertia.
- The abatement of cooling loads is achieved by reducing solar radiation penetration through the use of shading devices. These comprisemovable devices which can be controlled either manually or automatically; internal and external blinds which help control lighting level and uniformity, and allow stopping solar radiation before penetrating into the room when arranged externally.
- An increased energy performance of buildings is achievable by operating on the heating system. The overall efficiency of the space heating system includes the efficiency of the generator and the losses of distribution, emission and inaccurate control systems.

5.2.3.4 *Lighting*

5.2.3.4.1 Domestic and professional buildings lighting

Lighting consumes between about 29-35% of the energy used within tertiary sector while lighting only consumes about 11% of the energy used in a residential environment. Through conscientious design of the lighting systems, the lighting load can be reduced by more than half within both environments ([102]). A set of options in the lighting sector allows reaching up to 50% of savings. The most common measure is the replacement of lamps with more efficient ones (lower consumption with the same performance). Moreover, correcting the misuse of the lighting appliances shows to be a significant contribution in the saving options. In this perspective, the systems that can control and modulate the light sources (presence detectors, brightness sensors, dimmers, lighting systems) have a large impact on total lighting energy use. Savings may be also achieved by using high-quality and high-precision optical appliances that guarantee a high performance of the whole system and by implementing a careful lighting design process. The lighting influence on energy consumption varies according to the types of buildings. In particular, tertiary buildings and offices show the highest energy consumption due to lighting and, hence, may be the target where implement saving strategies to yield more efficient results. On the contrary, lighting in residential buildings have a lower impact on the overall energy consumption which implies a limited selection of measures to be implemented and a chance to increase the energy access to this aim. However, despite being accessible, there is a number of barriers that limits the implementation of efficient lighting. Among these, the unawareness of saving potentials and the higher initial cost of efficient lighting systems ([103]).

“India’s UJALA Story – Energy Efficient Prosperity” – by Energy Efficiency Services Limited (EESL) and the International Energy Agency (IEA) is a case study of the Indian Government’s domestic efficient lighting programme – the Unnat Jyoti by Affordable LEDs for All (UJALA - meaning light in Hindi). The programme is implemented by EESL, a super Energy Service Company (ESCO) under the Ministry of Power, Government of India. UJALA, the world’s largest zero-subsidy LED bulb programme for domestic consumers, is an extraordinary example of successful energy efficiency programmes ([104]).

5.2.3.4.2 Characteristic parameters and definitions

Luminous flux: is the measure of perceived power of light in the unit time [lm].

Luminous efficiency: is the parameter that allows an evaluation of the energy efficiency of the lamp. It gives an idea of the amount of absorbed electricity that is transformed into light. It represents the relationship between the luminous flux of the lamp and the electric power supply [lm/W].

([102]) Osburn, L. Green Building Handbook for South Africa, Chapter: Lighting CSIR Built Environment
([103]) The Greenlight project's webpage contains wider information about lighting http://www.eu-greenlight.org/index.htm
([104]) https://eeslindia.org/img/uajala/pdf/UJALA_Case_Studies_1.pdf

Colour Rendering Index (CRI): ranging from 0 to 100, it indicates how faithfully a light source reveals colours of objects in comparison with an ideal or natural light source. The higher the colour rendering index, the less colour shift or distortion occurs.

Incandescent lamps: typically emit 12 lm/W, representing energy-to light conversion efficiency of 5%.

Halogen lamps: are incandescent lamps with small sizes that allow their use in compact optical systems for projectors and illumination. They are banned since September 2021.

CFL (Compact Fluorescent Lamps) have attracted great interest in households as they can easily be adapted to the existing installation. Due to their Mercury contents, this kind of lamp requires well-planned recycling management. They show a luminous efficiency of about 40-60 Lumen/Watt.

LED (Light Emitting Diodes) originally used in electronics are now widespread also to as lighting systems. These lamps are energy efficient (class A) and characterised by a high life span. They show a luminous efficiency between about 50-100 Lumen/Watt.

Lighting controls are devices that regulate the operation of the lighting system in response to an external signal (manual contact, occupancy, clock, light level). Energy-efficient control systems include:

- Localised manual switch
- Occupancy linking control
- Time scheduling control
- Day lighting responsive control

5.2.3.4.3 Strategies for efficient lighting in buildings

Indoor illumination of tertiary-sector buildings uses the largest proportion of lighting electrical energy. A significant option is to encourage designs that provide artificial lighting with minimal energy consumption and recognise lighting design practices that offer greater flexibility for light switching, making it easier to light only occupied areas.

Strategies for improving the energy efficiency in lighting vary if either a new building or an existing one is considered. In the first case, more incisive results can be achieved, since architectural issues contribute to the lighting needs of spaces. Building modification to optimise use of natural light is restricted to initial construction and renovation. Natural light during daylight hours limit the use of artificial light, hence reducing electrical consumption and thermal load, and improve comfort. Alongside, 1) the planimetrical distribution of the building, 2) the geometric configuration 3) and the type of windows determine the natural light penetration in rooms.

In addition, these are the factors that influence the energy demand due to lighting in both new and existing buildings:

- the choice of the type of lamp;
- the positioning of lamps;
- the relation between lamp and luminaires.

In a typical lighting system only 30% of the lumens emitted by the lamp contribute to the lit environment. There is a huge amount of losses due to the luminaire, the light absorption on surrounding surfaces and the light redirection to avoidable areas. In existing buildings, the most common strategy is the replacement of old inefficient lamps, with new performing ones. Moreover, when estimating a building's lighting needs, various spaces shall be considered separately, both quantitatively and qualitatively.

Depending on the type of work developed, the frequency of use and the physical conditions of such spaces, the lighting installations will require different designs. It is important to control the lighting level, ensuring that spaces have required light and that no light is wasted. Particular tasks, such as reading, writing or drawing, require higher than average lighting levels. In this case, additional lighting should be supplied only in those areas where such tasks are performed. This approach is useful in open spaces, offices and studies.

Conventional offices often have large window façades, which is capable of adequately lighting the area near the window, the space in which the workstation is often placed. Allowing the energy conscious office worker to individually control the individual luminaries could result in significant energy saving. Such manual control can be used in conjunction with automatic dimming controls. Sensors and other control devices are frequently used tools for the design and the management of low consumption lighting systems with simple payback of 2-3 years. As a side-effect of the energy saving in lighting, designers should take into account the reduction of cooling needs due to the decrease of heat emitted by bulbs.

5.2.3.5 *Other measures in buildings*

Other simple measures may contribute in the reduction of energy consumption in buildings and in configuring sustainable buildings simultaneously. Along with lower environmental impact, sustainable buildings are relatively low cost to run and in the long term, more valuable properties ([105]). Some of the policies described below may need to be supported by specific political strategies adopted by the local authorities.

Behaviour and building management: adequate behaviour of building occupants may also generate significant savings. Information and motivation campaigns could be organised in order to get support of the occupants. In such cases, it is important that a good example is also given by the hierarchy and by the authorities in charge of the building management. There are numerous social approaches that may help in achieving a behaviour change: Sharing the savings between occupants and the local authority could be a good way of motivating action; cooperating to reach a common environmental goal (families in the same building can work together); competitive approaches provide motivation among occupants especially if publically recognised. Publicly displaying the energy certificate of the building is an example of sharing that may induce the mentioned approaches among citizens. Moreover, special efforts must be concentrated to lower the rebound effect. Expected energy savings might be reduced by behavioural reactions, which induces an increase in the usage of energy-consuming technologies, made less expensive by efficiency itself.

The management of technical installations in buildings may lead to energy savings: make sure heating is turned off during week-nds and holidays, make sure lighting is off after work, fine tuning of the heating/cooling operation, adequate set points for heating and cooling. For simple buildings, a technician or an energy manager could be appointed for such tasks. For complex buildings, the help of a specialised company may be necessary. Therefore, it may be necessary to renew or set up a new contract with a competent maintenance company with adequate requirements in terms of energy performance. Be aware that the way the contract is drafted could highly influence the motivation of such a company to effectively find out ways of reducing energy consumption.

Retro-commissioning: improve the efficiency of equipment and systems in existing buildings. It frequently addresses issues developed throughout the building's life. It consists in the adaptation and regulation of the technical installations to the current uses and owner's requirement (bring equipment to its proper operational state, improve indoor air quality, increase equipment lifespan, improve maintenance operations…). The Retro-commissioning ([106]) requires small investments related to the control and regulation of the technical installations which, however, may generate significant savings. Maintenance: good maintenance of the HVAC systems may also reduce the energy consumption with low budgets.

Location: buildings located in summer climates will require active protection against solar radiation in order to minimise cooling loads. Natural ventilation strategies help to increase the comfort in buildings and, hence, wind characteristics and building shapes should be studied in detail.

Hours of Operation: The most energy-intensive building types are those in continuous use, such as hospitals. In these buildings, the balance of heating and heat removal (cooling) may be dramatically different from that of an office building with typical working hours. For example, the around-the-clock generation of heat by lights, people, and equipment will greatly reduce the amount of heating energy used and may even warrant a change in the heating system. Intensive building use also increases the need for well-controlled, high-efficiency lighting systems. Hours of use can also enhance the cost effectiveness of low-energy design strategies. In contrast, buildings scheduled for operations during abbreviated hours, should be designed with limited use clearly in mind.

5.2.3.6 *Additional Demand Side Management Measures*

Utilities are able to meet their customers' energy needs in a number of different ways. DSM can be defined as measures taken by the utility to reduce energy demand through improvements in the way in which energy is used. DSM promotes energy efficiency and encourages the choice of energy sources by consumers (Kelly, and

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([105]) LEVEL(s) PROJECT http://ec.europa.eu/environment/eussd/buildings.htm

([106]) Book: Energy Efficiency Guide for Existing Commercial Buildings: The Business Case for Building Owners and Managers published by ASHRAE.

Marvin, 1995). DSM measures may be implemented by both the utilities and by public institutions. Measures include insulation programmes, high efficiency motors and lighting, timers on water heaters, direct load control, differential tariff pricing and interruptible service, information campaigns (replacement of obsolete electrical equipment, energy labelling…) ([107]).

The purchase of green electricity by the public administration, households and companies, is a great incentive for companies to invest in the diversification of clean energy generation power plants. There is some experience of local authorities buying green electricity from power plants owned by a local company.

5.2.3.7 *Energy Audits and measurements*

An energy audit is defined as a systematic inspection of energy use and energy consumption of a site, building, system or organisation with the objectives of establishing energy flows, identifying the potential for energy efficiency improvements and reporting them to the energy user.

ECBC 2017 (Energy Conservation Building Code) was launched in India in June, 2017 and is applicable for large commercial buildings with connected load of 100 kW and above or 120 kVA and above. ECBC focuses on building envelope, mechanical systems and equipment including heating, ventilating, and air conditioning (HVAC) system, interior and exterior lighting systems, electrical system and renewable energy, and also takes into account the five climates' zones (Hot Dry, Warm Humid, Temperate, Composite and Cold) present in India ([108]).

The purpose of energy audits is to perform an analysis of energy flows in buildings or processes that allows understanding how efficient the use of energy is. In addition, it should propose corrective measures in those areas with poor energy performance. Energy audits are generally carried out in public and tertiary buildings in order to understand the current state of the energy consumptions and implement methods and actions to improve the overall energy performance of building (including behaviour issues and appliances). The characteristics of the building or equipment to be audited, as well as the energy consumption and performance data, are collected by means of surveys, measurements or energy consumption bills provided by utilities and operators or simulations performed, using validated software. As measurement and data acquisition are an important issue in energy-efficiency projects, the way to do it has to be planned in advance.

Some benefits arising from the realisation of energy audits may include the identification of the greatest opportunities for energy savings, thus offering the opportunity to reduce the energy costs of buildings and organisations, improving profitability and investment capacity. Energy audits also can identify potentials for improvement in business and production processes and, thereby, contribute to improved productivity, help organisations reduce the environmental impact of their activities and project a positive image to costumers and the wider community.

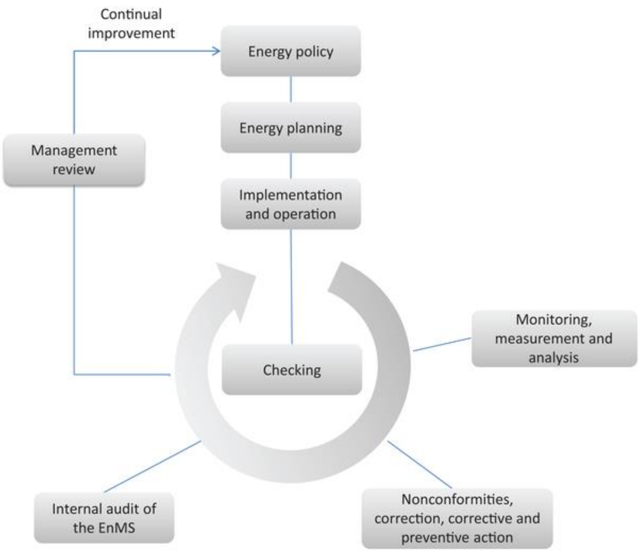
5.2.3.8 *Building Energy Management Systems (BEMS)*

The implementation of an energy management system requires to an organization of any king to follow a series of pre-defined steps, which typically include establishing an energy policy, assigning responsibilities within the organization, identifying main energy users, setting measurable goals and targets, implementing actions to meet these goals, checking for success of actions, and a continuous review of the system. Similarly,to other management systems like the ISO 9001 (**Error! Reference source not found.**), the principle of Plan, Do, Check, Act also applies with the continuous improvement as a main driver for the evolution of such system.

(107) Demand Side Management Information available on the International Energy Agency Demand Side Management webpage www.ieadsm.org. The Topten websites provide a selection of best appliances from the energy point of view www.topten.info (project supported by Intelligent Energy Europe)

(108) https://www.beeindia.gov.in/content/ecbc-residential

Figure 25: Energy Management System model for ISO 50001



Source : ISO 50001

Some tools that may be implemented within an energy management system are Building Energy Management Systems, which may be helpful for energy managers to better visualize the buildings' energy flows and act upon the information being served.

Building energy management systems (BEMS) are computer-based control systems generally applied to the control of systems such as heating, ventilation, and air-conditioning (HVAC). BEMS use software to control energy-consuming equipment or the full buildings' energy consumption, and can monitor and report on the buildings' performance, allow for dedicated controls and energy sub-metering by the individualization of energy flows by energy carrier and the type of use or equipment.

BEMS have been existing for quite some time now, especially in energy-intensive buildings, where a fine monitoring of the energy flows is of a greater importance.

BEMS are generally composed by:

- Controllers, sensors (temperature, humidity, luminance, presence…) and actuators (valves, switches…) for different types of parameters distributed in various zones of the buildings;
- HVAC central system with local controllers for each area or room in the building (zoning) and central computer assisted control;
- Central control hardware and software (with general control, monitoring functions) Monitoring through energy consumption measurement devices

With the advent of the smartphone and the massification of personal computers all over the world, being connected to the internet has passed from a work-related need to an almost basic need. This has allowed for the development of the "smart" ecosystem, especially within the residential market. With the roll-out of smart meters, an increasing development of smart grid projects, a growing Demand Response market and the access to fast internet, has potentiated the development of the Home Energy Management Systems.

The India Energy Management Systems Market size is expected to reach $2,145 million by 2023, from $635 million in 2016, growing at a CAGR of 19.1% during the forecast period. The systems gather the data through device sensors that are relayed to the database. In addition, sophisticated software algorithms facilitate assistance in reducing the energy consumption of the buildings through effective cost reduction approaches ([109]).

The most important feature of Building/Home management systems is probably the ease of access of information that is being delivered to the final energy consumer or the energy managers within organisations, giving them an actual tool to act upon this information and potentiate energy savings in the long run. The "JRC Science for Policy Report: Energy Feedback Systems: Evaluation of Meta-studies on energy savings through feedback" ([110]) has focused on the potential energy savings arising from energy feedback being given to residential energy consumers. In general, the study has found that effective feedback, other than the traditional energy bill can realistically reduce households' energy consumption up to 10%, especially when it is tailored to the householder, presented clearly and engagingly, accompanied by advice for reducing energy consumptions, delivered regularly and with high frequency.

5.2.3.9 *Office appliances*

Energy savings in office appliances are possible through the selection of energy-efficient products. Only an assessment of the systems and the needs can determine which measures are both applicable and profitable. This could be done by a qualified energy expert with IT experience. The assessment conclusions should include hints for procurement of the equipment, via purchase or leasing. The definition of energy-efficiency measures in IT in the early planning stage can result in a significant reduction of loads for air conditioning and UPS, and thus, can optimise the efficiency for both investments and operation costs. Additionally, the duplex printing and paper saving in general are important measures for saving energy for paper production, as well as reducing operation costs. The following tables (**Table 27, Source:** JRC own elaboration.

Table 28**,**

Table 29) show the potentially significant energy savings measures which might be applicable to your IT landscape. In each table the measures are presented, beginning with those that have a large potential impact and are the easiest to implement.

Table 27. Step 1: Selection of energy efficient product

Description of measure	Saving potential
Centralised multi-function devices replacing separate single-function devices save energy, but only if the multi-function is used	Up to 50 %
Centralised printer (and multi-function devices) replacing personal printers save energy, when well dimensioned for the application	Up to 50 %

Source: JRC own elaboration.

Table 28. Step 2: Selection of energy-efficient devices

Description of measure	Saving potential
The specific appliance dimension for the realistic application is the most relevant factor for energy efficiency	Not quantified
Use of Energy-Star criteria as a minimum criterion for call for tender will prevent the purchase of inefficient devices	0 – 30 % compared to state of the art

([109]) https://www.alliedmarketresearch.com/india-energy-management-systems-market
([110]) https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/energy-feedback-systems-evaluation-meta-studies-energy-savings-through-feedback

Make sure that the power management is part of the specification in the call for tender and that it is configured by installation of the new appliances	Up to 30 %

Table 29. Step 3: Power management and user-specific saving potentials

Description of measure	Saving potential
The power management should be initiated in all devices	Up to 30 %
Screensavers do not save energy and thus, should be replaced by a quick start of standby/sleep mode	Up to 30 %
Use of a switchable multi-way connector can avoid power consumption in off-mode for a set of office equipment for night and absence	Up to 20 %
To switch off monitors and printers during breaks and meetings reduce energy consumption in stand-by mode	Up to 15 %

Source: JRC own elaboration.

5.2.4 Infrastructure lighting

Low awareness about BEE star labels for office appliances in rural area highlights the need for year-round and sustained awareness campaigns, in regional languages and through diverse media, to capture the attention of consumers in smaller towns and rural area([111]).

Local authorities can establish specifications for outdoor lighting and infrastructure lighting including standards for lighting fixtures and requirements for light levels.

5.2.4.1 *Traffic Lights*

The availability of compact LED packages on the market boosts the replacement of incandescent lamps in traffic lights with more energy-efficient and durable LED ([112]) ones. This action yields a significant reduction of energy consumption. A LED array is composed by many LED unities. The main advantages of LED traffic lights are:

- The light emitted is brighter than the incandescent lamps, which make LED traffic lights more visible in adverse conditions.
- A LED's lifespan is 100 000 hours (about 10 times more than incandescent bulbs). This implies a significant reduction of maintenance costs.
- The energy consumption reduction is higher than 50% with respect to incandescent bulbs.

5.2.4.2 *Public lighting*

Public lighting is an essential municipal service. It offers significant potential for energy efficiency ([113]), in particular through the replacement of old lamps with more efficient ones, such as low pressure, high pressure lamps or LED. Over the years the efficiency of lamps has improved significantly. The high-pressure mercury

([111]) https://www.ceew.in/publications/awareness-and-adoption-energy-efficiency-indian-homes
([112]) LED – Light Emission Diode
([113]) Further information available at www.eu-greenlight.org and www.e-streetlight.com (European project supported by Intelligent Energy Europe)

lamp is the most frequent in public lighting. It has been used since 1960s and is extremely energy in-efficient. High-pressure sodium and Metal Halide lamps are very energy efficient ones and commonly used recently.

Replacing lamps is the most effective way to reduce energy consumption. However, some improvements, such as the use of more efficient ballast or adequate control techniques, are also suitable measures to avoid the excess of electricity consumption. In addition, the use of autonomous public solar street lighting systems powered by PV panels with energy storage battery is spreading across cities.

Luminous efficiency, CRI, duration, regulation or Life Cycle must be included in the set or design parameters for the choice of the most suitable technology. For instance, if a high CRI is required in a public-lighting project, the use of LED technology is recommended. This technology is a suitable solution to reach a good balance between CRI and Luminous efficiency. If CRI is not essential for a given installation, other technologies may be more appropriate. In the following **Table 30**, recommended lamps for public lighting are reported in case of either replacement or new installation.

Table 30. Recommended Lamps Direct substitution and new installation

Type of intervention	Original Lamp	Luminous efficiency	Recommended lamp	Luminous efficiency
Direct substitution	High pressure mercury lamps Arc lamps	32-60 lm/W 30-50 lm/W	Standard high pressure sodium lamp	65-150 lm/W
			Metal Halide Lamp	62-120 lm/W
			LED	65-100 lm/W
New Lighting Installation		Less than 60	Low pressure sodium lamp	100-200 lm/W
			Standard high pressure sodium	65-150 lm/W
		More than 60	LED	65-100 lm/W

Source: JRC own elaboration.

Arc discharge lamps, such as fluorescent and HID (High Intensity Discharge) sources, require a device to provide the proper voltage to establish the arc and regulating the electric current once the arc is struck**.**

Other measures may be implemented to achieve significant energy reduction:

- Take into consideration the use of the public area (parking, pedestrian, dangerous intersection) in order to provide the appropriate kind of lamp and level of lighting.
- Ballasts: compensate voltage variation in the electrical supply. Since the electronic ballast doesn't use coils and electromagnetic fields, it can work more efficiently than a magnetic one. These devices allow a better power and light intensity control on the lamps. The energy consumption reduction caused by electronic ballasts has been estimated around 7% ([114]). In addition, LED technology not only reduces the energy consumption, but also allows an accurate regulation depending on the needs.
- Electronic photo-switches can contribute to the electricity savings in public lighting by reducing night burning hours (turning on later and turning off earlier).

([114]) E-street project www.e-streetlight.com. Supported by Intelligent Energy Europe

- A tele management system enables the lighting system to automatically react to external parameters like traffic density, remaining daylight level, road constructions, accidents or weather circumstances. Even if a tele management system doesn't reduce the energy consumption in lighting by itself, it can reduce traffic congestion or detect abnormalities. Tele management systems can be used to monitor failed lamps and report their location. Maintenance expenses can be reduced by considering the remaining life of nearby lamps that might be replaced during the same service call. Finally, data collected by the tele management system that tracks the hours of illumination for each lamp can be used to claim warranty replacement, establish unbiased products and supplier selection criteria, and validate energy bills.

5.2.4.3 *Automation*

Different municipalities have different budgets and vendors for street lighting, raw materials and installation. Of the millions of streetlights currently installed, relatively small percentage use LED lights, while others might be CFLs, metal halide or sodium vapor. Thus, an automation solution must work with the current infrastructure, without needing major overhaul. Many options are available for LAs for automation using IoT:

- Remote monitoring: A street lighting automation system must allow supervisors to view streetlight statuses from the Internet.
- Integration with existing infrastructure: It’s not feasible to change the millions of existing streetlights to suit an automation system. Instead, it is essential for any automation system to work with the existing infrastructure.
- Fail-safe nature: Automation systems must be designed to work without a continuous Internet connection, and in all weather.
- Schedule: An automation system must have schedules to operate lights according to the time of day. Going a step further, the schedules must be flexible enough to account for changing sunrise and sunset timings throughout the year.
- Manual override: Under certain circumstances, it may be important for supervisors to control the lights—for example, switching off streetlights when under maintenance, or switching them on when the schedule is faulty.
- Sensor integration: Automation systems would be more efficient if they could sense the intensity of surrounding light. For example, in foggy, stormy or smoggy conditions, it would be essential for the streetlights to activate, regardless of the time of day.
- Wireless nature: An automated street lighting solution should avoid extra wiring, digging and re-paving of roads to enable monitoring and control. Instead, the solution must be wireless, plug and play, and low cost in nature.

5.2.5 Urban and Land Use planning

In many cities in India, which find themselves increasingly caught between worsening droughts and deluges, urban planners need to consider growing climate risks when designing projects, as well as their climate mitigation potential.

5.2.5.1 *Embedding Climate Change in land use planning*

There are many site-specific strategies that local authorities may adopt to face Climate Change and to reduce carbon emissions of cities. Land use and transport interaction, green infrastructures and local energy production are some of the main fields where urban planning may have a role to address Climate Change at local level. Furthermore, there is growing evidence and consensus that when local authorities act on these issues, there is a suite of economic, environmental and social ‘co-benefits’ which can fundamentally improve the liveability, sustainability and resilience of cities. As a consequence, Climate Change mitigation became a key pillar (alongside traditional economic, social and environmental aspects) in decision-making in cities.

The “Climate Smart Cities Assessment Framework” developed by Ministry of Housing and Urban Affairs (MoHUA) with National Institute of Urban Affairs (NIUA) ([115]) cities to incorporate urban land use planning and climate considerations in city’s management of water, waste and mobility, and in projects designed to make cities walkable and air breathable. Strategic planning decisions impact cities both in the way they function and in the behaviours of urban community. For this reason, these decisions need to be carefully and

([115]) https://www.niua.org/csc/key-documents.html holistically considered, by taking into account the complex interdependencies among fields and potential trade-offs due to the implementation of different measures. Furthermore, sustainable urban planning is most effective when policy instruments are bundled and coordinated towards a common vision and strategy. When local policies are integrated within a regional framework (i.e. urban clusters), the definition of how and where building a new development provides resource efficiencies for the constituent cities. This type of approach can build economies of scale and offer opportunities to establish efficient public transport networks, shared infrastructure investment and overall improved use of capital.

The following sections reference the key aspects for both existing and new developments to be taken into account in urban planning oriented to improve the energy efficiency and sustainability of cities. Despite being treated separately, all these aspects are deeply interrelated.

5.2.5.2 *Urban Form and Layout*

GHG emissions at urban level are deeply influenced by the layout of neighbourhoods. In particular the key issues that influence carbon emissions are urban density and efficient urban mobility. New urban developments give the opportunity to apply and test existing best practices implemented, in the whole or in part, worldwide to create sustainable urban environments. Urban form, land use and characteristics of the building stock are strategic issues in improving energy performance.

Mixed-use development and sprawl containment:

Sprawl represents one of the key aspects where the correlation that lies between energy and urban layout appears. Compact cities and the promotion of mixed-use developments can reduce mobility demand within cities and create more sociable, equitable and economical urban environments.

Urban density and limiting sprawl can have significant benefits in terms of reducing the overall environmental impact of cities. In terms of GHG abatement, dense cities offer reduced travel distances and, hence, increase the feasibility for public transport and active travels; provide improved opportunities for district energy; and preserve surroundings, green and rural areas, which may also potentially provide carbon sequestration. Policies aimed at requiring minimum values for density (by unit or floor area) and promoting green areas ([116]) can encourage low carbon developments with appropriate layouts when considered in context with other strategies for public and green areas (proper densities, mixed use, accessibility).

Mixed-use Development is a common approach to urban growth, especially in areas of higher urban density. There is significant evidence and consensus that creating high residential densities co-located with high commercial (employment) densities can lead to reduced commuting and mobility demand. This type of development needs to be considered closely with the public transport strategies and infrastructure to ensure that developments do not become isolated or difficult to service.

The future of urbanisation in India is mixed-use township development in the extended suburbs of cities. This has been a successful global phenomenon and India will scale up to global par excellence. The industry and government further need to collaborate to fuel growth of future sustainable greenfield developments. The emergence of new economic corridors will foster manifold GDP growth and employment.

5.2.5.3 *Transport and land use*

The integration of land use and transport planning is one of the key elements of a long-term strategy aiming at energy efficient districts. Moreover, other options are available to improve the energy performance of urban developments.

Transit Oriented Development (TOD) ([117]) is a planning strategy which aims at producing low carbon development, by considering public transport and transit stations as priorities. The development of housing, employment, activity sites and public services are placed around existing or new stations served by frequent and efficient service. TODs are characterised by medium to high densities, compact urban forms and mixed use. In this framework, both corridor and nodal approaches to development are considered with the goal of moving citizens as efficiently as possible. The main features of TODs are:

– rapid and frequent transit service

([116]) Green belt application needs to be carefully managed as it can result in the outward migration of development (i.e. outside the green belt).

([117]) Further information available at: http://www.tod.org/

– high accessibility

– mixed use

– high quality public spaces and streets

– pedestrian and cycle routes

– medium- to high-density development within 800 metres of the transit station

As a consequence, as well as optimising the infrastructure requirements for public and active travel, this type of development often provides other community benefits (i.e. creating mixed-use 'hubs').

Limiting vehicle infrastructure can reduce and control private vehicle travels and encourage the use of public transport. Similar measures to reduce the provision of parking spaces impose congestion charges and assign low speed zones can have similar impacts. See chapter **Error! Reference source not found.** for more details on these options.

Providing infrastructure for active travel to encourage cycling and walking as alternative forms of commuting and travel can significantly reduce vehicular traffic. Conversion of inner-city areas and peripheral neighbourhoods to pedestrian zones has far-reaching effects in terms of reduced car-related accidents, improved air quality (especially in central areas), and socio-economic benefit for local retail and public transport ridership.

5.2.5.4 *Green areas and heat island*

The heat island effect is the phenomenon whereby atmospheric and surface temperatures are higher in urban areas than in the surrounding rural areas (typically by 1-3°C in larger cities) ([118]). The issue is a result of the combination of low surface albedo (i.e. low reflectivity) of urban surfaces combined with high building density which can limit air circulation. This not only creates health problems and discomfort for urban citizens during extreme weather, but also increases the electricity demand for cooling buildings (by approximately 2-4% per 1°C). There is also a negative impact on air quality. A recent study from IIT Kharagpur called "Anthropogenic forcing exacerbating the urban heat islands in India" noted that the relatively warmer temperature in urban areas, compared to suburbs, may contain potential health hazards due to heat waves apart from pollution. Report studied the difference between urban and surrounding rural land surface temperatures, across all seasons in 44 major cities from 2001 to 2017. For the first time, report found evidence of mean daytime temperature of surface urban heat island (UHI Intensity) going up to 2 degrees C for most cities, as analysed from satellite temperature measurements in monsoon and post monsoon periods.

The heat island effect is best mitigated by carefully considering the configuration of (especially high-rise) buildings and green spaces and by creating more reflective, high albedo (i.e. light) surfaces.

Urban green space provides also carbon sequestration. However, it is generally marginal in the context of overall urban GHG emissions. Parks, greenways, green roofs and community gardens have other indirect benefits in terms of Climate Change mitigation, for example reducing the heat island effect (and therefore cooling demand) and encouraging active travel. Green spaces can also have significant benefits in terms of air quality and human health and climate adaptation/resilience (i.e. reducing storm water run-off and the urban heat island effect) ([119],[120]).

5.2.5.5 *Informal settlements*

Informal Settlements and urban informality are widespread in developing countries. Coping with risk in these settlements requires major efforts, also because of the high share of population living there and the absence of infrastructures. Buildings are built from non-durable materials such as plastics, cardboards, metal tins, zinc sheets and timber. Usually, service coverage in terms of potable water, sewerage, storm water drainage and electricity is not provided. Several planning policies have addressed this question with either efficacious or unsuccessful outcome, which are beyond the scope of this document. Climate Change mitigation and

(118) United States Environmental Protection Agency

(119) DG CLIMA Project Adaptation Strategies of European Cities (EU Cities Adapt); http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change

(120) For further guidance consult FEIX I., MARQUET S., THIBIER E., (2018) Aménager avec la nature en ville. ADEME, 100pages. Available at: https://www.ademe.fr/amenager-nature-ville
The guidance includes some examples focused on French study cases, that can be adapted to every context.

adaptation of these areas is challenging. In particular, people living "informally" are more vulnerable to climate related impacts being more sensitive and less able to adapt. Therefore, the coping with informal settlements, upgrading them and introducing infrastructure is highly important for climate change adaptation. Nevertheless, policies and actions on these areas shall be developed in an integrated way with mitigation. Providing good quality houses has benefits in reducing risks and improving resilience at the same time. Using local affordable building materials with environmental benefits, adopting a design that maximise natural ventilation imply mitigation co-benefits. Mitigation actions do not differ from other contexts (developing mass transit, energy-efficient buildings and renewable technologies are examples). On the contrary, the approach to be adopted, the timeline and the community involvement are the variables that change in this regard. In this perspective, strategic public investments and initiatives are crucial to develop mitigation strategies.

5.2.5.6 *Energy production*

Planning urban form to enable renewable, low carbon and smart energy can offer significant benefits in terms of reducing emissions, but also improving access to sustainable and secure energy supply and potential to reduce fuel poverty.

Heat mapping exercises can help determine where energy/heat surpluses and demands are and to create robust energy strategies. This can be further linked to plans for electric vehicle infrastructure or energy storage plans. Some cities have created municipal utilities to own, regulate and sell the energy produced, contributing to local authority revenue and local employment.

5.2.5.7 *Strategies for new developments: Urban regeneration and Eco districts*

One mechanism to reduce urban sprawl, while revitalizing brownfield sites and local economies is through urban regeneration initiatives. Former industrial or other economically redundant sites can be repurposed to make best use of available land without increasing the urban footprint on green land. Typically, there is a premium to pay to demolish, remediate and reconstruct brownfield sites (especially former industrial sites); however, this can have a positive impact on localised economies and for revitalising neighbourhoods.

'Eco Districts': District level approaches to resource efficiency are growing in application, especially in urban-regeneration of brownfield sites (particularly industrial). Large scale development sites offer the opportunity to create mixed-use districts which can adhere to all the latest approaches to urban sustainability. Developments are typically financed by public-private partnership and are focussed on using holistic approaches to create sustainable districts: efficient use of resources; vibrant communities; prosperity; liveability, health; equity, ecological enhancement. Usually "Eco districts":

- include buildings with low energy consumption (materials, orientation, insulation, ventilation);
- are based on renewable energy (solar, wind, biomass, geothermal) to meet the energy needs;
- consider waste and water management;
- are transit oriented, pedestrian and cyclist friendly;
- have active communities.

5.2.5.8 *Implementing Effective Sustainable Urban Planning*

The preparation of a CAP offers the opportunity for local authorities to bring together several departments and services and to redefine their approach to urban planning. For example, creating stronger connections between transport, planning, infrastructure, energy and economic development departments can foster a more cohesive approach to master-planning and urban form, which can further trickle down to intelligent application of localised infrastructure. To deliver climate mitigation policies this multi-disciplinary approach, paired with financial resourcing and political will should be aligned with the goal of reducing GHG emissions. As discussed, engagement between the local authority, private sector and academia, in a so-called 'Triple helix' approach, can provide added confidence to urban and land use planning decisions. In this context, the necessity of a linkage between planning instruments developed at local level (such as masterplans and land-use regulations, energy plans, building codes, urban mobility plans…) and CAPs arises in order to achieve sustainable and low carbon communities towards the 2030 targets.

To fund relevant policy and infrastructure, traditional forms of financing for urban development can be used, such as municipal revenue, central government investment, public-private partnerships and various forms of borrowing. Increasingly innovative means of raising municipal funds to deliver Climate Change mitigation are continually being developed. For example, municipal green bonds, congestion charges, raising parking charges, levies etc. have all been successfully deployed at a sub-national scale (see chapter 8). Regardless of the source of financing, the business case for projects should be assessed not only in the context of Climate Change, but considering all the other potential economic, environmental and social benefits.

The achievement of rapid growth that is both inclusive and sustainable, presents formidable challenges for urban planning in India. New cities will have to be built and additional spaces generated within existing cities and their peripheries so as to facilitate and accommodate rapid urbanisation. Since systems of urban planning practiced in India have not been in sync with the processes of economic growth, they will need to be revitalized to address the challenges of structural transformation of the economy with rising share of non-agricultural sectors in GDP, relocation of people and resources from rural to urban areas, and the associated increase in urbanisation. There is a case for an integrated approach recognising the interplay of factors which have a bearing on the urban condition for better living as well as better environment for economic growth, which should be inclusive and sustainable. Focus should be on reorientation of urban planning to address the challenges of existing cities and emerging towns, which are likely to be very important in India's current stage of development ([121]).

In summary, local authority should look at establishing the following measures to create more sustainable, low carbon urban areas:

- a multi-level, multi-departmental governance structure which empowers cities to coordinate effective urban transformations, including political will at the highest level;
- formalised institutional arrangements that ensure Climate Change mitigation is a key aspect in the decision making alongside other (more traditional) urban priorities;
- sufficient and diverse sources of finance (including incentives/disincentives) to support mitigation policies and actions.

Box 24. Quick Tips

Introduce energy and Climate Change criteria in planning (land use, urban, mobility planning).

- Promote mixed use developments (housing, services and jobs).
- Plan to avoid urban sprawl: control the expansion of built areas, develop and revitalize old (deprived) industrial areas, position new development areas within the reach of existing public transport lines, avoid 'out-of-town' shopping centres.
- Plan car free or low car use areas by closing areas to traffic or introducing congestion charge schemes and provide more active transport infrastructure
- Identify opportunities to increase and improve green spaces.

5.2.6 Urban Transport

Transport plays a key role in delivering on the Paris Agreement, the Sustainable Development Goals and the New Urban Agenda. While providing essential services to society and economy, transport is also an important part of the economy and it is at the core of a number of major sustainability challenges, in particular Climate Change, air quality, safety, energy security and efficiency in the use of resources.

Indian cities swiftly grow in terms of population and physical size due to contemporary and widespread process known as urbanization. In the coming years, as urbanization increases, cities will face a critical problem of massive increase in population which leads towards unsustainability. City's efficiency, prosperity, economic development and sustainability essentially depend –among others- on the efficacy of its transportation systems. The pressure increases on urban transportation system by increased demand of travel and dominance of private vehicles due to unrepressed urbanization in India ([122]).

This part of the guidebook summarises key actions to decarbonise urban transport and to promote low-carbon solutions to contribute to sustainable cities and opportunities for synergies of sustainable development and Climate Change objectives. There are various levers where local authorities can shape the energy

([121]) http://icrier.org/Urbanisation/pdf/Ahluwalia_Planning_for_Urban_%20Development.pdf

([122]) Role of Sustainable Urban Transportation System in Environmental Sustainability: A Review Satya Prakash Panwar, Bhawna Madan and Sakshi Nagpa consumption and the sustainability of urban transport systems through infrastructure, service and policy decisions. In the following, key areas for local policy and planning interventions holistically focused on the urban transport system are reported. These address transport planning, transport activity, the modal structure, the energy intensity and the fuels and energy carriers. **Error! Reference source not found.** summarises actions and benefits of four general actions for low carbon mobility. The first two lines comprise actions that have influence on the transport demands by reducing the need of mobility. On the contrary, the second two lines regard vehicles and their efficiency, on which actions have no influence on the demand side.

Table 31. Summary of sustainable urban mobility actions and potential benefits

Mobility actions	Emission reduction potential	Benefits/synergies
Activity and flows (short distances, mixed use, compact cities)	Potential to reduce energy consumption by 10 to 30%	Reduced travel times; improved air quality, health, safety and access
Structure (shift to more energy efficient modes)	Potential for energy efficiency increases varies greatly, but for example Bus Rapid Transit (BRT) systems can deliver up to 30% reductions at a cost of $1-27 M/km	Reduced urban congestion and increased accessibility
Intensity (vehicle fuel efficiency)	Efficiency improvement of 40-60% by 2030 feasible at low or negative costs	Improved energy security, productivity and affordability
Fuel (switch to other fuels)	Changing the structure of the energy consumption, but not necessarily overall demand.	Diversification of the fuels used contributes to climate, air quality and/or energy security objectives

Source: JRC own elaboration.

More recommendations can be found on the website of the MobiliseYourCity initiative, which focuses on the development of sustainable urban mobility plans in developing countries at the national and local levels (http://mobiliseyourcity.net/?lang=en_us).

5.2.6.1 *Urban mobility solutions*

This section explores key strategies for sustainable urban mobility, including integrated urban planning, public transport, walking, cycling, pricing measures, urban logistics, intelligent transport systems and options to boost electric mobility. Indian cities are characterized by increasing levels of congestion, pollution, road accidents and inequality in access to mobility. The need for better urban mobility in order to build inclusive, safer and more sustainable cities cannot be underestimated.

There are a large number of possible interventions that local authorities can initiate in their jurisdiction to positively influence travel behaviour, vehicle choice and use. Local authorities have a key role to play in shaping urban form and planning local transport infrastructures. With integrated urban planning and the ability to regulate, fund and often even operate public transport services, a local authority can shape the modal structure of its transport system substantially. These policies have further good implications on energy security, on the reinforcement of social and economic cohesion, on the improvement of the quality of life and on the reduction of externalities. A number of policies that manage the energy efficiency of the transport sector are driven at national (e.g. vehicle and fuel tax) or international level. However, several policies that have a similar effect on the choice and use of means of transportation are applicable at local level, such as road and parking pricing or access limitations. As further detailed in the following, the widely recognised standard "ASI" for transport planning (Avoid, Shift, Improve) has been adapted for the African context, with the integration of "Enable" approach, becoming "EASI" (The World Bank, 2015). The "E" stands for the governance interventions required to enable the policies. The "EASI conceptual framework" aspires to become a powerful policy tool to improve accessibility and mobility in urban areas of Africa, and could be of relevance for Indian LAs. Four levers of intervention are framed in the EASI approach:

ENABLE: to establish an efficient and responsible governance system, capable of anticipating needs, guiding action and ensuring integrated management and development of urban transport systems;

AVOID: to limit and minimize the need for individual motorized travel through adequate land-use and transport planning and management;

SHIFT: to orient transformations towards low impact transport models (public transport and non-motorized transport modes such as walking and cycling);

IMPROVE: to improve the efficiency and safety of transport modes while minimizing their environmental footprint (advancement in the technical and technological characteristics of vehicles).

Error! Reference source not found. reports the policies recommended in the EASI framework, while **Table 33** provides an overview of good practices classified according to the type of strategy (enable, avoid, shift and improve) showing also potential benefits in other fields.

Table 32. Summary of EASI policy recommendations

ENABLE - To establish an efficient and responsible governance system, capable of anticipating needs, guiding action and ensuring integrated management and development of urban transport systems.	
E1	To define, adopt and implement, at central government level, a national urban transport strategy that ensures the sustained development and management of urban transport systems.
E2	To ensure that the main urban transport public responsibilities at urban / metropolitan level of government are assigned and carried out.
E3	To set up an entity in charge of urban transport planning and of guiding and coordinating public action aimed at the provision of the multimodal urban transport system.
E4	To provide all institutions and stakeholders in the urban transport sector with adequate human resources.
E5	To increase financial resources allocated to urban transport systems and to ensure the availability of long-term funding for urban transport
E6	To create the preconditions for continued civil society participation in the development of urban transport systems
E7	To enhance the involvement of the private sector in the provision of transport infrastructure and services
AVOID - To minimize the need for individual motorized travel through adequate land-use and transport planning and management.	
A1	To plan for urban forms and land use that minimize the need for individual motorized travel and promote public transport and non-motorized transport modes
A2	To deploy transport infrastructure and services in a manner that promotes sound urban forms and land use
A3	To strengthen land use management.
SHIFT - To maintain or increase the modal shares of public transport and non-motorized transport modes such as walking and cycling	
S1	To adopt and systematically introduce, at all levels and scales, a multimodal approach to the development and management of urban transport systems.
S2	To develop and maintain for each urban area a pedestrian network that is continuous, safe and accessible for all throughout the day; and to develop and maintain bicycle paths with similar characteristics.
S3	To provide an integrated and hierarchical public transport system that is efficient, reliable and capable of serving the needs of constantly evolving populations and the urban economy.

S4	To plan and implement mass transit systems that operate on exclusive infrastructure and can form the backbone of the urban public transport system.
S5	To enhance the level of service provided by paratransit operators by way of full integration in the public transport system, which requires restructuring, modernizing and promoting them.
IMPROVE - To improve the efficiency and safety of transport modes while minimizing their environmental footprint.	
I1	To improve planning, operation and maintenance of urban roads taking into account and balancing the needs of all transport modes, and keeping the use of individual motorized vehicles under check.
I2	To define and implement realistic and gradually more demanding requirements in terms of fuel components, energy efficiency and gas emissions.
I3	To promote safe and environmentally responsible behaviour by all urban transport stakeholders by strengthening technical control of vehicles and by keeping the public informed of the negative externalities of individual motorized transport.

Source: The World Bank (2015), "Policies for sustainable accessibility and mobility in urban areas of Africa"

Table 33. Energy efficiency measures, CO_2 emission reduction potential

Strategy	**Good practice cities/projects**	**CO_2 emission reduction**	**Sustainable development benefits (and risks for trade-offs)**		
			Economic	**Social**	**Environmental**
Enable					
Strong governance for public transport	regulatory systems that improve control over paratransit services		paratransit sector in the ownership and operation of new BRT systems		Reduced the individual transport load
Avoid					
Road user charging	Road user charge in Stockholm, London, Gothenburg	Example London: 25% CO_2 reduction	Travel time reductions	Social costs : reduction: €144 million / year	Funds can be re-invested in e.g. public transport
Shift					
Bus Rapid Transit (BRT)	Trans Milenio Bogotá (2)	Reduction of carbon dioxide emission by 200.000 tons (in 3 years)	Rationalised bus system, 32% commuting times reduction, Increases employment	Access for disabled and poor, 90% lower accidents in BRT corridors	Air quality improvements
Non-motorised Transport (NMT)	Walking and Cycling in Copenhagen: Cycle-friendly city	Overall GHG emission reductions not quantified	Faster transport, Green jobs (650 full time in Copenhagen)	Improved mobility access (free / very low cost so affordable) Reduction of	Zero air pollutants, Less noise

				road accidents	
Improve					
Fuel switch options for public vehicle fleets	Public Transport fuels switch from e.g. hybrid/electric bus (9)	Medium to high potential for CO_2 savings		Emission reduction, reduce congestion delays	CO_2 emission reduction potential depends on the electricity mix. SO2, NOx emissions may be reduced significantly if switch to hybrid/electric.

Source: JRC own elaboration.

Within the framework of sustainable transport planning, a package of complementary measures is required to actively manage travel demand and improve transport energy efficiency. This includes improvements of the public transport system as reliable and affordable alternative to the car and measures targeting the efficiency of the vehicle fleet. This chapter will explore some of these measures and in doing so will focus primarily on measures that can be implemented at the local level.

Vital to the success of sustainable urban transport concept is a mix of measures that improves the efficiency of the vehicle fleet, reduce travel distances via integrated land-use planning and provide modal alternatives to the private vehicle. Whereas the vehicles fleet policies fall only partially in the jurisdiction of city councils, the land-use planning and modal efficiency are key areas of responsibility for local authorities.

Government of India's recent initiatives to address Urban Transport issues are ([123]):

Jawaharlal Nehru National Urban Renewal Mission JNNURM, 2005: JNNURM was launched in 2005 and closed in 2014 (now succeeded by Atal AMRUT Mission). It attempted to improve the public transport system in larger cities through funding of public transport buses, development of comprehensive city mobility plans and supporting city transport infrastructure projects.

National Urban Transport Policy, 2006: The policy envisages safe, affordable, quick, comfortable, reliable and sustainable urban transport through establishment of quality focused multi-modal public transport systems.

Green Urban Transport Scheme, 2016: The scheme aims to improve non-motorised transport infrastructure such as dedicated lanes for cycling, pedestrians, increasing access to public transport, use of clean technologies and adoption of intelligent transport systems (ITS).

Mass Rapid Transit/ Transport Systems (MRTS): The metro rail has come up as a favoured alternative of mass transport in Indian cities. In 2017, the government introduced new Metro Policy which aims to improve collaborations, standardising norms, financing and creating a procurement mechanism so that the projects can be implemented effectively.

Bus Rapid Transport System (BRTS): BRTS segregates the movement of buses from all other transport modes and introduces other changes in the road infrastructure that are associated with safety. BRTS is an important component of AMRUT (Atal Mission for Rejuvenation and Urban Transformation).

National Transit Oriented Development Policy, 2017: The policy framework aims to promote living close to mass urban transit corridors like the Metros, monorail and bus rapid transit (BRT) corridors.

Sustainable Urban Transport Project (SUTP): The project in partnership with Ministry of Urban Development and UNDP aims to promote environmentally sustainable urban transport in India.

Personal Rapid Transit System (PRT): It is a transport mode combining small automated vehicles, known as pods, operating on a network of specially built guideways. In 2017, the National Highway Authority of India

([123]) NITI Aayog and Boston Consulting Group (BCG) report titled "Transforming India's Mobility- a Perspective" at the Global Mobility Summit, 2018

(NHAI) had called the expression of interest (EOI) for launching India's first driverless pod taxi systems on a 70 km stretch from Dhaula Kuan in Delhi to Manesar in Haryana

National Public Bicycle Scheme (NPBS): In 2011, NPBS was launched to build capacity for the implementation and operation of cycle sharing systems across the country. The first public bicycle sharing (PBS) initiative — Trin Trin was launched in Mysuru.

Promotion of Electric Vehicles: Indian Government plans to have an all-electric fleet of vehicles by 2030. For promotion of electric vehicles FAME (Faster Adoption and Manufacturing of (hybrid &) Electric vehicles. Under FAME, the Centre subsidizes the cost of electric buses and has sanctioned 390 buses in 11 cities (as of April 2018).

5.2.6.2 *Integrated urban planning*

Integrated land-use planning focuses on higher densities, mixed use and the integration of public transport and non-motorised transport infrastructure ([124]). Combined, these factors can reduce travel distances, can enhance the role of non-motorised modes and can improve accessibility and efficiency of public transport. Smart land-use planning only takes effect over longer time scales, but impacts are lasting. Local authorities can largely influence future travel patterns.

Integrated land use planning is also a strategy to prevent climate impacts like flooding, drought, water scarcity and heat stress, as well as to avoid exposure of valuable elements to risks. Climate impacts can be prevented when changing land use in a way that it positively affects the regional water balance, which influences the evapotranspiration process through infiltration, the soil water redistribution process, and surface roughness, which controls overland flow velocity and floodplain flow rates. Afforestation, forest transformation, sustaining wetlands, avoiding bare soil during precipitation season, modified vegetation cover, and introducing drought/flood-tolerant crops can also reduce flood and drought risk. Measures to avoid exposure of valuable elements to risks generally involve zoning, building codes, such as minimum floor heights and water proofing, as well as land use permits.

Thereby, land-use planning decisions of today can ease the traffic management task in the future. Cities can limit the increase in car use with mixed use developments that play an important role in improving the efficiency of the transport system, by reducing the need to move. The integration of land use and transport is, indeed, a strategy that improves the connectivity and the accessibility, providing a better mobility service and making closer people and places. As part of this, cities may want to consider integrating fares, infrastructure and operations for integrated public transport planning, and create easy connections with non-motorised transport.

5.2.6.3 *Sustainable Urban Mobility Planning (SUMP)*

Sustainable Urban Mobility Plans (SUMPs) can be strategic planning documents that guide the integration of all transport modes and work towards a sustainable transport system within a city. The development of a SUMP includes a number of steps from the identification of the main transport issues in a city, to the development of a joint vision and the identification of specific measures and a process to implement actions. Quality of public transport infrastructure, frequency of services and lack of seamless travel are the top barriers to adoption of sustainable urban public transport among urban population in India ([125]).

A vital component of the process of developing a SUMP is the involvement of stakeholders and the active participation of the public. SUMP integrates multiple modes of transportation such as buses, metro, autorickshaws to address the problem of first and last-mile connectivity. By addressing the needs of various sections of the society such as women, children and differently-abled through the provision of special amenities, it strives to foster an inclusive ecosystem. Green and eco-friendly commute options promoting conservation of natural resources and the reduction of carbon footprints are the central tenets of this planning. Affordability, convenience and smart planning taking into account the requirements of cities over time, are its key hallmarks.

Accessibility and urban mobility in India are critical for promoting sustainable urban economic development in Indian cities. However, urban mobility has not contributed to desired outcomes owing to car-centric policies adopted by successive plans and projects at the city level. Urban mobility is multi-dimensional in terms of

([124]) Banister D. (2011). "Cities, mobility and climate change". Journal of transport geography, 19, 1538-1546
([125]) https://www.ceew.in/publications/sustainable-and-green-mobility-in-urban-india

policy and operational implications. Sustainable mobility is a key enabler of economic growth and towards eliminating poverty and shared prosperity in Indian cities. Comprehensive integration of urban transport and land use planning systems is needed so that synergies are harnessed, Interconnections are promoted and functionality optimised through multimodal mobility solutions for Indian cities most importantly, mechanisms for transparency, oversight and accountability of such institutions towards its people need to be ensured. All this can only be possible by strong political will and sustained public pressure for change ([126]).

5.2.6.4 *Urban Access Regulation*

Low Emission Zones

Restricting access to certain areas of a city, normally the city centre, can have a direct effect on local air quality noise pollutions and traffic safety in this area. The effect on greenhouse gas emissions depends on the design and complexity of the scheme and the provision and integration of modal alternatives. The main objectives are to reduce congestion and pressures, to improve safety, and to decrease noise and harmful emissions.

There are different types of access restriction schemes, including those that control access at specific points (e.g. when crossing a bridge), cordons or areas (e.g. around a specific location), which may differentiate further between different types of vehicles or times of the day. While these schemes can be very effective in managing congestion, noise and air pollution, they may have unintended consequences. Hence, access restrictions should be implemented in combination with other measures that minimise trade-offs.

5.2.6.5 *Urban Road Tolls/congestion charges*

One very effective option to improve traffic flows and reduce overall travel demand by avoiding and shifting traffic to more sustainable transport modes is congestion charging, which is a pricing scheme for peak hours. Congestion charging lies at the intersection of traffic management and travel demand management, as information gained from real-time traffic information systems could be used to improve the pricing mechanisms of congestion charging by introducing real-time variable pricing systems, which can encourage more efficient travel behaviour.

Congestion charging systems have been operating in Singapore for several decades and were implemented more recently in London and Stockholm. As early as 1975, the road pricing was implemented in Singapore to manage the choked streets of the rapidly growing city. First, an Area License System was established, which required a permit to enter Singapore's central area. The city entry charge boosted public transport patronage almost immediately after its introduction and led to a 45% reduction in traffic, road site accidents decreased by 25% and average travel speeds increased from about 20 km/h to over 30 km/h (OECD & ECMT, 2007). The system resulted in a public transport share of over 60% in daily traffic, an increase of nearly 20% (SOLUTIONS, 2016). The success of the system in improving infrastructure capacity, safety and air quality and reducing travel demand, fuel use and greenhouse gas emissions inspired the congestion charge systems in London and Stockholm and provided the basis for several feasibility studies for similar schemes for cities around the world (Prud'homme and Bocarejo, 2005).

5.2.6.6 *Public transport infrastructure, operation and vehicles*

A reliable and affordable public transport system is a key element of a sustainable urban transport concept. Transport in India consists of transport by land, water and air. Public transport is the primary mode of road transport for most Indian citizens, and India's public transport systems are among the most heavily used in the world. While providing a similar level of mobility, public transport only requires a fraction of energy and space compared to the private car. Public transport not only contributes to lower energy consumption and emissions, but it also reduces congestion, which improves traffic flows and decreases travel times. Moreover, provision of new infrastructures has the potential for revamping outdated and sectorial planning practices, towards a comprehensive approach of strategic and sustainable planning (La Greca and Martinico, 2018). As public transport is typically more than twice as energy-efficient per passenger kilometres as individual motorised transport, enhancing the share of public transport in urban passenger transport yields the potential to mitigate rising energy consumption and emissions. Thus, it contributes to the objective of reducing congestion and at the same time is part of the wider concept of sustainable urban transport. Vital elements to

([126]) Sustainable Urban Mobility: Challenges, Planning and Initiatives in Jalandhar Sahil, Sahil Dugg and Manpreet Singh Saini shift transport demand from individual motorised transport to public transport are investments in capacity and reliability and physical integration with walking and cycling and park & ride facilities.

An efficient and convenient public transport (PT) will go a long way in answering the twin problems of pollution and congestion. There is a need to improve both the adequacy and adoption of PT in India, and this would need holistic focus across multiple dimensions ([127]):

- Data-driven planning and urban transport, with a clear hierarchy amongst different modes
- Focus on multi-modal systems
- Make PT attractive for urban India, to increase adoption

Reliability is an important factor for modal choice. The predictability of travel times with metro (MRT) and/or bus rapid transit (BRT) compared to a journey in the private car may provide enough incentive to shift from individual to public transport. Public transport systems generally require substantial public investments and the operation often requires continued subsidies. Linking public transport investments with road user charging and parking pricing schemes can help to reduce the pressure on public funds and at the same time it creates disincentives to use the private car and encourage the use of public transport.

5.2.6.7 *Car sharing*

Owning a car is increasingly recosgnised as uneconomical, considering the initial costs of buying a vehicle, insurance, registration, vehicle tax, parking space and maintenance. Car sharing schemes are becoming increasingly popular worldwide. Among the various providers of car-sharing schemes there are free floating and stationary systems. Users of stationary car sharing systems (such as Zoomcar, Revv and Drivezy) return the vehicle to designated parking areas, reservation and payments are normally also handled through apps. Charges can be time based and/or kilometres driven and usually cover all costs including fuel. Most of the free-floating car sharing providers focuses on larger cities and, even there, focuses on the most densely populated areas. This may lead to a more competitive approach than to a complementarity with public transport. Many mid-sized cities work with providers of stationary sharing schemes, which often have a higher rate of replacing privately owned vehicles.

5.2.6.8 *Parking management*

Similar to road user charging, parking management and pricing can help discouraging the use of a privately owned car and raise revenue to fund public transport, walking and cycling infrastructure and improve public spaces. Parking management schemes lead to a reduction in the number of cars entering the city, which can reduce congestion and can encourage the use of public and non-motorised transport. The parking pricing structure and the level of enforcement are important aspects to consider. A structured fee that differentiates between different zones of a city or times depending on the demand is one aspect that needs strong enforcement to be meaningful. Coordination of parking pricing and zoning among relevant local authorities is another vital aspect. Parking management can be a powerful tool for local authorities to manage car use and to raise revenue. Parking management also includes time restrictions and a control of the number of available parking spaces.

Parking time restriction for non-residents, e.g., to two hours, is a proven tool to reduce commuting by car without affecting accessibility to urban shops. In fact, in many cases shops and other local businesses become more accessible when public space is freed up by a reduced number of parking spots.

5.2.6.9 *Supporting Walking and Cycling*

Non-motorised modes, i.e. cycling and walking, can take a substantial share of the urban transport sector, in particular on short distances. As a consequence, soft mobility contributes in the reduction of emissions, energy consumption and congestion. Walking and cycling are suitable for urban transport as in cities the majority of trips covers short distance (below 5 km). The fundamental advantage of non-motorised modes is that they are low cost compared to other transport options, not only for the individuals, but also for public authorities. Moreover, cycling and walking leads to further benefits, such as health benefits for the cyclists or pedestrians, environmental and economic benefits resulting from zero emissions and energy consumption While taking up a noticeable share of the transport task, walking and cycling infrastructure consumes less space than roads, yet this kind of infrastructure is often neglected in transport planning. The provision and

([127]) https://www.niti.gov.in/writereaddata/files/document_publication/BCG.pdf maintenance of infrastructure for pedestrians and cyclists is crucial to make these modes more attractive and, hence, an alternative to private motorised transport.

Frequently, citizens are discouraged from cycling because of safety issues. However, not only infrastructure must be safe, but it also must be perceived to be safe by the users. Separate crossing signals, cycle lanes, well-marked lanes and crossing, and buffers between road and lane can reduce the risk of accidents. Well maintained routes, free from litter and with appropriate lighting increase the feeling of safety. Moreover, beyond these measures, creating a cycle friendly environment may boost the cycle use. In this perspective, users may consider cycling convenient (e.g. networks should be more advantageous in terms of directness than roads, covered and safe cycle parking should be provided); the routes must be accessible and integrated with the transit network; the routes and surroundings should be attractive, with pleasant settings, and linked to well-designed public spaces, allowing users to stop, chat and rest in a pleasant environment.

These measures may be applied in case of both existing and new infrastructure for pedestrians and cyclists. However, cycling policies are successful when developed as part of an integrated transport policy for all modes of transport, which may be also reinforced by other policies such as land use policies, urban development policies and socio-economic policies.

5.2.6.10 *Supporting the up-take of clean vehicles*

Local authorities have a number of options to encourage the purchase and use of electric vehicles, which can start with an active dialogue with stakeholders, such as electricity suppliers, car-park operators and where applicable vehicle manufacturers and continues with concrete actions. For examples introducing reduced or free parking for EVs (as in Oslo, Norway), exemption from road user charges or city tolls (e.g. London, UK), allowing access to high-occupancy vehicle lane, and giving priority to electric vehicles in municipal and car sharing fleets.

5.2.6.11 *Registration management*

A managed approach to vehicle registrations can help limiting the amount of cars in a city by differentiating registration fees for vehicles e.g. according to their CO_2 emissions or engine size. This can guide purchasing behaviour and can encourage people to opt for cleaner vehicles or more sustainable modes such as public transport and non-motorised modes. This approach has been implemented very successfully in several cities in Asia, e.g. Singapore and Shanghai. Vital to this approach is that the authority to register vehicles lies with the local authority. This would be feasible for the purchases of new cars, while it will be less practical for second-hand vehicles.

5.2.6.12 *Implementing urban mobility solutions*

The transport sector is unique in its complexity with regard to the number and diversity of its users and the various types of mobility solutions. Accessibility and mobility are vital components of city live and its economy. Moreover, addressing urban mobility in an integrated way can make the essential difference to the success and the liveability of a city. If applied in combination, sustainable transport interventions can be mutually reinforcing and create synergies between policy objectives. **Error! Reference source not found.** reports the combination of potential measures.

Table 34. Mobility Measures combination and complementarities

Examples for urban mobility measures	Complementarity of measures
Compact city design and integrated planning	The planning of compact and mixed use areas enables to reduce the length of trips and therefore, o modal alternatives and accessibility are provided.
Provision of public transport, walking and cycling infrastructure and services	Reliable and affordable public transits in a compact city allow reducing the car dependence for daily activities. Moreover, with a high-quality environment, also walking and cycling modes expand.

Road User Charging, parking pricing, access restrictions, registration restrictions and number plate auctions, eco-driving schemes, urban logistics	Complementary measures at the local level help managing travel demand and can generate funds that can be re-distributed to fund low-carbon transport modes

5.2.6.13 *Sustainable sources for Transport*

Vegetable oil methyl esters (biodiesel) can be used for transport applications, either in pure form or blended with fossil diesel. Use in blends below 7% does not require any modification of the engine. Pure vegetable oils can also be used but engines have to be adapted. Ethanol can be used in gasoline engines either at low blends (up to 10%), in high blends in Flexible Fuel Vehicles or in pure form in adapted engines. Ethanol can also be processed into ETBE (ethyl tertio butyl ether) and blended in gasoline. Biomethane can also be used by vehicles equipped for natural gas. Advanced biofuels from wood, lignocelluloses and waste, such a biomass to liquid (BTL), Dimethyl ether (DME) or ethanol are subject to intense R&D efforts. In India non-edible oil like Karanjia, Jatropha, etc. are the desirable source for production of bio-diesel. These plants could be grown on wasteland, about 80 million hectares of which is available in India. The National Policy on Biofuels-2018 approved by the Government envisages an indicative target of 20% blending of ethanol in petrol and 5% blending of bio-diesel in diesel by 2030. Under EBP programme, ethanol blending in petrol is being undertaken by the Oil Marketing Companies (OMCs) in whole country except island Union Territory (UT) of Andaman Nicobar and Lakshadweep wherein, OMCs blend up to 10 % ethanol in petrol under the EBP Programme ([128]).

5.2.7 Local Energy Generation

Local energy generation and distribution systems are an important area of intervention within the GCoM that concerns effective action at the local level within the competence of the local authority (Kona et al., 2017). Local authorities usually control or have influence over the local energy supply system as the owner or a partner in the local energy utilities, which can effectively enhance the opportunities by which renewable energy sources can be effectively integrated to support CO_2 mitigation targets.

This chapter aims at providing an overview of the key municipal policies and strategies to promote local energy generation, ranging from decentralised renewable energy in buildings to centralised options for promoting integrated and sustainable energy systems at the urban level ([129]). Well-rounded policy support from a synthesis of urban climate governance options, including those that relate to municipal self-governing, governing by provision, governing by regulation and planning, and governing through enabling (Kern et al., 2009) is required to transform the local energy structure. In turn, such policies have a crucial role in demonstrating, guiding and influencing key measures for achieving emission reductions through efficient electricity and local heat/cold production.

A holistic understanding of the key measures and technological options that are available at the local level is required to support the design and implementation of policies to promote local energy generation. For this reason, key measures are described with the aim of providing guidance towards potential application areas. Insight from signatories that have already undertaken the technological options is summarised to underline the rapid transition that is taking place at the local level based on the promotion of local energy generation with renewable energy.

Box 25. 100% Solar Powered Kochi Airport

The CIAL Solar Power Project is a 40 megawatt (MW) photovoltaic power station built at COK airport, India, by the company Cochin International Airport Limited (CIAL). Cochin International Airport became the first fully solar powered airport in the world with the commissioning the plant. It is the 7th largest airport in India.

The project started operating on 18th August 2015, and the following is a breakdown of its characteristics:

It will prevent over 300,000 metric tons of carbon pollution over the next 25 years. The environmental

([128]) https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1575404
([129]) IRENA (2016). Renewable energy in cities. International Renewable Energy Agency (IRENA). Abu Dhabi, *http://www.irena.org/publications/2016/Oct/Renewable-Energy-in-Cities*

benefit is comparable to planting a forest of three million trees!

The project cost was around 620 million rupees, equivalent to 9.3 million dollars, and the expected payback period is six years.

The photovoltaic system covers over 45 acres of land belonging to the Cochin airport, located around the international cargo complex.

The total number of solar panels installed was 46,150.

The output of the solar array is equivalent to the energy needs of 10,000 Indian homes.

The project was feasible thanks to a net metering arrangement with the Kerala State Electricity Board, or KSEB.

This allowed Cochin airport to fully meet its energy needs with a power source that only operates during daytime.

They sized the photovoltaic system according to their energy needs over a 24-hour period.

During daytime, the solar farm produces more energy than what the airport needs and the surplus is exported to the grid.

During night time, or during cloudy days with insufficient solar power production, CIAL can purchase back energy from the grid.

The net energy consumption is close to zero.

In fact, their daily production frequently exceeds their daily needs! The airport needs from 48,000 to 52,000 kWh per day, but the output of the solar array can go as high as 60,000 kWh per day. This is not an issue, however, since the surplus can be exported to the grid for other consumers to use it.

Projects like this one illustrate the importance of net metering for pushing forth solar photovoltaic power. Without net metering, this project would have been impossible given the enormous amount of energy that would have to be stored for night time and cloudy weather.

A new terminal is being built at CIAL, and the corresponding solar power plant expansion is already being planned to keep the facility 100% solar-powered.

Policy measures give direction to increasing the valorisation of local opportunities in the context of local characteristics and available measures. This section is intended to provide a collection of key measures to promote the uptake of renewable sources and integrated urban energy systems. The options for the transition to sustainable local energy generation systems range from decentralised renewable energy options to centralised solutions, such as cogeneration ([130]).

In this context, there is increasing interest in the decentralisation of the energy supply with more local ownership. Local energy supply options can take the form of local power generation utilities and energy services companies (ESCo). Local authorities can be in whole or partial owners of these utilities and promote community partnership.

Decentralised renewable energy technologies offer the possibility to produce energy with a much lower impact on the environment when compared to conventional energy technologies. Distributed electricity generation allows to reduce electricity transport and distribution losses and to use micro-cogeneration technologies while increasing the penetration of low-scale renewable energy technologies. The electricity grid must be able to distribute this energy to the final consumers when the resources are available, and rapidly adapt the demand, or cover the energy that is required using more adaptable technologies when the former are not available, such as hydropower or biomass.

Centralised options include cogeneration power plants. Cogeneration (or CHP – Combined Heat and Power) offers an efficient way of producing electric power and thermal energy for cities. Cost-effective policies that maximise efficiency benefits should focus on measures targeting areas with high heating and cooling densities.

Error! Reference source not found. summarises the key measures to promote local energy generation by renewable energy source or technology. The relevant modes of urban climate governance that are involved

([130]) https://www.eacreee.org/

are marked to showcase the integrated approach that is needed for supporting particular renewable energy solutions.

Table 35. Policy measures to promote local energy generation

Area of intervention	**Policy measure**
Local electricity generation: Photovoltaics	Municipal financing and ownership of PV pilot plants on public buildings (rooftop PV and building-integrated PV systems)
	PV installations on the roofs of bus sheds or parking lots
	Construction of a PV park on ground of municipal property at a former landfill site
	Concession of surface rights and renting of rooftop areas in public buildings for PV
	PV installations in public buildings based on collaboration with the ESCo and third-party financing for PV systems in school buildings
	Public-private partnership for Photovoltaic Solar Park
	Mandate for PV system installations equal to a given share of the total installed power in the city
	LAs bonus for photovoltaic and solar thermal installation on citizen's roof
	Interest-free loans for associations or schools for PV panel installations
	PV systems that supply electric vehicle charging stations
	Awareness building and supporting tools Solar land registry for roof-top photovoltaic or solar thermal installations Solar chart for identifying preferable areas for solar energy technologies
	Real time electricity generation data on PV systems of the Municipal Corporation and visual consoles on CO_2 reductions
	Public awareness to reach annual increase targets for PV in the private buildings
	City supported photovoltaic campaign
	Land use planning for utility-scale photovoltaic plants in the city
Local heat generation: Solar thermal	Solar collectors on rooftops of municipal buildings, swimming pool facility, sport buildings and schools (including flat-plate and parabolic solar collector installations) Replacement of electrical heaters and boilers in public buildings

Area of intervention	Policy measure
	Ordinance for installing solar collectors Solar collectors in all buildings in the health care sector Solar thermal systems in 100% of schools that include south-facing facades and terraces
	Purchasing groups to allow widespread diffusion of solar thermal technology
	Targets to increase the area of solar thermal in the city
Local electricity generation: Wind energy	Wind and solar farm with citizen cooperation
	Installation of wind power farms Promotion of locally owned wind turbines Public procurement of municipal wind turbines Co-ownership of wind-power plants (municipal company)
	Attraction of companies that want to generate electricity from wind energy Prioritized case handling and licencing of wind turbines
	Land use planning for wind turbines
Local electricity generation: Hydroelectric power	Mini-hydro plants on municipal waterworks
	Attraction of investment to realize an in-stream tidal hydro power plant
	Run-of-river hydroelectric plants Produces the amount of electricity needed for public building and public lighting loads
	Hydroelectric power plant construction
Bioenergy	Biogas cogeneration plant for electricity and thermal energy provision based on anaerobic digestion
	Biogas cogeneration based on zootechnical wastewater and silage cereals
	Biogas driven district heating network
	New anaerobic digestion plant in public waste recovery and treatment company
	Public-private partnership between the local authority and waste management utility for anaerobic digestion of biowaste
	Recovery of methane gas from landfills to produce electricity based on gas engines
	Consortium for a cogeneration plant based on biomass certified as sustainable

Area of intervention	Policy measure
	(waste produced locally or from local consortium companies)
	Installation of wood chip boilers
	Collection and recycling of used cooking oil for biodiesel production
Geothermal energy	Construction of a geothermal power plant
	Low enthalpy geothermal heating for municipal residential building
Renewable energy (other)	City Council grants and subsidies for renewable energy (PV, solar thermal, biomass, ground source heat pumps) Subsidy per square meter of solar thermal collector area Grants for solar collector and heat pump installations Subsidy to renewable heat sources in residential buildings
	Clean technology funds for renewables
	Promotion of distributed energy generation based on Urban Building Regulations and simplified building authorization procedures
	Public buildings that are self-sufficient based on on-site renewable energy Self-sufficient town hall based on bioenergy and PV
	Demonstrations of net or nearly zero energy building with renewable energy Net zero energy schools Pilot public school built according to the Nearly Zero Energy (NZE) Standard Co-financing of a near zero energy school building with local and national funds
	Public buildings with bioclimatic design principles and renewable energy utilization Public social building complex Energy renovation of public buildings including solar thermal collectors
	Brownfield urban development with renewables and sustainable districts Transformation of former port and industrial area into a new sustainable district
	Co-financing between local and regional authorities for public energy upgrading Co-financing of solar thermal systems on public buildings
	Purchasing of certified renewable power for public buildings and public lighting Joint framework agreement for purchasing 100% green electricity
	Onshore Power Supply with high-voltage

Area of intervention	Policy measure
	Awareness building actions Experimental sessions on renewable energy for students Training campaigns organized by the local energy utility/agency

Source: Compiled from good practices of Covenant of Mayors EU

In addition to the energy sector, opportunities for local energy generation exist within the water and waste sector. A cross-sectoral perspective that is not limited to only one sector is therefore necessary. Error! Reference source not found. complements this aspect based on a compilation of policy interventions for measures involving waste management, wastewater treatment plants, and water management. The relevant modes of urban climate governance are marked to emphasise the integrated approach that is needed also in these areas of intervention.

Table 36. Policy measures for waste and water management

Area of intervention	Policy measure
Waste management	Separate waste collection to increase the recycling of municipal solid waste and the use of organic waste for biogas production
	Use of green waste for the production of compost and pellets
	Utilization of organic waste for composting rather than waste-to-energy incineration
Wastewater treatment plants	Self-sufficient wastewater facility based on methane driven combined heat and power plant
Water management	Integration of renewable sources for supplying power to pumping tapwater
	Reduction in electricity usage for pumping based on reductions in water losses in the drinking-water distribution network
	Information system for energy and water use in the public sector

Source: JRC own elaboration.

5.2.7.1 *Renewable energy in buildings*

Renewable energy will play a major role in tackling Climate Change and can provide an affordable and secure source of energy, including in the building stock. Renewable energy is cheaper now than ever due to technological developments, mass production and market competition. In the case of photovoltaic (PV) electricity generation, the technology has reached or on the verge of matching household electricity prices for grid-parity in certain contexts (Haas et al. 2013). Key measures for the deployment of decentralised renewable energy in buildings consist of photovoltaic electricity generation, solar thermal systems, biomass systems, and geothermal heat pumps.

5.2.7.1.1 Solar thermal systems

Solar thermal systems convert sunlight directly into heat and make this heat available for various applications. Solar thermal energy, together with biomass and geothermal energy, can be a major source of heating. Currently, solar thermal applications are mainly used for domestic hot water (DHW) and space heating in single and multi-family homes although large-scale uses of solar thermal systems are increasing. Heating DHW during the summer is one of the easiest and therefore cheapest ways of using solar thermal energy. In addition, solar thermal heat can be used to drive a thermal cooling machine and can be used as an energy source for cooling ([131]).

A relevant contribution of solar energy to space heating requires an increase of the solar fraction per building, which is the share of solar energy on the overall heat demand for DHW and space heating. Combi systems for DHW and space heating have a size of typically 10 to 15 m^2 of collector area and can provide a solar fraction of about 25%, depending on the size, efficiency of the building, and on-site climate conditions ([132]).

The 3,287,240 sq. km area of India receives solar radiation worth 4,300 quadrillion kcal (5,000 trillion kWh) every year, which is equivalent to 430 trillion kgs. of OIL equivalent. The daily average solar energy incident over India varies from 14,000 to 25,000 kjoules/sq.mt./day. Depending on the geographic location the annual solar grade sunlight hours vary from 1,200–1,700 hours annually.

Each sq.mt. of flat solar collector area conserves between 400 – 700 kWh or 60 litres to 100 litres of diesel annually assuming 275 days of operations. For every 1 million m^2 of installed collector area 10 GW of peak load shaving can be achieved ([133]).

In addition to solar thermal systems, photovoltaic/thermal (PV/T) systems are an option for the utilization of solar energy to produce both electricity and thermal energy. Typical electrical conversion efficiencies are found to vary from 10% to 20% while those for thermal efficiencies range around 50% or more so that it is possible for PV/T systems to reach higher efficiencies (Al-Waelia et al. 2017). The comparison of building integrated PV/T systems with building integrated PV (BIPV) systems indicated similar results (Agraval et al., 2010). The use of phase change materials (PCM) can further increase performances.

5.2.7.1.2 Bioenergy for bioheat and/or bioelectricity in buildings

Currently, the use of bioenergy for heating as bioheat in the residential, services, and industry sectors exceeds the use of bioenergy in the power and transport sectors as bioelectricity and biofuels ([134]). In the case of biomass, sustainably harvested biomass is considered a renewable resource. However, while the carbon stored in the biomass itself may be CO_2 or greenhouse gas neutral, the cropping and harvesting (fertilisers, tractors, pesticide production) and processing to the final fuel may consume an important amount of energy and result in CO_2 releases, as well as N_2O emissions from the field. Therefore, it is imperative to take adequate measures to make sure that biomass, used as a source of energy, is harvested in a sustainable manner and used in the most efficient manner possible, including in systems for both bioheat and bioelectricity.

Biomass is considered as a renewable and carbon-neutral energy source when the territorial approach is used for the CO_2 accounting. If the Life Cycle Analysis (LCA) approach is chosen for the CO_2 emissions inventory, the emission factor for biomass will be higher than zero so that differences between both methodologies in the case of biomass may be very important.

Biomass systems are available on the market from 2 kW onwards. During a building refurbishment, fossil fuel boilers (in particular coal) can be replaced by biomass systems. The heat distribution installation and radiators are the ones used with the previous installation. A biomass storage room must be foreseen for the accumulation of pellets or wood chips. The performance of the combustion and the quality of the biomass are critical to avoid the emissions of particles into the atmosphere and the system must be adapted to the type of biomass that is to be used.

([131]) European Technology Platform on Renewable Heating and Cooling, Strategic Research Priorities for Solar Thermal Technology, *http://www.rhc-platform.org/fileadmin/Publications/Solar_thermal_SRP.pdf*

([132]) Solar-Activehouse, *http://www.activehouse.info/cases/solar-activehouse/*

([133]) http://www.stfi.org.in/

([134]) Bioenergy insight – Bioheat, Biopower, Biofuel, *http://www.aebiom.org/bioenergy-insight-bioheat-biopower-biofuel/*

5.2.7.1.3 Heat pumps and geothermal heat pumps in buildings

Heat pumps ([135]) combine high energy conversion with the capability of utilising aerothermal, geothermal or hydrothermal heat at useful temperature levels. Heat that is extracted from the environment by a heat pump (ambient heat) is considered renewable as long as a minimum Seasonal Performance Factor (SPF) for the unit is met. Heat pumps present a versatile energy technology that can provide both heating and cooling in a great variety of building contexts and applications, which can be combined with smart technologies and storage. Heat pumps can also provide for flexibility in the electricity system and contribute to the management of the variability of heating and cooling demand. For these reasons, heat pumps have the potential to become a mainstream technology in the heating and cooling sector, including at the building level.

Heat pumps are composed by two heat exchangers. In winter the heat exchanger located outdoors will absorb heat from the environmental air. The heat is transferred to the indoor exchanger to heat the building. In summer the role of each part is inverted. The outdoor unit must transfer heat in summer and absorb it in winter so that a heat pump's performance is highly influenced by the outdoor temperature. In winter (summer), the heat pump's performance will decrease according lower (higher) temperatures. Since the performance of heat pumps depends on both the indoor and the outdoor temperatures, it is convenient to reduce the difference between them as much as possible to increase performance. Accordingly, in the winter season, an increase of temperature in the heat pump's cold side (outside) will improve the performance of the cycle. The same reasoning can easily be applied to the hot (outside) side in summer.

In addition, a possible solution to increase typical performance values is to use ground water as a source of heat in winter and source of cold in summer. This can be done due to the fact that, at a certain depth, the ground temperature does not suffer significant fluctuations throughout the year. Generally, the coefficient of performance (COP) or energy efficiency ratio (EER) values can be improved by 50%. Seasonal Performance Indicators can be improved by 25% ([136]) with respect to an air-water cycle. This leads to the conclusion that the electricity consumption in this case could be 25% lower than the case of an air-water conventional heat pump.

The heat transfer process between the Ground Heat Exchanger (GHE) and surrounding soil is dependent on local conditions such as the local climatic and hydro-geological conditions, the thermal properties of soil, soil temperature distribution, GHE features, depth, diameter and spacing of borehole, shank spacing, materials and diameter of the pipe, fluid type, temperature, velocity inside the pipe, thermal conductivity of backfill and finally the operation conditions such as the cooling and heating load and heat pump system control strategy. Geothermal energy systems can be used with forced-air and hydronic heating systems while also designed and installed to provide "passive" heating and/or cooling. Passive heating and/or cooling provide cooling by pumping cool/hot water or antifreeze through the system without using a heat pump to assist the process. The geothermal energy potential in the country is estimated at more than 10,000 MW, but it has remained untapped so far ([137]).

5.2.7.1.4 Local electricity production

Local electricity production can be supported by photovoltaic electricity generation, wind power, hydroelectric plants and mini-hydro, as well as the power output of cogeneration. (**Error! Reference source not found.**) These options are overviewed based on technical aspects to guide policy support and the key measures that are being used to promote these options based on best practices.

Table 37. Technologies available for local authorities

Photovoltaic (PV)	**Conversion of solar radiation to electricity by using solar cells**

([135]) Further information available at http://www.egec.org and http://www.groundmed.eu
([136]) Geotrainet Project Webpage, http://www.geotrainet.eu
([137]) https://www.thinkgeoenergy.com/gujarat-set-to-the-be-first-region-in-india-to-use-geothermal-power/

Photovoltaic (PV)	**Conversion of solar radiation to electricity by using solar cells**
Wind Power	Electricity generated by wind power through wind turbines
Hydroelectric	Powered by the kinetic energy of flowing water. Electricity converted by turbines and generators
Combined heat and power	simultaneous generation of thermal energy and electricity from a single input of fuel

Source: JRC own elaboration.

5.2.7.1.5 Photovoltaic electricity generation (PV)

Photovoltaic modules permit the conversion of solar radiation to electricity by using solar cells. The majority of photovoltaic modules are used to generate power connected to an electricity grid while there is also a smaller market for off-grid power, particularly in remote areas and developing countries. The integration of renewable energies in cities, in particular building integrated photovoltaics (BIPV), represents significant opportunities in combination with increased energy efficiency ([138]). The integration of solar modules has been improved by manufacturers. In addition to roofs and bricks, modules are integrated to external building walls, semi-transparent façades, skylights, and shading systems ([139]).

A European solar radiation database was developed using a solar radiation model and climatic data integrated within the Photovoltaic Geographic Information System (PVGIS). PVGIS is a web application for the estimation of the performance of photovoltaic (PV) systems in Europe and Africa, as well as a large part of Asia, which has become widely used by the PV community. The online interface to the PVGIS database lets the user estimate the long-term energy performance of different types of PV systems (Huld et al., 2012). The database, with a resolution of 1 km x 1 km, consists of monthly and yearly averages of global irradiation and related climatic parameters, representing the period 1981–1990. The lifespan of PV modules can reach about 25 years, after which material recovery may be an option to improve security of critical raw materials (Latunussa et al., 2016).

The calculation of electricity generation potential by contemporary PV technology is a basic step in analysing scenarios for the future energy supply and for a rational implementation of legal and financial frameworks to support the developing industrial production of PV.

Policy measures include municipal financing and ownership of PV pilot plants on public buildings, concession of surface rights and renting of rooftop areas in public buildings, PV installations on the roofs of bus sheds, and the construction of a PV park on municipal property at a former landfill site. Policy measures further include PV installations in public buildings and third-party financing for PV systems in school buildings, public-private partnerships for Photovoltaic Solar Parks, energy supplier obligations for PV systems, the provision of a bonus from local authority for photovoltaic installations on citizen's roof, interest-free loans for associations or schools for PV installations, PV systems that supply electric vehicle charging stations, solar land registry for PV installations, real time electricity generation data on PV systems of the City Council, and supported PV campaigns.

Given the key role of PV technology in future energy systems, strategies are needed for dealing with large future volumes of end-of-life PV panels. Reuse and recycling technology is available today although the short-term lack of waste volume means that economies of scale often can't be realised. For further information on this aspect, consult the Annex 6 of this document and contact IEA Task 12, which focuses among other activities on recycling of manufacturing waste and spent modules ([140]).

5.2.7.1.6 Wind Power

Similar to PV systems, the use of electricity that is generated based on wind power systems displaces the electricity demand that would have otherwise been supplied by the local utility. Since no emissions are

([138]) IRENA (2016). Renewable energy in cities. International Renewable Energy Agency (IRENA). Abu Dhabi, http://www.irena.org/publications/2016/Oct/Renewable-Energy-in-Cities

([139]) Building integrated photovoltaics. A new design opportunity for architects, http://www.aie.eu/files/RES%20TF/BIPV_web.pdf

([140]) Some good quality documents and reports are found on its website (http://www.iea-pvps.org/index.php?id=56).

associated with the operation of wind turbines, the emission reductions from this mitigation measure are equivalent to the emissions that would have been produced had electricity been supplied by the local utility.

For this reason, local authorities are mobilising resources to enable the use of a greater share of electricity from wind turbines in the local energy mix. Other policy measures in support of wind power include wind farms with citizen cooperation, promotion of locally owned wind turbines, public procurement of municipal wind turbines, co-ownership of wind-power plants, attraction of companies to generate electricity from wind energy, prioritized case handling and licencing of wind turbines, and land use planning for wind energy among other measures. Ministry of New and Renewable Energy, Government of India introduced National Wind-Solar Hybrid Policy in 2018. The main objective of the Policy is to provide a framework for promotion of large grid connected wind-solar PV hybrid system for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability. ([141])

India has set an ambitious target of reaching 175 GW of installed capacity from renewable energy sources by the year 2022, which includes 100 GW of solar and 60 GW of wind power capacity. Various policy initiatives have been taken to achieve this target. At the end of 2017-18 the total renewable power installed capacity in the country was almost 70 GW.

5.2.7.1.7 Hydroelectric plants and mini-hydro

Hydropower represents an essential example of the energy-water nexus in which the availability of water resources based on rainfall affects the amount of energy production. Different types of hydroelectric plants have different capacities, including run-of-the-river hydro plants that do not require a dam, or if so, only a very small one. While large-scale hydropower technology is one of the most mature renewable energy technologies, research is ongoing to better adapt turbines and facilities to the head flow to optimise the techno-economic performance of small hydropower applications (Manzano-Agugliano et al., 2017). Best practices that involve hydropower technologies include those to attract or allocate investment.

In India, electricity and electricity generated from hydro projects fall under concurrent subjects. Water being State subject, the actual implementation of SHP projects is governed by the State policies. The decision of setting up SHP projects or its allotment is taken by the State Government. 24 States of the country have policies in place towards private sector participation to set up SHP projects. ([142])

5.2.7.1.8 Bioenergy for electricity generation (biomass, biogas)

Combustion followed by a steam cycle is the main technology for utilising biomass for electricity generation. Newer technological alternatives include the use of biomass in organic Rankine cycle (ORC) plants and gasification systems. Biomass is used as the main fuel but can also be co-combusted with coal or peat. Biogas from anaerobic digestion is mainly used on-site for co-generation applications while biogas can also be upgraded into biomethane towards injection into the existing natural gas grid.

Best practices for the use of bioenergy for electricity generation include biogas cogeneration based on anaerobic digestion, anaerobic digestion in the public waste recovery and treatment company, biogas cogeneration based on zootechnical wastewater and silage cereals, and biogas driven district heating networks. Other best practices include public-private partnerships between the local authority and waste management utility for anaerobic digestion of biowaste for CHP-based district heating, the recovery of methane gas from landfills to produce electricity based on gas engines, and consortiums for cogeneration plants driven by sustainable certified biomass based on waste produced locally or from local consortium companies.

Biofuel in India is of strategic importance as its augers well with the ongoing initiatives of the Government such as Make in India, Swachh Bharat Abhiyan, and skill development, and offers great opportunity to integrate with the ambitious targets of doubling of farmers' income, import reduction, employment generation, and waste-to-wealth creation ([143]).

5.2.7.2 *CHP – Combined heat and power generation*

A cogeneration or CHP plant is an energy production installation that simultaneously generates thermal energy and electrical and/or mechanical energy from a single input of fuel. Signatories have implemented

([141]) https://mnre.gov.in/Wind/policy-and-guidelines
([142]) https://mnre.gov.in/Small%20Hydro/policy-and-guidelines
([143]) https://mnre.gov.in/Bio%20Energy/policy-and-guidelines

measures towards high-efficiency cogeneration power plants in close collaboration with local utilities for sustainable energy systems ([144]).

CHP plants are usually very close to the electricity consumer, thereby avoiding network losses during transmission and distribution to the end-users. CHP plants can be part of distributed generation schemes in which several smaller CHP plants produce energy being consumed nearby. Cogenerated heat may also be used to produce cold through absorption refrigeration chillers. Other types of thermally driven chillers are commercially available although their market presence is more limited than that of absorption chillers.

Plants that simultaneously produce electricity, heat and cooling are known as trigeneration ([145]) plants. A part of the trigeneration units offer significant relief to electricity networks during the hot summer months. Cooling loads are transferred from electricity to gas networks.

CHP leads to a reduction of fuel consumption by approximately 10 - 25% compared with conventional electricity and separate heat production. The reduction of atmospheric pollution follows the same proportion. The power range and efficiencies of CHP technologies are summarized in Error! Reference source not found.. CHP may be based on gas turbines, reciprocating engines, Stirling engines, or fuel cells. The electricity produced in the process is consumed by the users of the grid and the useful thermal energy may be used in industrial processes, space heating or in a chiller for the production of cold water.

Table 38. Power Range and Efficiencies of Cogeneration Technologies

Technology	Power range	Electric Efficiency	Global efficiency
Gas turbine with heat recovery	500 kWe - >100 MWe	32 – 45%	65 – 90%
Reciprocating engine	20 kWe -15 MWe	32 – 45%	65 – 90%
Micro gas turbines	30 - 250 kWe	25 – 32%	75 – 85%
Stirling engines	1 - 100 kWe	12 – 20%	60 – 80%
Fuel cells	1 kWe - 1 MWe	30 – 65%	80 – 90%

Source: COGEN ([146]) Challenge Project

Small-scale heat and power installation can play an important role in the energy efficiency improvement in public, residential and commercial buildings, including hotels, swimming pools, hospitals and multi residential dwellings. As compact systems, they are convenient to install. The dimensioning of the micro-cogeneration installation will depend on the heat loads. Combined electrical and thermal efficiency varies between 80% and well above 90%. Similar to electrical efficiency, unit capital costs per kW_{el} depend on the electrical capacity of the system. A significant decline of capital costs due to scale effects are observed particularly as systems reach the 10 kW_{el} range (Pehnt et al.,2006) . CO_2 emissions of natural gas driven micro-cogeneration systems are in the range 300-400 g/kWh.

5.2.8 Waste and water management

Local waste management strategies are particularly crucial for enabling the minimization of the amount of waste generated through waste prevention, the diversion of waste from landfills through recycling, reuse, and

([144]) Kona et al. 2017

([145]) POLYSMART - Polygeneration with advanced small and medium scale thermally driven air-conditioning and refrigeration technology, http://www.cordis.europa.eu/project/rcn/85634_en.html

([146]) http://www.cogeneurope.eu/challenge/

composting, and the utilization of environmentally-conscience waste-to-energy options ([147]). Water management also has a direct impact on energy usage at the local level through the electricity that is used for the preparation of tap water and its pumping through pressurized water distribution systems to reach end-users. Minimizing water leakages in the water distribution system and reducing water usage through conservation can thus reduce the level of energy usage for water services. In addition, the selection of water supply reservoirs in proximity to the city, which can reduce extraction and transport costs, can be directly affected by the effectiveness of water management practices at the local level. Especially in cases where desalination may be required for water supply, including those in islands, the integration of renewable energy sources can support the energy loads of the energy intensive infrastructure (Duic et al., 2008).

In the aspect of wastewater treatment, opportunities for local energy generation involve the combustion of digester gas or its use for cogeneration as well as the extraction of residual heat from wastewater based on heat exchangers and heat pumps. The integration of renewable energy, such as solar and geothermal energy to assist in covering the energy requirements of the wastewater treatment plant, is another option. Cases in which wastewater treatment plants (WWTPs) have reached energy self-sufficiency based on the utilization of such options take place among the best practices. At the same time, the heat generation potential in WWTPs often exceeds the amount that is required on-site, which provides opportunities to satisfy other local heat demands in the vicinity, including those of buildings and industries (Kollmann et al., 2015). In the context of the energy system as a whole, WWTPs can offer opportunities for demand response, particularly in the sludge processing equipment, thereby assisting in any power load levelling (Aghajanzadeh et al., 2015).

Box 26. In managing water, Surat takes lead

The government of Gujarat Launched a policy for Treated WasteWater reuse on 28th May 2018, which promotes the reuse of Treated sewage for different purposes of Gardening, Industrial Reuse, Tanker Filling, Lake restoration, Flushing, Construction reuse etc. The policy of treated wastewater is prepared by Government of Gujarat with a vision to maximize the collection & treatment of generated sewage and reuse of treated wastewater on a sustainable basis, thereby reducing dependency on freshwater resources. Also, the reuse of treated wastewater can become a source for revenue generation. The policy aims to achieve ultimate goal of reuse of treated wastewater fully by the year 2030.

The Surat Municipal Corporation has 11 nos. of STPs in different area of Surat city having total design capacity of 1072 MLD. Currently, about 930 to 950 MLD of waste water is being treated at these STPs. So at the end of year 2021, it is planned to reuse about 747 MLD of Waste Water collected at various Sewage Treatment Plants of Surat City. The reuse of sewage water will:

- Contribute towards reducing the dependency on conventional resources of water. Action Plan: Reuse & Recycle of Treated Wastewater (2019)
- Facilitate recycling of wastewater - an environmentally sound and progressive advance practice.
- Enable SMC to free up potable water earlier supplied to Industrial area, which can be used to supply the drinking water to the citizens of the city.
- Reduce dependence of Industrial Units on bore-wells and private tanker operators.
- Reduce pressure on ground water resources in the city for the benefit of environment.
- Conserve valuable ground water resources for future generation.
- Assure resource of water for industrial units during scarcity.
- Guarantee revenue generation for Surat Municipal Corporation.
- Assure more stability in level of water supply by supplementing the source of water.

https://www.suratmunicipal.org/Content/Documents/Departments/DRAINAGE/RR_TWW_ActionPlan_2019.pdf

([147]) Waste Framework Directive 2008/98/EC, *http://ec.europa.eu/environment/waste/framework/*

Box 27. India's First Solar-Powered Desalination Plant

A team from the Indian Institute of Technology Madras (IIT Madras) has set up the country's first solar powered desalination plant in Tamil Nadu. Built on a 120 square meter (sqm) area near Vivekanada Memorial at Kanyakumari, the plant has a capacity to generate 10,000 litres of freshwater a day. The Rs 1.22 crore experimental project, funded by the Ministry of Earth Sciences, will be inaugurated soon.

Surface seawater is pumped in a collector that traps sun's radiation and converts it into heat. The sun's energy is used to heat seawater, which is at 37 degrees Celsius, to 70 degree Celsius and above. The hot water is then pushed into a flash chamber under vacuum and around one per cent turned into vapour, which is sent to a condenser and cooled with sea surface water to generate freshwater. Solar energy is used to heat water and generate power through photo-voltaic panels to operate the plant, which requires about 15kv power a day to function. The panels installed at the plant can generate around 324 watts each. The power generated is then converted from direct current to alternating current using an inverter and stored in 14 batteries to provide 30 minute of power backup. Five solar-powered motors operate the plant.

Since the plant is powered by the solar power, it can only be operated during the day. The freshwater generated by the plant has only 2 parts per million (ppm) of dissolved salts. As WHO recommends water with 500 ppm for drinking purpose water generated by the plant is mixed with local municipal water.

https://academia.electronicsforu.com/category/updates/innovation/page/2

5.2.8.1 *Utilization of biogas resources at the local level*

Biogas is a naturally occurring by-product of the decomposition of organic waste in sanitary landfills or from sewage and residual waters. It is produced during the degradation of the organic portion of waste. Biogas essentially contains methane (CH_4), which is a highly combustible gas. Therefore, biogas is a valuable energy resource that has wide range of uses for biogas for heating, electricity, and transport fuel (Achinas et al., 2017). Biogas can be used as in a gas turbine or a reciprocating engine, as a supplementary or primary fuel to increase the production of electric power, as a pipeline quality gas and vehicle fuel, or even as a supply of heat and CO_2 for nearby greenhouses and various industrial processes. Biogas is mostly produced based on sewage sludge while production from landfill, food-processing residues and wet manure are expected to increase ([148]) **(Figure 26)**. In contrast, methane is a greenhouse gas (GHG) with a global warming potential (GWP) that is 21 times higher than CO_2. The use of methane content that would otherwise be released without being utilised as an energy source is a valid climate mitigation option.

Local policies can promote low-carbon waste practices and the recovery of its energy content when appropriate either as biogas or incineration. Through municipal initiatives or private–public partnerships, waste-to-energy can be promoted as a potential source for heat and electricity, including possible interventions is wastewater treatment plants (Box 28). The use of biogas as an energy source has a role in upholding circular economy principles in which outputs are streamlined to provide inputs for other systems.

Box 28. Biogas Options from Waste and Wastewater

Organic waste streams used in bioenergy gasification or composted

Landfill gas capture

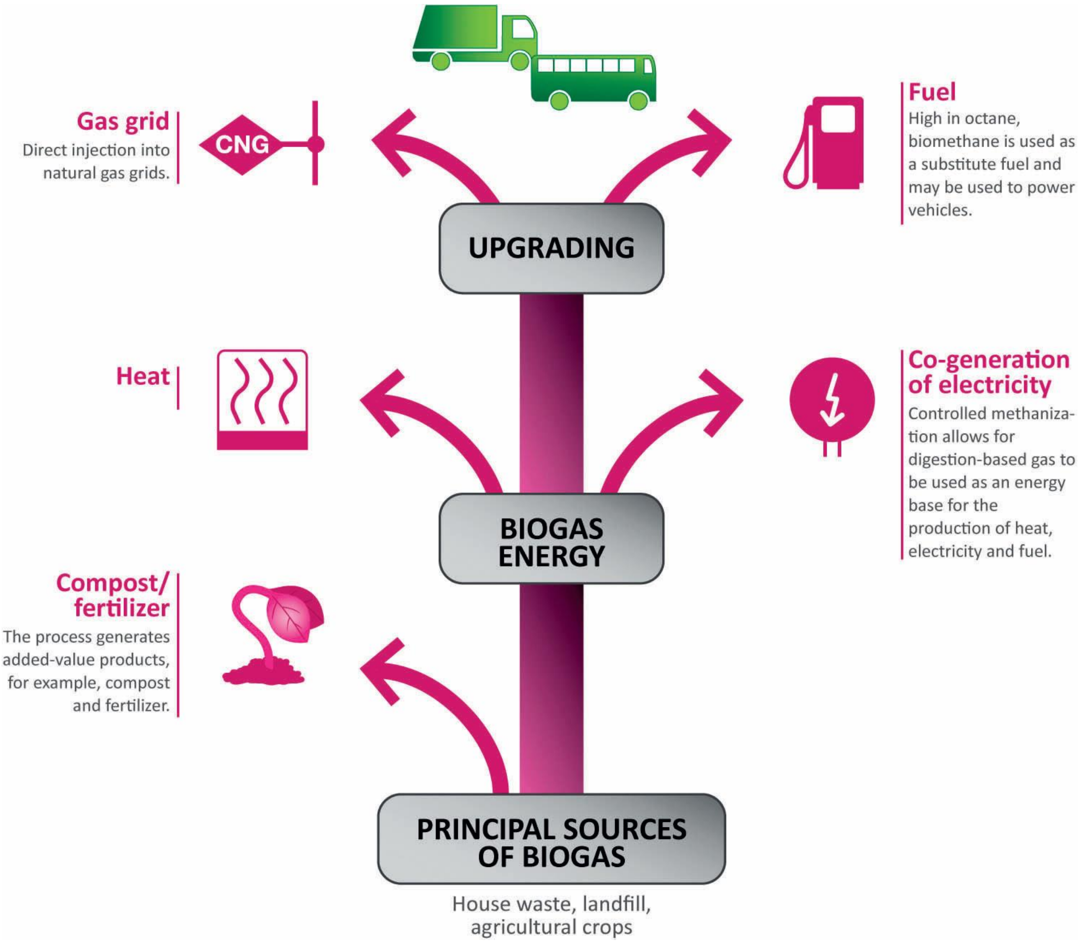
Upgrading of biogas to biomethane for distribution via the exiting natural gas grids

Methane recovery from the wastewater for reuse

Integration of low enthalpy geothermal sources for the digestion of the sewage sludge in the wastewater systems in the process of producing biogas

([148]) European Environmental Agency, (2006). How much bioenergy can Europe produce without harming the environment? Copenhagen: EEA, *https://www.eea.europa.eu/publications/eea_report_2006_7*

Figure 26: Biomethane Chain Involving Compost, Cogeneration and Upgrading



Source: Achinas, S., Achinas, V., Euverink, G., 2017.

5.2.8.2 *Landfill biogas recovery*

Waste disposal in landfills can generate environmental problems, such as water pollution, unpleasant odours, explosion and combustion, asphyxiation, vegetation damage, and greenhouse gas emissions ([149]). Landfill gas is generated under both aerobic and anaerobic conditions. Aerobic conditions occur immediately after waste disposal due to entrapped atmospheric air. The initial aerobic phase produces a gas mostly composed of CO_2. Since oxygen is rapidly depleted, a long-term degradation continues under anaerobic conditions, thus producing a gas with a significant energy value that is typically 55% CH_4 and 45% CO_2 with traces of certain volatile organic compounds (VOC) ([150]).

Practices for sustainable landfilling can monitor such indicators as leachate composition, methane production, landfill settlement and in situ waste temperature (Van Vossen, 2010). Emissions are relatively greater in operating landfills than in closed landfills due to the time of decay and degradation of the landfilled waste (Lou and Nair, 2009). The economic viability of utilizing landfill gas for local energy generation depends on

([149]) The information given may not be relevant for countries where landfills are no longer allowed.

([150]) IEA Bioenergy – Task 37 Energy from Biogas and Landfill Gas, Methane emissions in biogas plants - Measurement, calculation and
evaluation, *http://www.iea-biogas.net/files/member-upload/DRAFT_Methane%20Emissions.pdf*

the methane content of the available gas, local energy prices, and the selected equipment based on the engine and turbine (Zamorano et al., 2007).

Globally, landfills are estimated to account for 8% of anthropogenic CH_4 emissions, an important source of anthropogenic CH_4 emissions. As mitigation options, landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared" ([151]). Similarly, the Environmental Protection Agency (EPA) of the US presents a method for calculating GHG emissions associated with three different landfill management systems ([152]). These are landfills that do not capture landfill gas, those that recover methane and flare it, and those that recover methane and combust it for cogeneration. A conservative value for the percentage of methane that is chemically or biologically oxidized is 10% for landfills with low permeability cover while the default efficiency of methane capture systems is 75%.

5.2.8.3 *Renewable energy in wastewater treatment plants*

Another possibility to produce biogas is through the installation of a biodigester in sewage and residual waters facility. The residual waters are conducted to the sewage plant where the organic matter is removed from the wastewater. Organic matter then decays in a biodigester in which the biogas is produced through an anaerobic process. Around 40% to 60% of the organic matter is transformed in biogas with a methane content of around 50% to 70% (Bruno et al., 2009). The biodigester can also be fed by vegetable or animal wastes. Modern plants can be designed to reduce odours to a minimum extent. Biogas plants may be designed to fulfil the prerequisites for approval by the food industry to use the bio-fertilizer in agriculture.

Other best practices include the integration of renewable sources for supplying power to pumping tap water, including photovoltaic electricity generation, while reducing electricity usage for pumping based on reductions in water losses in the tap water distribution network and an information system for energy and water use in the public sector.

Box 29. Panaji Solid Waste Management Practice

Panaji Municipal Corporation set up an exemplary solid waste management practices in the state of Goa. Project involves source segregation into eight clear waste streams (wet, paper, plastic bags, metals or glass, non-recyclable, tetrapacks, cardboard, and plastic bottles) with designated colour coding. Decentralised composting units for converting wet waste into manure for community usage. Mechanical transfer of garbage from trolley to truck without manual intervention. Material recycling stations within colonies for further segregation of dry waste.

Financial aspects essentially include User charges levied, Revenue from sale of compost and Revenue from sale of segregated waste to recyclers for recycling.

Implementation of project resulted into:

— 100% Collection of segregated waste from households and sorted into 8 streams.

— Segregated wastes transported to recycling units and compost units for further processing.

— Waste to landfill minimised.

Project was jointly set up by Goa waste management corporation and Hindustan Waste Treatment Private Limited (HWTPL) by converting old dumping yard into scientific integrated solid waste management, converting wet waste to biogas energy, segregating dry waste and compacting of dry waste. Capacity of the plant is 100TPD fully automated unit for processing, except for the sorting of dry waste which is a manual process.

Process involved:

— Transfer of mixed waste from garbage truck to the tipping floor to conveyor belt, where manual monitoring and sorting is performed by trained workers.

— Segregation of dry waste is sold to recyclers.

([151]) Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31999L0031*

([152]) US EPA, (2006). Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, Section 6.

— RDF is sent to cement and brick kiln industries to be used as fuel.

— Reject is compacted and sent to sanitary landfill site within the premises.

— Wet waste is converted to biogas which is used to generate electricity which is partially self-consumed and rest is sold to the grid.

— The slurry from Biogas plant is subjected to In vessel composting, compost generated is sold to Zuari Agro Industries.

— Waste water treatment plant for treatment and reuse of water within premises.

— The full plant is controlled and monitored via a SCADA system and CCTV Cameras.

— Employment of rag pickers.

Total cost of the project was Rs.456 crores equivalent to US$ 75 million which was invested by HWTPL while the land for the project was given by Government of Goa.

The plant generates 340kW an hour, over 7,000kW on a daily basis of this 4000kW is self-consumed and 3,000kW is sold to the grid at the rate of Rs 2.4 per unit ie cents 3.5 per unit. ([153])

5.3 Elaboration of the plan: Adaptation actions

Adaptation to Climate Change requires a multilevel approach involving local, regional, national levels. In particular, adaptation to Climate Change is a shared competence between local and regional authorities and should be defined according to a city´s peculiarities and needs, which might be neglected by a solely large-scale national framework.

Countries are faced with the growing challenge of managing increasing risks from climate change and climate variability, putting development and the achievement of the Sustainable Development Goals at risk. The adoption in 2015 of the Sendai Framework for Disaster Risk Reduction and the Paris Agreement on climate change provides a clear mandate for increased coherence in countries' approaches to climate and disaster risk reduction. Countries increasingly recognise the benefits of improved coherence between the two policy areas, exemplified by the number of countries that either have developed joint strategies or put in place processes that facilitate co-ordination. India has examined the potential for increased coherence in approaches to climate change adaptation and disaster risk reduction across levels of government and sectors. It has identified ways in which government officials, development co-operation and other stakeholders can support efforts to further enhance coherence between the two policy areas.

Table 39. Goals and indicator of the three post 2015 Agendas

		UNFCCC and Paris Agreement	Agenda 2030 and SDGs	Sendai Framework for Disaster Risk Reduction 2015-2030
Level	Global	Global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal of limiting temperature increase to well below 2 degrees and	17 global goals, with SDG 13 to take urgent action to combat climate change and its impacts Several targets for each goal. 232 indicators as part of the global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable	Objective of substantially reducing disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries 7 targets 38 indicators were

([153]) http://ccpgoa.com/swachhbharat/uploads/download/24_down_Report-Disposal-of-MSW-In-Panaji-City_-_Copy.pdf

		UNFCCC and Paris Agreement	Agenda 2030 and SDGs	Sendai Framework for Disaster Risk Reduction 2015-2030
		pursuing efforts to limit the temperature increase to 1.5 degrees C above preindustrial levels No targets or indicators	Development	identified to measure global progress
	National	Countries have reported on progress made towards national goals and indicators through their national communications, their national adaptation plans or nationally determined contributions	Countries may define national SDG indicators (based on the global framework), set baselines and assess progress through scorecards	Countries may select national indicators from the Sendai Framework Monitoring System
	Sub-national / local	Variety of indicators used across different sectors and funders of programmes and projects	Variety of indicators used across different sectors and funders of programmes and projects	Variety of indicators used across different sectors and funders of programmes and projects

Source: JRC own elaboration.

Climate change considerations can be integrated with disaster risk reduction (DRR) in cities. DRR efforts may be used as a platform from which to develop climate change adaptation plans. In practical terms, disaster risk reduction and climate adaptation can be integrated in many instances, although cities should also consider incremental or gradual changes in climate that affect government operations or community life in less immediate and visible ways than conventional disasters.

5.3.1 Indian Commitment to Adaptation

For our cities adaptation is not a one-time effort but an ongoing cycle of preparation, response, and revision. It is a dynamic process, and one that should be revised over time based on new information. Underpinning the strongest adaptation processes will be leadership and commitment to measuring progress and assessing effectiveness. This will help ensure that cities invest scarce resources in truly adaptive ways and achieve the maximum co-benefits, while avoiding unintended consequences or maladaptation. Those cities that are able to integrate adaptation well with a broad spectrum of existing planning processes and goals, including priorities in disaster risk reduction, sustainable development, and poverty reduction will be best positioned to thrive in this new era of climate change.

Mainstreaming adaptation can have multiple approaches and entry points. Apart from access to climate information and services, mainstreaming on the ground requires coordination among multiple stakeholders and processes, including government and private institutions. Identifying the right approach is essential for leveraging finance for climate adaptation and meeting sustainable development goals. Important elements required to ensure accelerated mainstreaming of adaptation in India are:

1. Evidence-based planning

   Measures must be based on reliable and scientifically sound evidence on climate change impact in a particular region. It is important to look at climate in smaller regions and not just annual averages, and seasonal variations in rainfall, number of rainy days and number of dry days. Analyse data in smaller administrative areas, like at the Panchayat level, before scaling it up to the district level. Decentralised planning and participation of local communities, including traditional knowledge and perceptions, are crucial to improve adaptation interventions and curb climate impacts. Portals such as www.climatevulnerability.in provide easy-to-understand information about future climate scenarios and associated risks, which can be used by a wide range of stakeholders.

2. Identifying entry points in existing policies or schemes

   For mainstreaming to work, climate change interventions need an entry point, in an existing development policy or scheme in a relevant thematic area/sector where they can be incorporated. To start with, it would be helpful to tag a prioritised adaptation intervention to a specific sector such as agriculture, water, or rural infrastructure. Such mapping provides a strategic direction and umbrella for ground-level activities, as well as helps leverage funding for adaptation interventions.

3. Engaging local communities

   To maximise the benefits of mainstreaming, local communities, women and marginalised groups need to be engaged. Unfortunately, access to useful climate information and the capacity to understand climate data is often limited. Non-governmental and community-based organisations play a crucial role in bringing the right information to the local government bodies and communities. They also play an important role in assessing climate vulnerability and local impacts through a bottom-up approach. Engaging with the gram sabha or village council members helps in identifying and prioritising adaptation interventions and planning at the local level.

4. Capacity building and knowledge networking

   State Actin Plans on Climate Change (SAPCCs) provide a combined view of sustainable development and climate change, merging science, public finance and governance. Capacity building is essential for an effective mainstreaming process. It must include identifying climate risks, implementing adaptation measures, monitoring and evaluation. Capacity building needs to cover all aspects of the administration horizontally, and all levels of the governance machinery vertically. Stakeholders include policymakers, state officials, district officers, panchayat and village council members, non-government organisations, and vulnerable groups. Creating a cross-sectoral network of agencies and stakeholders can optimise resource allocation, and streamline scientific expertise and local knowledge towards achieving both SAPCC and Sustainable Development Goals.

5. Leadership and key stakeholders

   In this process it is also important to identify and define the key stakeholders and develop champions/leaders amongst government, civil society, academia or politics. They play a key role in influencing policy decision, find solutions to problems. Their involvement and the use of their expertise tied in with the SAPCCs will create the network necessary for mainstreaming of adaptation efforts. Ideally, "champions" are members of the state steering committee, or they support it with advice and information.

One of the overarching goals of India's National Action Plan on Climate Change and NDC for adaptation is to achieve development goals by mainstreaming adaptation into development. In this regard, SAPCCs serve as a key policy framework half-way between the national-level goals and realities on the ground. The localization of SAPCCs to the district and city level will offer a roadmap for state and national programs and will provide an entry point for strengthening decentralised climate governance. For efficient localisation, continued cross-sectoral coordination, stakeholder engagement and capacity building both horizontally and vertically across all levels of governance will ensure the implementation of SAPCCs in an inclusive and participatory manner.

There is no one-size-fits-all approach to adaptation planning. Experience of working on implementing India's SAPCCs at the local level has shown the number of benefits of supporting decentralised planning and community participation, by easing the convergence of funds for various sectoral schemes/programs and providing co-benefits with developmental goals ([154]).

The institutionalisation of adaptation at different levels is the key to successful climate action. There cannot be a better time to bring these perspectives to bear. States have been mandated to review and revise their

([154]) https://www.weadapt.org/knowledge-base/national-adaptation-planning/accelerating-adaptation-in-india-with-state-action-plans-on-climate-change

State Action Plans, and herein lies an opportunity to make substantive headway in achieving India's Nationally Determined Contributions and the Sustainable Development Goals ([155]).

Box 30. Programme on Climate Action in India

India's post-2020 climate goals:

For post-2020 period, in response to the decisions of the Conference to the Parties, India submitted its Nationally Determined Contribution (NDC) to the UNFCCC on 2nd October, 2015, outlining the climate actions intended to be taken under the Paris agreement. The eight goals put forth by India in its NDC are:

— To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.

— To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.

— To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005

— To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).

— To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.

For preparing the of roadmap for implementation of India's NDC in post-2020 period, in the year 2016, the MoEF&CC constituted an NDC Implementation committee Chaired by Secretary, EF&CC, and six thematic Sub-committees, involving key Ministries and Departments of the Government of India. The committee and sub-committees are working on to identify specific policies and actions aimed at achieving the NDC goals ([156]).

5.3.2 Multi-level governance of urban adaptation action ([157])

City Governments can play important catalytic and convening roles in adaptation action. There are many ways to organize and govern an adaptation process, whether with a dedicated climate change unit in the Mayor's office or in the environment agency, an inter-agency task force of the city government, or a wider stakeholder group beyond the city government itself. In all of these approaches, city governments are well positioned to be an integrating force, fostering communications and mutually beneficial partnerships among experts and stakeholders at multiple levels.

Some cities can consider starting a climate leadership team within the government. Several basic elements are necessary for successful city leadership to set the course for climate change adaptation. These include the following:

- Political support, representing high-level commitment to adaptation, initiated and sustained by executive leadership of a mayor or other city officials, and supported by effective public communication
- Operational knowledge of the rules and norms of city operations, as well as relationships to city and external actors who may need to be involved in adaptation efforts
- Scientific expertise or competency, with which city staff can translate science into sound advice for decision makers

Significant progress can be made by simply encouraging departments to communicate openly with one another about climate change impacts and shared adaptation strategies. External partnerships can also be useful in several ways. Some cities may not have the internal capacity to create and maintain a team that is dedicated to climate change adaptation, in which case city officials may find that partnerships with civil society organizations can offer a strategic capacity-sharing benefit. Even cities that do have robust internal capacity, however, may find that a partnership provides an opportunity to catalyse improved coordination and innovation among individuals, groups, and city governments. In fact, because cities may face problems related to climate change impacts that originate outside of jurisdictional boundaries, they may find it critical to

([155]) https://wri-india.org/blog/mainstreaming-climate-change-adaptation-india
([156]) http://moef.gov.in/environment/climate-change/
([157]) https://isbinsight.isb.edu/institutional-arrangements-for-evolving-climate-policy-in-india/

engage a wider array of actors. This also has the positive co-benefit of strengthening communications and relationships among critical players, in turn building social resilience to cope with future risks.

Following Table show Multi-level governance actors of urban adaptation action ([158])

Table 40. Multi-level Governance actors of urban adaptation action

Sr	Actor	Roles
1	Academic and Scientific Organizations	Provide information on scientific developments, vulnerability, and information on potential policy responses.
2	Community-Based Organizations and Small Businesses	Can be helpful intermediaries, especially when led by influential individuals who know how to navigate local social networks. May already be implementing adaptive management responses, whether formally or informally.
3	Governments	Departments or individual actors often serve as first responders to climate-related hazards and primary planners for hazard mitigation or disaster risk reduction. Engage in planning of a wide range of vulnerable built and natural systems that affect the well-being of city residents. Enforce stronger management policies to improve good governance. Convene adaptation partnership among other cities; county, regional, state and federal entities; adjacent towns; special districts; and commissions (for example, for public schools, water, and energy).
4	International Nongovernmental Organizations	Support advocacy and dialogue about adaptation. Offer strategic advice and technical assistance to cities on mitigation and adaptation.
5	United Nations and International Financial Institutions	Provide financing for specific investments and projects, during and after emergencies and on an ongoing basis. Offer strategic advice and technical assistance to cities on mitigation and adaptation
6	Large-scale Industry or Business	Potentially interested in how to make their operations resilient to climate change impacts. Business vulnerability assessments and adaptation strategies may provide useful supplements to city-focused assessments. Key sources of employment, goods, and services for city population. By generating economic activity, they contribute to financial capacity for a city's government and population to adapt. Some businesses may be interested in adaptation investments as corporate philanthropy.

Source: JRC own elaboration.

([158]) Sources: World Bank 2010c; Hardoy and Pandiella 2009; McGranahan and others 2007; CARE 2011; Red Cross / Red Crescent 2011; Rockefeller Foundation 2009; Mercy Corps 2007; IDB 2011; IFC 2011; UN-HABITAT 2011; Chandra 2008, Children's Safe Drinking Water 2008; WorldVision Singapore 2007; and USAID 2006, as cited in Sida 2009.

Table 41. Measures to improve multi-level governance

Actor	Recommended Measures
International level	Define a coherent framework to help mainstream adaptation into national and regional policies, helping to optimize possibilities of synergies with other policy areas and exploiting co-funding opportunities.
	Develop a common reporting system for national, regional and urban projects on adaptation to Climate Change by defining the list of indicators, criteria and standards for reporting and assessment, among others
	Further explore the possibility of leveraging private sector investments within cities
National level	Establish clear coordinating procedures between national and subnational governments (vertical governance) and coherent national legal frameworks in order to enable local adaptation actions
	Include the spatial aspect of Climate Change impacts (e.g., according to administrative units) in national strategies (usually shaped according to policy sectors)
	Use national budgets to support local adaptation and provide technical support to access financing mechanisms
	Establish national communication programmes on Climate Change and support national data sharing and good-practice exchange on adaptation issues
	Improve mainstreaming adaptation into country sectoral strategies (e.g., health, transport, water management, among others), in order to optimise synergies and explore further funding opportunities (horizontal governance across sectors)
Regional level	Define a regional legal framework to coordinate inter-municipal adaptation strategies
	Support smaller cities to develop their adaptation strategies through capacity building, regional data sharing and participatory processes with a broad range of local and regional stakeholders from public and private sectors thus pooling capacities and resources ([159])
City level	Define a horizontal governance to foster inter-agency and cross-sector collaboration on adaptation, define accountability and leaderships, avoiding policy trade-offs and spill-over effects, and improve use of resources
	Create a local/regional platform (or/and communication channels) to share knowledge and data about Climate Change impacts and vulnerabilities across different sectors, with higher resolution available (downscale to local context)
	Foster participatory processes with local communities (especially the most affected and vulnerable by Climate Change impacts) and private sector actors increasing their engagement in decision-making processes and data/knowledge exchange

Source : JRC Own elaboration.

5.3.3 Key adaptation measures for climate hazards

In general climate change impacts across the various sectors in cities: land use; housing; transportation; public health; water supply and sanitation; solid waste; food security; and energy. Following **Table 42** summarises an overview of climate impacts, the sectors involved, and examples of adaptive responses ([160]).

([159]) Create hubs and knowledge exchange platforms at the regional level such as in Durban,: http://www.durbanadaptationcharter.org/news/the-central-kwazulu-natal-climate-change-compact-meeting

([160]) Sources: IPCC 2007; Foster and others 2011; Horton 2009; Action Aid 2006; UN-Habitat 2011; Simply Green 2009; Henriques 2009. See end of Chapter 6 for full list of citations.

Table 42. Climate Impacts, sectors involved and adaptive responses

Projected Change in Climate Phenomena (Likelihood)	**Drivers of Urban Exposure and Vulnerability**	**Consequences for Cities, if Unaddressed**	**Sectors Involved**	**Sample Adaptive Responses (not an exhaustive list)**	**Relative Investment Level / Cost**
Warmer with fewer cold days and nights, more hot days and nights (virtually certain)	Urban heat island effect. Lack of electricity and cooling systems, especially in many informal settlements.	Exacerbated air pollution Heat-induced illness and death	Transportation, housing, private sector building industry, public health	Green infrastructure, including improved vegetation and green building investments for natural cooling.	Medium to high with significant economic and sustainable development cobenefits
Hot spells/heat waves—increased frequency (very likely				Retrofit of existing bus fleet with white roofs to reduce solar heat gain and ventilation to ensure adequate air circulation. Undertaking public relations campaigns to encourage passengers to carry water with them to avoid heat stroke.	Low to medium
	Lack of diversified energy supply and substandard energy infrastructure.	Energy shocks and disruptions because of increased demand	Energy	Investment in clean energy and energy efficiency	Low to high, depending on the specific energy investment; significant cobenefits for economic prosperity and "green growth."
Heavy precipitation events—	Rapid urban growth leading to informal settlements on	Exacerbated flooding and landslides	Land use, housing, solid waste, public health, emergency	Development and enforcement of a sound land use plan that a) is based on understanding of climate change vulnerabilities, b) effectively encourages dense, mixed-use development in	High, involving significant political and staff investment

Table 42. Climate Impacts, sectors involved and adaptive responses					
Projected Change in Climate Phenomena (Likelihood)	**Drivers of Urban Exposure and Vulnerability**	**Consequences for Cities, if Unaddressed**	**Sectors Involved**	**Sample Adaptive Responses (not an exhaustive list)**	**Relative Investment Level / Cost**
increased frequency (very likely)	marginal land with no roads or drainage systems, or drains that are clogged with debris and silt		management	resilient areas, and c) engages ecological planning approaches outside of city limits (for example, village-level watershed management on the outskirts of a city, protection of mangroves and wetlands on nearby coastline).	
Intensity of tropical cyclone activity increases (likely)		Contaminated waters and spread of disease in stagnant waters		Improved solid waste handling practices (for example, proximity to drinking water supply, corrosive-resistant containers) to prevent leakage and contamination.	Medium to high.
				Short-term clearance/disposal of solid waste from drains to prevent clogging.	Low
Rising sea level (virtually certain)				Public health engagement and risk prevention around likely flood related diseases.	Low

Table 42. Climate Impacts, sectors involved and adaptive responses

Projected Change in Climate Phenomena (Likelihood)	Drivers of Urban Exposure and Vulnerability	Consequences for Cities, if Unaddressed	Sectors Involved	Sample Adaptive Responses (not an exhaustive list)	Relative Investment Level / Cost
	Non-existent or substandard transportation infrastructure.	Blockage of emergency routes because of road flooding, resulting in delayed emergency evacuations Losses in commercial activities	Transportation, emergency management, private sector	Investment in roads and other transportation choices for informal settlements.	Medium to high.
				Green infrastructure.	Medium to high with significant economic and sustainable development co-benefits
				Relocation of storage yards for buses and train cars out of flood-prone areas to reduce the risk of damage or loss of this equipment.	High
	Storm water infrastructure unable to deal with current or future runoff, compounded by deforestation / degradation of natural storm water filtering functions.	Increased runoff in absence of vegetated land Increased flooding	Sanitation, solid waste Natural resources management	Short-term clearance/disposal of solid waste from drains to prevent clogging.	Low
				Investment in “green infrastructure” and ecosystem planning to improve natural storm water function. (for example, contour planting, terracing and afforestation for erosion control).	Low (localized planting) to high (large-scale infrastructure or afforestation) with significant economic and environmental co-benefits.
	Already high	Loss of property and	Private sector	Relocation of facilities out of flood-prone areas.	High

Table 42. Climate Impacts, sectors involved and adaptive responses

Projected Change in Climate Phenomena (Likelihood)	Drivers of Urban Exposure and Vulnerability	Consequences for Cities, if Unaddressed	Sectors Involved	Sample Adaptive Responses (not an exhaustive list)	Relative Investment Level / Cost
	population densities and concentrated commercial activities located in coastal cities or in river deltas	infrastructure, potentially before the end of their useful life		Sea walls or other structural investments to protect against coastal flooding.	High
	Lower structural quality of homes, especially in informal settlements	Loss of property and life	Housing, emergency management	Retrofit of old buildings and improved design of new buildings (if residents remain in vulnerable location).	Medium to high
				Stricter risk disclosure requirements for housing developers.	Political and staff investment for sound enforcement
				Public awareness / emergency preparedness initiatives to educate residents on flooding risks.	Low
	Location of aquifers, wastewater treatment plants and other infrastructure in coastal areas or on river deltas	Saltwater infiltration of infrastructure (for example, potable water supplies and wastewater treatment)	Water supply Wastewater treatment	Modification of pipes	Medium
Areas affected	Existing water	Exacerbated water	Water supply (with	Utility piped water supply (assuming water supply is resilient).	Medium to high

Table 42. Climate Impacts, sectors involved and adaptive responses					
Projected Change in Climate Phenomena (Likelihood)	**Drivers of Urban Exposure and Vulnerability**	**Consequences for Cities, if Unaddressed**	**Sectors Involved**	**Sample Adaptive Responses (not an exhaustive list)**	**Relative Investment Level / Cost**
by drought increase (likely)	scarcity and competing pressures for water use (for example, potable water, irrigation, wastewater, hydropower). Food shortages or higher food prices because of impacts in other parts of the region or world.	scarcity and competition	implications for energy sector in areas of hydropower generation)	Reclaimed wastewater (resilient if properly managed).	High
				Long-term demand management and water use efficiency programs.	Low to medium
			Food and agriculture	Raising public awareness and developing municipal competency about food supply.	Low; with staff investment
				Promotion of urban agriculture.	Staff investment and potential high costs, if involving land purchase
				Development of city-level food storage infrastructure.	High

Source: JRC own elaboration.

Box 31. Flood 'risk' and 'adaptation in Chennai

Coastal city of Chennai is selected based on the food risks, anthropogenic activities and vulnerability from food hazards. Another factor which exacerbates food risk in this city is the lack of proper drainage and sewerage system. Community-based adaptation strategies in grassroots level supported by local governments show some successes in adaptation for tackling food risk scenarios in urban areas. Economic minorities are mostly affected by food risk and associated problems in the city. Future planning and management of flood risks in the city included economic minorities for the sustainability of city environments. Early warning systems combined with information technology is effectively implemented in food risk management and adaptation strategies to make the strategies more effective and practical. Chennai is representative of other Indian coastal cities which have similar trends in environmental and demographic settings.

Tamil Nadu has deployed an 'intelligent flood warning system' in Chennai, which will enable officials to get area-wise inundation details during the monsoon. The technology, called CFLOWS, is India's first integrated coastal flood warning system. It was conceptualised by the office of the Principal Scientific Adviser to the Union Government, after the devastating 2015 Chennai floods ([161]).

The system is being considered a game-changer, not just for Chennai, but also for other coastal cities such as Mumbai where urban flooding has become the norm. The link to the fully-operational CFLOWS is handed over to the State Disaster Management cell on Friday, by the National Centre for Coastal Research (NCCR).

The system is designed for core urban area of the city, spread across 426 sq.km. Later, it will be extended to cover the Greater Chennai Corporation limits, for which work is underway.

It is a Web GIS-based decision support system, integrating data and outputs, derived from weather forecast, hydrologic, hydraulic and hydrodynamic models. Based on these models a flood library, comprising 796 flood inundation scenarios, were developed corresponding to different rainfall return periods, tidal and water discharge conditions. A complete WebGIS-based decision support system has been built with six modules as per the requirement of TN government.

Chennai is prone to flooding due to a combination of topography, high population density and unplanned rapid urbanisation. Though it is blessed with three natural drainage systems- Cooum, Adyar and Buckingham Canal, the city literally went underwater in 2015 with three consecutive weather systems bringing unprecedented rain.

Box 32. Kolkata may be slowly sinking, Go Bangkok Way

Kolkata, the city of joy, is one of the densely populated cities in India. Situated on the banks of the Hooghly River, in the Indo-Gangetic plain, the city is home an estimated 14.1 million people. But, like most cities in India, the city of joy has a big worry -- depleting groundwater. Data from the Kolkata Municipal Corporation report of 2007 shows a fall in groundwater from 11m to 7m between the years 1958 to 2003. Now, an alarming study shows that this depletion could slowly sink the city due to land subsidence.

Land subsidence or the vertical lowering of the earth is a result of compaction of aquifers -- a reduction in the porosity of the underground sediments due to compaction of confining layer above the aquifer due to over extraction of groundwater. That is the over extraction lead to reduction in water pressure resulting in downward movement of water from the clay layer present above. This results in compaction of upper clay layer and hence the land subsidence, causing serious damage to buildings, roads and other infrastructure.

These results call for an immediate action on groundwater management in growing urban areas to prevent further sinking of land in the years to come ([162]). The study will help Central Ground Water Board to prepare a groundwater management policy. Stringent laws can also be imposed by the state groundwater boards on the industries which are the water guzzlers.

([161]) https://www.nccr.gov.in/sites/default/files/clChen.pdf
([162]) https://researchmatters.in/news/kolkata-may-be-slowly-sinking-shows-study

In Bangkok, extreme land subsidence by groundwater extraction was successfully reduced by regulations and restrictions. A specific law (Groundwater Act) was enacted in 1977. Most severely affected areas were designated as critical zones, with more control over private and public groundwater activities. Groundwater use charges were first implemented in 1985 and gradually increased. Currently, Bangkok uses a very small amount of groundwater. Only 10 per cent of water is sourced from the ground. The rate of subsidence has gone drastically down.

Box 33. Engaging Local Communities for Participatory Planning

In addition to modelling data, it is important to engage local communities, with special attention to women and vulnerable groups to capture local information. It is important to value knowledge from community level experiences to design robust adaptation strategies. At the local level, access to actionable climate information is challenging. Climate data and projections are available at the district level and capacities to translate that information into impacts and make inferences for work are often limited at ground level. In such cases NGOs or other agencies can play a crucial role in bringing the right information and capturing local socio-economic and climate information. Engaging with communities helped identify existing challenges, cropping system, and water related infrastructure to design needbased adaptation interventions. Further to integrate these prioritised interventions at the local level planning process it is crucial to continuously engage with the Gram Sabha (village council) members and district officials, firstly to create awareness about past and future climate change and impacts and secondly to work on the budget and policy cycle at local level to find entry points.

Testimonials:

(Vandana Kumari)

(Prabh Dya)

Vandana Kumari

I am an Anganwadi (rural child-care centre) worker in Kandraur Village. Baolis (traditional wells) are an important source of drinking water in our village. There is a baoli near my house, but it is damaged and the water is not suitable for drinking. Under the CCA RAI [Climate Change Adaptation in Rural Areas of India] project, I understood how climate change is affecting our daily lives. Water is becoming a scarce resource. Earlier, the rainfall was enough to refill the ground water, and water was easily available in government-installed handpumps. However, now the condition is getting worse every year. With multiple interactions and training programs held by projects in our village, I got the confidence to raise the issue in the panchayat. We discussed the water situation in the village panchayat at lengths and came to a solution that the baolis need repair. The panchayat approved the project, and recently the district administration has also released funds for the same. The baoli near my house has the potential to provide drinking water to 20 households nearby.

Prabh Dyal

I am a farmer in Kandraur Village. The base of my farmland is near the river Satluj and is barren. During monsoons, the water levels in the river Satluj rise and erode the base of the farmland. Every year, I and other farmers lose some part of our land to erosion. If trees are planted on that land, our farms can be protected from erosion. The planting of trees is also expected to provide fodder for cattle and livelihood for the landless. Under Climate Change Adaptation in Rural Areas of India project, I raised the issue during village meetings and in the panchayat. The concerned farmers joined me, and we got approval for the plantation on the forest land. The funds have been released by the district administration, and plantation drive started from June 2019.

There are different types of adaptation measures and actions – e.g. soft measures (like policies, awareness, education, research, information, early warning etc.) grey measures (like construction of engineered protection infrastructure) and green measures nature (based solution addressing the hazards/impacts). Accordingly, a research project can also be considered as an adaptation project.

Projects working to address vulnerability to the impacts of climate change in India are presented alphabetically in the Table 43 below.

Table 43. Impacts of Climate Change in India

Name of Project	Objectives	Type of Project
Adaptation at Scale in SemiArid Regions	**This project will enable proactive, longer-term approaches to climate change adaptation in semi-arid regions, while supporting the management of current risks. It draws on a number of disciplines to address the complex interactions among climate, biophysical, social, political, and economic dynamics. Research on each of these aspects will be integrated through transformative scenario planning, involving stakeholders throughout. The project will generate credible information that decisionmakers and others can use to develop robust adaptation strategies.**	**Research; capacity building; knowledge communication**
Building Adaptive Capacities of Small Inland Fishers for Climate Resilience and Livelihood Security, Madhya Pradesh	**The objective of the project is to showcase climate-resilient pond designs, institutional arrangements between farmers and traditional fishermen, and insurance schemes that will provide farmers with options for adapting more effectively to climatic variability. The project focuses on implementing and testing adaptive strategies that aim to prevent risk (e.g., modification of pond design for larger and longer water retention), transfer risk (e.g., weather-based insurance that absorbs losses from climate change), and terminate risk (e.g., changing fish species or by introducing alternative technological options).**	**Field implementation; community-based adaptation; knowledge communication**
Climate Change: Addressing Heat-health Vulnerability in Rapidly Urbanizing Regions of Western India	**Implemented in the city of Ahmedabad, the first phase of this project focused on developing a comprehensive early warning system and preparedness plan for extreme heat events. Through research, engagement, and awareness raising, Ahmedabad's Heat Action Plan was created. It includes three key strategies: building public awareness, initiating a simple early warning system, and building the capacity of medical and community health professionals.** **The ongoing second phase focuses on firmly embedding the action plan in the government systems by supporting an assessment of implementation of the plan to date, updating and refining policies, and helping to build a strong surveillance and monitoring system for extreme heat. It is also reaching those that are most at risk by working with sectors and groups**	**Research; assessment; knowledge communication; policy formation and integration**

	that directly affect the vulnerable (e.g., construction industry, police) and further operationalizing the early warning system.	
CCKN-IN	Using a multi-level and multifactor approach, the project is piloting climate change knowledge networks by a variety of state and non-state actors at the district, state, and union levels. Additionally, the project will systematically record and process lessons learned and best practices to support upscaling to other states and finally to the national level.	Knowledge communication
Climate Resilience through Risk Transfer	Pioneering an innovative community-based insurance scheme that will offer composite insurance—covering health, crops, livestock, and natural disasters—to directly meet the needs of vulnerable communities affected by climate change	Field implementation
Climate Proofing Growth and Development in South Asia	This project seeks to integrate climate change (adaptation and mitigation) into development planning, budgeting, and delivery in national and subnational governments in Afghanistan, Bangladesh, India, Nepal, and Pakistan, by strengthening planning, budgeting, and delivery mechanisms; building awareness and capacity of stakeholders; providing technical and some implementation support; helping leverage domestic finance; and actively sharing knowledge.	Capacity building; knowledge communication; policy formation and integration
Climate Resilience through Risk Transfer	Pioneering an innovative community-based insurance scheme that will offer composite insurance—covering health, crops, livestock, and natural disasters—to directly meet the needs of vulnerable communities affected by climate change.	Field implementation
Climate Risk Management in Urban Areas through Disaster Preparedness and Mitigation	The main objectives of the project are (1) to reduce disaster risk in urban areas by enhancing institutional capacity to integrate climate risk reduction measures into development programs and undertake mitigation activities based on scientific analyses and (2) to enhance community level capacity to manage climate risk in urban areas by increasing preparedness.	Assessment; capacity building; knowledge communication; policy formation and integration
Conservation and Management of Coastal Resources as a Potential Adaptation Strategy for Sea Level Rise	The project aims to overcome the consequences of salinization and other impacts on coastal areas due to sea level rise and seawater inundation caused by increased cyclonic storms and storm surges. This goal will be achieved through appropriate adaptation strategies, such as the restoration of degraded mangroves and demonstration of the Integrated Mangrove Fishery Farming System.	Field implementation
Deltas, Vulnerability and	This project aims to understand adaptation	Research; capacity

Climate Change: Migration and Adaptation	**choices in delta regions with a strong focus on the role of migration as an adaptation strategy, including temporary, periodic, or permanent migration. Working with stakeholders and key decision-makers, and taking gender into account, the project will integrate climate and socio-economic data for each delta to assess when migration might be appropriate for the most vulnerable, compared with other adaptation options.**	**building; knowledge communication**
Enhancing Adaptive Capacity and Increasing Resilience of Small and Marginal Farmers in Purulia and Bankura Districts of West Bengal	**The proposed project aims at developing climate-adaptive and resilient livelihood systems through diversification, technology adoption, and natural resource management for rural small and marginal farmers associated with agriculture and allied sector in the Lateritic Zone of West Bengal, India. Specifically, it would seek to enhance the adaptive capacity of vulnerable farm families in semi-arid regions of Purulia and Bankura districts of West Bengal by introducing measures to alleviate the adverse impacts of climate change on their food and livelihood security.**	**Field implementation; community based adaptation**
Enhancing Institutional and Community Resilience to Disasters and Climate Change	**The project will support efforts to strengthen the capacity of governments, communities, and institutions to accelerate implementation of disaster risk reduction and climate change adaptation plans.**	**Capacity building; knowledge communication; community based adaptation**
Future Proofing Indian Cities	**The project aims to support the development of urban development strategies and investment plans in Bangalore and Madurai that are future proofed. The longer-term objective is to reduce urban poverty and catalyze economic development in both cities. This will be accomplished by supporting the identification and implementation of investments that generate environmental, social, and economic benefits.**	**Assessment; capacity building; policy formation and integration**
Gender and State Climate Change Action Plans in India	**The project aimed to (1) influence governments in four states to mainstream and articulate gender and inclusiveness in their SAPCCs, (2) demonstrate that adaptation policies need to promote climate-resilient low input agricultural practices and address gender-based differences, and (3) examine adaptation-related gender budgeting. Activities implemented included analysis of draft SAPCC, meeting with state- and national-level bureaucrats, attending policy roundtables involving collaborating departments working in the area of agriculture, preparing policy briefs, and producing a gender framework for the SAPCCs.**	**Research; capacity building; policy formation and integration; field implementation**
Groundwater Resilience to Climate Change and Abstraction in the	**The project aimed to develop a strategic overview assessment of the occurrence and status of groundwater resources in the Indo-**	**Research; knowledge communication**

IndoGangetic Basin	**Gangetic basin and strengthen the evidence base linking groundwater resources, climate and abstraction, and emerging policy responses.**	

Source: (Taylor et al., 2014)

A preliminary list of adaptation actions identified from the international literature and the best available practices are presented in **Table 44** for five main sectors. Actions could be framed as strategic actions, related to alert and communication and as technical measures. With time, this list will be progressively completed with examples from GCoM signatories. Additional measures, depending also on the local needs and the national situation, would be necessary. However, these actions represented in the table below can be considered as a very good starting point.

Table 44. Adaptation actions by sector.

Sector	Actions	
Public health and quality of life	**Strategic actions**	Regularly improve monitoring systems in order to ensure that any disease development or any strong disturbance in public health shall be detected and efficiently addressed in its early stages. Improve sheltering capacities by ensuring that the cities have well-established air-conditioned facilities (hospitals, city halls, mosque, etc.) that can protect citizens who do not have the necessary infrastructure to protect themselves from extreme weather events (heat waves, storms, floods)
	Alert and communication	Develop and regularly maintain an early warning system that can alert citizens ahead in case of extreme weather events. Such systems should be set up as early as possible and connected to National systems to be able to transmit the message in the most efficient and quick way to the citizens Regularly conduct educational and awareness raising campaigns to inform people about possible health impacts of heat waves, floods, vector borne diseases and how to address them
	Technical measures	Regularly improve water quality that can serve to cover the basic needs of citizens during heat waves Improve the quality control of sewage, waste dumps, dormant waters and draining systems to avoid the high risk of being serious diseases reservoirs Identification of potential hot spots for the development of vector borne diseases
Infrastructure management	**Strategic actions**	Develop good systems to ensure the proper management of water flux especially in case of heavy waves that might overpass absorption capacities of cities Improve infrastructure monitoring to anticipate problems related to extreme events such as floods and heat waves and quickly fix problems that may arise Develop smart models to predict demand and electricity supply to avoid blackouts in times of heat waves New specifications for bridges, according to maximum expected flow during floods or sea level rise and highest temperatures
	Alert and communication	Develop early warning systems to alert citizens in case a part of the infrastructure has been or expected to be severely damaged Regularly conduct awareness raising campaigns to increase people's awareness and advise them on how to save water and use the electricity efficiently
	Technical measures	Develop efficient and sustainable drainage systems Establishment of underground water reservoirs Building desalination plants based on the best available technologies Establish or upgrade flood defence systems near affected facilities

Sector	Actions	
Buildings management	**Strategic actions**	Modify the building codes to promote more energy efficient and heat tolerant structures Set up incentives for innovative climate friendly buildings Develop integrated land use planning with zoning system depending on different areas
	Technical measures	Go towards greening the infrastructure such as developing building's roofs and walls and cover them with plants to increase the amount of shade and refresh the environment and generate a cooling effect on the environment Develop green areas in the city by planting trees and setting fountains to help reduce the heat island effect
Economy	**Strategic actions**	Elaboration of drought, water and ground water management Plan
	Alert and communication	Educate tourists and citizens on personnel on ways to conserve natural resources, especially during extreme weather events
	Technical measures	Utilisation of drip irrigation practices Promote the use of renewable energy technologies
Biodiversity	**Strategic measures**	Establish a fire management plan Elaborate an integrated coastal management plan
	Technical measures	Improve or develop beach nourishment or replenishment ([163])

Source: JRC own elaboration.

5.4 Elaboration of the plan: Access to energy actions

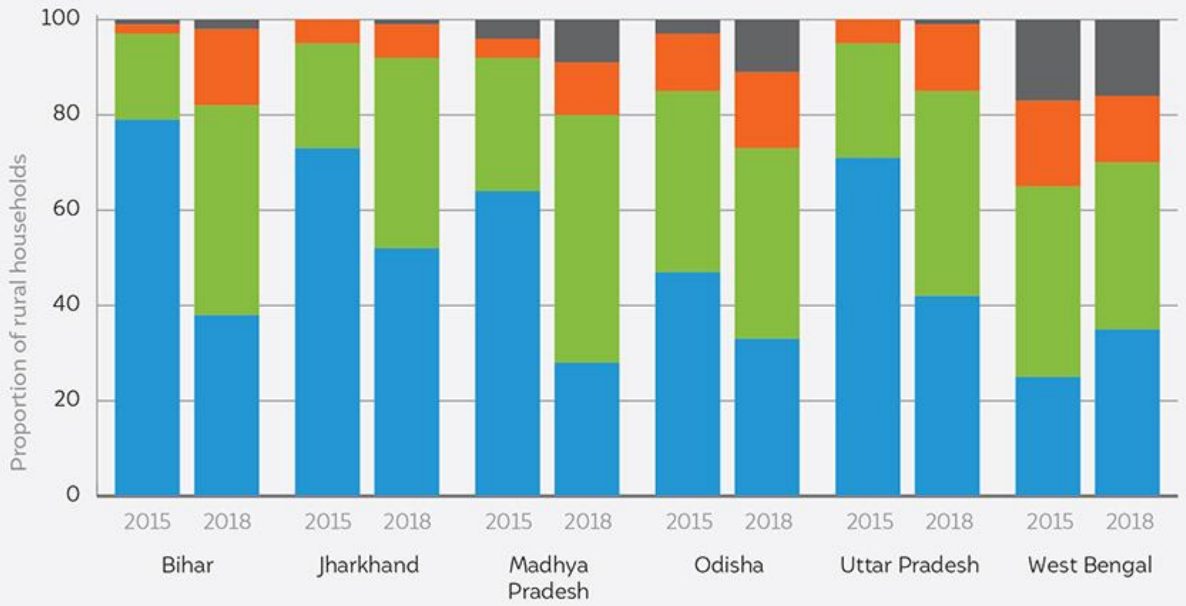
The Access to Clean Cooking Energy and Electricity – Survey of States (ACCESS) is India's largest multidimensional survey on energy access. The largest panel-data on energy access in India, the survey is conducted across six of the major energy-access-deprived states in the country – Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal. The 2018 study conducted by CEEW, with support from the Shakti Sustainable Energy Foundation (SSEF) and the Lee Kuan Yew School of Public Policy (National University of Singapore), covered more than 9,000 households from 756 villages in 54 districts collecting about 2.5 million data points.

The results from the first round of the study, ACCESS 2015, highlighted the need to look beyond connections to enable rural India's access to modern forms of energy **(Figure 27)**. In 2018, we revisited the households to understand the changes in their energy access situation over the last three years, and to study the impact of government policies during this period.

The study analyses energy access for households using a multidimensional, multi-tier framework. Households are assigned tiers on the basis of their level of access to energy. Tier 0 indicates the lowest level of access and Tier 3, the highest ([164]).

([163]) Artificial placement of sand on eroded shore to maintain the amount of sand in the foundation of the coast. Beach nourishment also often aims at maintaining beaches (beach width for tourism and recreational purposes).
([164]) https://www.ceew.in/publications/access-clean-cooking-energy-and-electricity

Figure 27: Distribution of households across electricity access tiers across states



	Bihar 2015	Bihar 2018	Jharkhand 2015	Jharkhand 2018	Madhya Pradesh 2015	Madhya Pradesh 2018	Odisha 2015	Odisha 2018	Uttar Pradesh 2015	Uttar Pradesh 2018	West Bengal 2015	West Bengal 2018
Tier 3	1%	3%	0%	1%	4%	9%	3%	12%	0%	1%	16%	17%
Tier 2	2%	16%	5%	7%	4%	11%	12%	16%	4%	14%	18%	14%
Tier 1	18%	44%	22%	40%	28%	52%	38%	40%	24%	43%	40%	35%
Tier 0	79%	38%	73%	52%	64%	28%	47%	33%	71%	42%	25%	35%

Source: CEEW analysis, 2018

Energy is a key input for meeting basic needs and for achieving socio-economic development goals: access to energy, fuel for cooking, heating and lighting in households, power for industry, agriculture, and petroleum products for transportation.

Energy access is linked to other basic services such as water and sanitation The use of energy, the types of energy used and the lack of access to sufficient energy have far reaching implications for a city's economic development, its environmental health and for the poor. Access to energy is one of the factors that bring together human development, economic growth and sustainability. Living without energy has impacts on a wide range of development indicators, including health, education, food security, gender equality, livelihoods, and poverty reduction.

5.4.1 Energy challenges faced by cities

Local Governments in cities need to be prepared to deal with several energy challenges:

- how to meet increasing demand for energy services caused by high population growth and rapid urbanisation, while addressing inadequate supply and system inefficiencies;
- how to increase access to clean, affordable, and reliable energy; in a model of development that slows the growth of carbon emissions and that is not fossil fuel dependant.

The growing urban population will need access to energy. The challenge for municipal authorities is to make sure that this energy use is as sustainable as possible. Because defining a local strategy to address energy poverty and provide modern energy services coherent with sustainable development, will not only promote local economic development and enhance resiliency (Batchelor et al., 2017) but it will also save money for cities, business and households. And not just that, it would:

- Reduce global warming emissions.
- Improve energy security, by increasing the share of domestically available alternative or renewable energy sources.

- Stimulate household welfare: poor households often have limited access to modern, safe, clean energy sources such as electricity, or cannot afford them even when they are available. This leads to continued dependence on polluting and unsafe fuels such as paraffin, coal or wood.
- Promote equity: the poor often are burdened with inadequate, unsafe and inconvenient energy sources while wealthier, particularly urban people consume high levels of energy and are inefficient in their use of energy.
- Local environment /local air quality: In addition to local (indoor/outdoor) air quality, the use of traditional biomass impacts the local environment. High demand from urban centres coupled with unregulated charcoal industries result in deforestation lowers the resilience of communities to cope with natural disasters such as flooding.
- Improve financial efficiency: Current inefficient energy use patterns mean that countries, cities and people have to spend more money than necessary for the energy service required (e.g. cooking, lighting, water heating etc.). Many more efficient and cost-effective appliances and practices are available, including modern energy cookstoves, efficient lighting, using solar water heaters and constructing buildings in a way that reduce the use of energy for cooling and lighting.

5.4.1.1 *The energy-poor*

Energy-poor households suffer from a wide range of impacts, from increased risk of premature death due to indoor pollution to forgone productivity gains and lower quality of life. On top of these impacts, energy-poor households must spend a greater proportion of their income to meet their basic energy needs. They also spend more time engaging in energy-intensive tasks than do wealthier households who have access to modern energy sources (Morrissey, 2017).

Energy poverty poses at least three requirements of the actors, institutions and processes of energy governance: access, affordability, and quality (Bazilian et al., 2014).

a) Access: First, governance arrangements must ensure access in a physical sense for poor people (who may have limited consumption needs,and live in relatively remote areas) to meet their needs for cooking, lighting, entertainment or use of information technology, and potentially other services. Different technologies or fuels may be needed to deliver each of these services.

b) Second, access to energy means little if people cannot afford it. Affordability may be ensured through institutions that assess the ability of poor consumers to pay for energy services and tailor pricing to their circumstances in the context of ensuring the viability of the system as a whole, or by enabling access to finance to enable people to invest in energy service technologies (for example finance for solar water heaters through bill repayments, lease and use access to renewable energy systems).

c) Third, these arrangements should ensure acceptable quality of service, including adequacy, reliability, and safety. A final cross cutting consideration is environmental sustainability, for example air quality. A recent analysis of the institutional complexes that govern climate, energy and development found that “decisions affecting the nexus have often been made in an uncoordinated manner within each of the domains”.

5.4.2 Role of local authorities

5.4.2.1 *Local authorities key players*

Energy in the city is essential for almost every activity and function in urban areas: cooking, cooling, heating water, industry, offices, lighting, communication and entertainment, transportation, construction, housing (SEA, 2017). Local authorities have a big influence within their boundaries over current and future energy use patterns through building regulations, urban layout, transport planning, bylaws, standards & codes, air quality control measures and electrification.

Cities will be instrumental in achieving national energy targets. Local authorities can serve as a vehicle to implement top-down policies from national governments, deliver meaningful results, and ensure national mandates are carried out. They can design solutions to climate change that are adapted to the needs of local constituents and are consistent with local policy priorities. Most countries have published some form of national energy plan, and most have introduced some kinds of renewable energy policy, but they do not include binding targets. A number of governments have introduced various policy and finance mechanisms to help reach targets, such as tax reductions. However, support is not yet available at a local government level (Batchelor et al., 2017).

It is the responsibility of leaders in all spheres of government, commerce, industry and civil society to promote action towards more efficient and renewable energy use.

5.4.2.2 *Integrating energy and physical planning:*

LAs are not in charge of the energy distribution networks management. For electricity, this is the responsibility of the national agencies and companies under the supervision of a National Ministry. However, LAs have a significant role to play with national authorities to integrate and articulate physical and energy planning. Indeed, for example, every new constructed area will generate an additional need for energy with two potential solutions: connection to the grid or renewable based off-grid. To be efficient in the decision-making process, it is important to work hand in hand to integrate energy and physical planning.

India's target of 175 GW RE can be integrated at a national level without major storage needs, but even this will involve more transmission across longer distances. The real challenge comes after, when RE grows far higher. The 175 GW target is mostly one that relies on low-hanging fruit of variable RE. Further scaling, towards deep decarbonising of India's electricity system, is a hard task, and one that will require a host of technical, policy, and regulatory improvements spanning storage, time of day pricing, and flexibility of both operations and of power purchase agreements.

5.4.2.3 *Institutions, policies, and regulatory frameworks*

In the context of the energy sector, "energy governance" refers to the actors, institutions and processes that shape how decisions are made about how to provide energy services. It involves the actors connected to energy such as governments, NGOs, civil society groups, corporations, citizens, and public-private partnerships (PPPs), as well as the institutions or rules according to which decisions are made and the processes of agenda-setting, negotiation, implementation, monitoring and enforcement of rules related to energy (Sovacool and Florini, 2012).

The energy field is a particularly complex issue when compared with other sectors not allowing for simple governance, cooperation or regulation. Problems and externalities which transcend the jurisdiction of national government, limit their ability to address these issues unilaterally (Sovacool and Florini, 2012). Cascading down these administrative powers to local governments might create situations and challenges difficult to be addressed solely by municipal authorities.

Joint Electricity Regulatory Commission (JERC)/State Electricity Regulatory Commissions (SERC) of 29 States/UTs namely Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Meghalaya, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal, Andaman & Nicobar and Lakshadweep Islands, Chandigarh, Dadra & Nagar Haveli, Daman & Diu, Delhi and Pondicherry have notified regulations/tariff order for grid connected solar rooftop projects.

5.4.3 Actions

Departmentalisation within local government often means that cities do not have a complete understanding of energy use, energy issues and energy initiatives within its boundaries. This is best gathered and understood in order to inform longer term energy planning (Batchelor et al., 2017).

- *Develop a State of Energy Report.* This summarises current energy use, energy supply and key energy issues in a city. This can be used for discussion among colleagues, to help them understand the role of energy in the municipality.
- *Develop a Sustainable Energy Strategy.* This will coordinate energy planning with an overarching city energy vision and set realistic renewable and energy efficiency targets based on current data.
- *Develop an Action Plan.* This maps out how the targets are going to be achieved and explores the technical opportunities for addressing energy poverty, as well as the policy challenges involved in promoting and deploying these technologies.

Box 34. Recommendations for household energy access

— Align and coordinate government plans and policies

— Strengthen city level information and data systems

— Review and rethink how policies are implemented

— Engage communities and civil society

5.4.3.1 *Access to electricity*

In the policy environment surrounding energy access, a major focus has been put on providing access to electricity, and recent changes in the price of renewable energy technologies have sparked debate about the best way to do so. Different approaches include the following technologies (Morrissey, 2017):

Large-scale grids: Expanding the central electrical grid is the most established approach to provide access to electricity.

Mini-grids: Mini-grids are still capable of supplying electricity in quantities that can match the services supplied by the grid. However, the current cost of renewable components and battery storage might negatively impact the cost of electricity when compared to the grid. In addition, although the up-front costs of mini-grids are lower than grid expansion, they are still high compared with the incomes of local entrepreneurs - who might be expected to finance and run such grids.

Solar home systems (SHSs): SHSs can supply electricity to isolated households that are too dispersed to be connected through mini grids. However, SHSs suffer from limited capacity, which is sufficient only for lighting, information and communication technologies (ICTs), entertainment, and cooling. In addition, electricity from SHSs is more expensive than electricity from both the grid and mini-grids. Although SHSs can provide households with basic quantities of electricity, they can also suffer from regulatory issues and be compromised in conditions where thefts of solar panels are a problem and where demand on the system grows rapidly. Due to high irradiation potential, the falling cost of solar photovoltaic, the speed of roll-out, and the limited capital investment required (compared to grid connections), SHS may be attractive solutions in sparsely populated rural areas of India. Even low levels of electrification, especially solar lamps, can bring substantial economic and noneconomic benefits.

Solar appliances: Solar appliances provide electrification on an even smaller scale than SHSs and therefore result in the lowest up-front cost, but also the highest cost of electricity of all the technologies mentioned here. Nonetheless, given the high value placed on electrical energy for lighting, electronics, and cooling, solar appliances have been observed to generate rapid transitions in household energy economies.

Table 45 summarizes the relative strengths and challenges associated with electricity technologies.

Box 35. Renewable energy, empowering people

Ashray Nagar slum on the outskirts of Bangalore is a mix of poverty and modernism. Most huts here have no attached toilet or running water, but solar panels of all sizes appear on their rooftops.

Such contradictory scenes aren't rare across India. In the northern state of Bihar, small businesses charge their mobile phones with electricity generated from rice husk gasification. In farmlands here in south India, villagers harvest wind power to pump groundwater for irrigation.

India is doing something important to empower the poor with renewable energy. Right now more than 1 billion people in the world live without electricity. But experts say that as the world's poorest people climb the income ladder, their demand for modern power and other comforts will further stress global energy supply while boosting greenhouse gas emissions. India, which has an unelectrified population almost equivalent to the total population of the United States, is becoming a global laboratory where such challenges are being resolved.

Table 45. Electricity technologies, strengths and challenges.

	Key features	Strengths	Challenges
Expanding the grid	Success in providing electricity to population around the world. Advantage of economies of scale. Large role for the state.	Can sell electricity at low cost. Can provide large quantities of electricity. Essential for increasing overall penetration of renewables.	Very expensive to build State bureaucracy and unresponsiveness. Currently heavily reliant on fossil fuels.
Mini-grid	Very limited economies of scale. Future reductions in price of storage.	Very large scope for renewables. Can provide large quantities of electricity. Lower capital costs. Quick to deploy. Some role for the private sector.	Possible lack of supply chains and relevant skilled personnel. Challenges to new technology.
SHSs	No economies of scale.	Large role for private sector 100% renewable. Established technology.	Expensive electricity Limited quantities of electricity. Adaptation to new technologies, from social and cultural point of view.
Solar appliances	No economies of scale.	100% renewable. Large role for the private sector. Potential to drive rapid changes in household fuel use.	Very limited quantities of electricity. Electricity very expensive. Difficult to exercise quality control over different appliances.

Source: (Morrissey, 2017)

5.4.3.2 *Renewable energies*

Cities must target specific renewable energy resource that best suits their conditions. For example, solar PV systems suit cities in lower-latitude, high sunshine regions; geothermal power suits cities located near the tectonic plates; and bioenergy is most common in areas with a forest industry nearby. Cities with such a prime resource often try and develop, or attract, business ventures and investments relating directly to it.

These commonly include waste-to-energy combined heat and power (CHP) plants, geothermal heat systems, solar thermal collectors on roofs and building integrated solar PV systems. Other forms of renewable energy carriers such as wind power, hydro power, concentrating solar power, solid biomass and liquid biofuels, usually need to be purchased from outside of the city and brought in by transmission lines, pipelines, road, rail or boats.

Given the key role of PV technology in future energy systems strategies are needed for dealing with large future volumes of end-of-life PV panels. Reuse and recycling technology is available today although the short-term lack of waste volume means that economies of scale often can't be realised. Likewise, the end-of-life management of batteries in the off-grid solar sector creates new related challenges (Annex 6 and Annex 7).

5.4.3.2.1 Policy recommendations for local governments for improving access to electricity and scale up renewable energies (IEA, 2009):

- *Consumer centred policies*: too often, energy access planning is addressed exclusively from techno-economic perspectives, without seriously questioning the ways in which those services are perceived, used, and paid for by consumers. But, to serve these populations well, it requires an understanding of ability to pay, willingness to pay, the value of unserved energy, and how consumers value different attributes of energy service. In short, successful energy access measures require consumer-centred policies and business models (Morrissey, 2017).

- *Planning should focus on the energy services provided*: requires a shift from top-down to bottom-up planning of the electricity system.

- *Governance should involve stakeholders from multiple sectors*, not just energy, as well as local authorities. An integrated framework for electricity access relies on a strong enabling environment, a solid supply of products and services, and a robust demand for these products and services.

- Regardless of size, a city should undertake policy development to support *renewable energy deployment in association with other policies*, including national policies linked to sustainability goals and climate change, and local policies relating to energy security, energy access, health, employment, equity and reducing energy demands. Policies that are not directly energy-related, but could influence renewable energy uptake, can have direct or indirect impacts.

- *Enabling environment with the right policies, institutions, strategic planning, regulations, and incentives is imperative for achieving universal access.* When addressing energy issues, municipalities can be either constrained or empowered in what they can achieve by national policy instruments. For example, if a building act has building codes that specify energy efficiency standards, then authorities can use that as a means to improve the energy performance of new building stock. For example, a review of energy related policy instruments in 46 Sub-Saharan African countries showed that 63% had some kind of national energy policy in place, and 48% even had some kind of instrument specifically relating to renewable energy (sometimes these were technology specific e.g. solar, biogas) (Batchelor et al., 2017).

- *An assessment of available energy resources*, together with analyses of future energy demands and costs of alternative supplies to meet heating, cooling, electricity and transport demands, should be undertaken prior to promoting the use of renewable energy. The assessment should include the potential for renewable energy projects based around water supply, wastes, and land managed by the local authority.

- The *evolution of decentralised energy* systems will vary with the location, existing energy infrastructure, renewable energy resources available, and energy business ownership status. Local governments could take a lead role by developing policies that will help support the transition of the conventional energy sector to a less centralised system.

- *Setting priorities:* based on prior assessment and knowledge of the local circumstances, considering that resources are limited, LA would define their own priorities, targets and actions. Energy services for healthcare, for schools or clean water access; discover where services are falling short will highlight where priorities should focus.

- *Development of renewable energy deployment policies should be undertaken in association with energy efficiency measures.* In most countries, leading cities have attempted to reduce their energy demand through improved efficiency and energy management incentives, and this has been recognised as a key policy priority. Putting parallel policies in place to support the use of renewable energy by the local community usually makes good sense.

5.4.3.3 *Clean cooking fuels and technologies*

Box 36. Clean cooking campaign in Gujarat

The Clean Cooking Alliance (the "Alliance") and Tata Trusts, in association with Chef Sanjeev Kapoor and the Self-Employed Women's Association (SEWA), rolled out a behavior change communications campaign in Rasnol village, Anand District, Gujarat. A joint effort by the Alliance, Shell, Tata Trusts, McCann Health, Sambodhi Research, Nexleaf Analytics, SEWA, and Dharma Life, the six-month campaign will aim to reach thousands of households across two districts each in Gujarat and Uttar Pradesh. The goal of the campaign is to influence consumer purchasing decisions and encourage the consistent use of cleaner, more modern stoves and fuels, such as Liquified Petroleum Gas (LPG), improved cookstoves, and induction cooktops.

The campaign will engage people at the district, village, and household levels through a variety of evidence-based communications strategies, including cooking competitions, street theater, door-to-door household interactions, informational videos aired through mobile movie theaters, and close collaboration with village and district leaders. In addition, campaign organizers will distribute bangles that can detect carbon monoxide and emit audio and visual warnings when the wearer is exposed to harmful emissions. Research will be conducted to understand the impacts of this campaign, and to identify the most effective tools.

www.CleanCookingAlliance.org.

Table 46. Clean cooking fuels and technologies.

Clean Fuel Intervention	Description	Potential scope
Liquefied Petroleum Gas (LPG)	A bottled gas containing mainly propane and butane, among the most effective and available large-scale alternatives to solid fuels. Requires an LPG stove connected to a LPG cylinder (different sizes available) through a hose and a regulator. A distribution infrastructure should be in place to ensure fuel supply.	LPG is already a fuel largely used in urban middle-income households of most LMICs for all or most cooking tasks and increasingly represents a likely alternative for less advantaged households in a number of areas with emergent supply and infrastructure.
Biogas	A combustible gas (mainly methane) produced by anaerobic digestion of organic materials such as animal wastes and, to a lesser extent, agricultural residues and human excrement. Biogas is not a universal fuel, as its potential is largely restricted to rural households owning a sufficient number of livestock and being located within a certain temperature and altitude range to ensure adequate gas production.	Construction and installation of biogas plants is usually expensive, and requires some form of financial support even among high and middle-income rural households. Proper operation and maintenance of the plant is crucial for ensuring biogas production.

Clean Fuel Intervention	Description	Potential scope
Solar cooking	Emission free solar stoves convert solar radiation into energy used for cooking.	Although the actual energy source is free, the use of solar energy for cooking is restricted to countries and settings with high levels of solar radiation, and needs to allow for day-to-day and seasonal variation. These considerations, and the need to plan for use around the middle part of the day, limit the opportunities for widespread promotion.
Alcohol fuels	Ethanol (bio-ethanol) is a high-viscosity liquid produced by sugar fermentation from a variety of feedstocks including sugar-, starch- and cellulose-containing materials. Ethanol is a renewable fuel.	Ethanol: The low cost and availability of raw material for ethanol production make it a competitive fuel in a number of countries, although land competition with agricultural production may present a challenge, as well as taxation related to the use of alcohol for beverages.
	Methanol is a fossil fuel produced by natural gas or oil products at a production cost usually lower than for ethanol. Methanol is toxic to humans and should be handled carefully. Its use in the cooking sector is limited to feasibility studies.	Methanol: Potential for methanol for the domestic cooking market may be greater in countries with natural gas supplies.

Source: (Puzzolo et al., 2016)

- *Increase support for clean cooking solutions*, while maintaining momentum for intermediate and basic ICS technologies where cleaner alternatives are not feasible in the near term.
- Design interventions to drive *consumer behavior change*; simply distributing cleaner cooking solutions and fuels will not lead to optimal health and environmental outcomes. The challenge of achieving the benefits of universal clean cooking in India is not simply one of technology and economics. Like water and sanitation programs and other public health initiatives, clean cooking solution promotion efforts can achieve health impact objectives only when accompanied by large-scale behavior change in the target end-user population.
- *Prioritize market-based approaches*, but also deploy direct subsidies linked to health and climate impacts. Market-led models should be emphasized wherever feasible to ensure sustainability. However, maximizing climate and health benefits might also require targeted subsidies delivered through carbon markets and focused “pull” mechanisms (e.g., results-based credits for health benefits).
- *Support sustainable production of clean-biomass and renewable fuel alternatives* alongside efforts to improve stove efficiency and reduce emissions. Given rapidly rising demand, more efficient cooking solutions alone will not be enough if the sustainability issues in Indian wood fuel value chains remain unaddressed.
- Focus *on providing critical public goods* to accelerate the development of the clean cooking sector. Policy makers should emphasize consumer education, access to finance, funding for R&D, the expansion of standards and testing, and enabling fiscal and trade reforms (e.g., tax, tariff, and subsidy reform).

5.4.3.4 *Energy efficient lighting and appliances*

India is improving the efficiency of its equipment and appliances through energy efficiency standards and labels, market-based programmes including bulk procurement models, and for the manufacture of efficient appliances. Efficient use is promoted through regular awareness-raising campaigns, such as the recent campaign on setting air conditioners at 24°C.

The BEE initiated an energy efficiency standards and labelling programme for equipment and appliances in 2006. The scheme covers 23 types of appliances and equipment, of which 10 are mandatory ([165]) and 13 are voluntary([166]). The requirements are periodically updated. The labels consist of 1-5 stars where 5 stars is the most efficient and 1 star corresponds to the mandatory energy performance requirement. The BEE has developed a mobile application to help consumers make energy-efficient purchasing decisions (www.beestarlabel.com/Home/MobileApp) and an online platform including an online product registry (www.beestarlabel.com). The BEE regularly conducts training for retailers and other stakeholders. Companies that produce non-compliant products are publicly named. According to a recent study conducted by the BEE, the programme resulted in savings of 40.46 TWh (excluding LEDs) in 2017 and in 18.7 TWh in the year 2018/19 (BEE, 2019d).

The Super-Efficient Equipment Programme (SEEP) was initiated by the BEE in 2013 with the aim of leapfrogging to an efficiency level of about 50% higher than market average. It provided a time-bound incentive to manufacturers to produce super-efficient equipment and sell it at a discounted price. The programme initially focused on ceiling fans.

India has achieved impressive results through bulk purchasing programmes. The Unnati Jyoti by Affordable LEDs for ALL (UJALA) programme has radically pushed down the price of LEDs available in the market globally and helped to create local manufacturing jobs to meet the demand for energy-efficient lighting. LEDs now cost less than INR 60 (1 USD). EESL has helped replace over 350 million lamps with LEDs, resulting in 45.5 TWh annual savings. The success of this procurement model is being replicated across different product categories. To date more than 2.2 million efficient fans have been deployed saving 0.2 TWh per year and 6.9 tubelights saving 0.3 TWh per year (MoP and EESL, 2019).

In 2017, in the first procurement round of air conditioners, the lowest-price bidder offered high-efficiency five-star air conditioners that can save 30-40% on a cooling electricity bill at a cost only slightly higher than that of the cheapest air conditioners on the market. Prices are expected to fall further as more air conditioners are procured and product manufacturers exploit the economies of scale that bulk procurement can induce. EESL's Super-Efficient Air Conditioning programme allows consumers to buy a super-efficient Air conditioners at prices that are comparable to the most energy-efficient ACs in the market, but reduce the cost of cooling by 50%.

In 2018 India had around 36 million air conditioners and by 2050 it is expected to have in the region of 1 billion (or 1 144 million units). Without major improvements in air conditioner energy efficiency, electricity demand for space cooling in buildings in India looks set to increase to nearly 1 350 TWh in 2050 and require an additional 800 GW of power generation capacity just to meet space cooling needs. About 70% of that growth is assumed to come from the residential sector (IEA, 2018c). Policies to improve the energy efficiency of air conditioners could by 2050:([167])

- Reduce cooling electricity demand by 45%.
- Deliver more than 8 000 TWh of cumulative electricity savings.
- Save USD 295 billion in cumulative power generation investments. Reduce average per capita electricity costs for cooling by a third (IEA, 2018c).

([165]) Frost-free refrigerators, direct cool refrigerators, tubular fluorescent lamps, fixed-speed room air conditioners, variable capacity inverter air conditioners, room air conditioners (cassettes, floor-standing), electric geysers, colour televisions, distribution transformers, light-emitting diode (LED) lamps.

([166]) Induction motors, agricultural pump sets, ceiling fans, domestic LPG stoves, washing machines, computers (notebooks, laptops), electric and magnetic ballast, office equipment (printer, copier, scanner, multi-function device), diesel engine-driven mono-set pumps for agriculture, solid-state inverters, diesel generators, chillers, microwave ovens.

([167]) According to the IEA Efficient Cooling Scenario as compared to the Baseline Scenario in IEA (2018c).

By combining efficient air conditioners with building envelope measures, cooling energy demand could be cut by another 35% by 2050 (IEA, 2018c). In India, stronger requirements for air conditioners came into effect in January 2018, which will push the Indian market to greater levels of efficiency.([168]) *Source:* (CLASP, 2018).

Box 37. BEE Star Labelled Appliances

Bureau of Energy Efficiency of Government of India provides Energy 'labeling' which is one of the most costeffective policy tools for improving energy efficiency and lowering energy cost of appliances/equipment for the consumers. The program has been developed in a collaborative and consensus driven approach with active participation from all the stakeholders.

What is Standards?

Prescribe limits on the energy consumption (or minimum levels of the energy efficiency) of manufactured products.

What is Labels?

Describes energy performance (in the form of energy use, efficiency or energy cost). "Labels" mainly give consumers the necessary information to make informed purchase. There are two types of labels:

'Comparative Label' Allow consumers to compare the energy consumption of similar products, and factor lifetime running cost into their purchasing decision.

'Endorsement Label' Provide a 'certification' to inform prospective purchasers that the product is highly energy efficient for its category.

Standards and Labels in India works on a model in which the permittee provides information related to energy efficiency of the product on the label as prescribed in the respective product regulation, statutory order and/or schedule issued by the Bureau from time to time. A star rating, ranging from 1 to 5 in the ascending order of energy efficiency is provided to products registered with the Bureau. An endorsement label is also provided for some products.

For the labelling program, the Bureau works through technical committees of experts and stakeholders, comprising of representatives from industry, industry association, consumer organizations, academia, on-Government Organizations (NGOs), Research &Development (R&D) institutions, testing laboratories, government organizations and regulatory bodies etc.

5.4.3.5 *Partnership and awareness campaigns*

Support from citizens and local businesses for the greater deployment of renewable energy technologies and promoting energy access is essential, based on a good understanding of the issues. The personal benefits that would result for individuals and businesses need to be identified and disseminated. Leaders can motivate residents, offer them enhanced pride in their community as a result of being an early adaptor, as well as provide them with greater energy independence, energy security, employment and social cohesion. Strong leadership based on clear objectives is essential (See also chapter 5.2).

Table 47 shows examples from State Climate Change Action Plan for raising an individual awareness.

Table 47. What can I do to contribute? Raise awareness

Individual	Ride bicycle instead of motorized vehicle; Reduce, Reuse, Recycle; Take the bus; Plant a tree; Use train service.

([168]) IEA India 2020 Energy Policy Review

Household	Use solar energy; Switch off power when not in use; Make compost from food/ organic waste; Harvest rainwater; Plant trees; Plant greens around the home; Recycle and reuse waste.
Institutions (schools, hospitals, government, donors)	Grow green for students meals; Segregate and reuse waste; Use energy efficient cookstoves or briquettes instead of firework; Harvest rainwater; Conduct energy audit; Develop biogas system to reduce energy costs; Allocate funds to climate smart projects; Promote shared transport systems for staff; Train staff in sustainable daily practices; Support public awareness campaigns; Set up climate smart policies.
Corporates (big and small business)	Promote staff awareness; Develop climate smart policies; Use energy efficient cookstoves or briquettes instead of firewood; Use energy efficient equipment; Take your waste to others who can reuse it; Conduct energy audit; Support the green economy.
Groups (Communities, religious cultural leaders, associations)	Hold dialogues to answer questions and solutions; Raise awareness; Advise people on why they need to take action now; Collect data on climate smart actions in your area; Do recycling projects, get your friends to join inl Support local actions e.g.: cleaning; Harvest rainwater; Support local actions e.g.; planting trees; Compost organic waste to set up community garden.

Source: (State Climate Change Action Plan)

6 Implementation

The implementation phase takes the longest time, the most efforts and the largest portion of financial resources. It requires the involvement of all stakeholders, including national authorities, industry and citizens. Whether a thoughtful, effective CAP is successfully implemented, largely depends on the human factor. Staff involved in CAP implementation needs to be empowered with clear responsibilities, sufficient resources and good communications. Shortcomings and mistakes should be considered as chances to learn, improve and expedite results. Local authorities should consider pilot and/or demonstration projects to test innovative ideas on a small scale.

Furthermore, during the implementation phase, it will be essential to ensure good internal and external communication between the different departments of the local authority, the associated public authorities and all the persons involved as well as with citizens and stakeholders. This will contribute to awareness-raising, increase the knowledge about the issues, induce changes in behaviour, and ensure wide support for the whole process of CAP implementation.

Monitoring and communicating progress on energy and CO_2 emissions reductions as well as climate vulnerability/risk reduction and increasing access to energy should always be integral components of CAP implementation. The local authority should decide on key indicators on mitigation, adaptation and access to energy for monitoring progress (see section 7) (such as percentage of compliance with deadlines, percentage of budget deviations, and percentage of emissions reduction with the actions already implemented and decisions already taken regarding adaptation and resilience).

Moreover, frequently informing the municipal corporation (or equivalent body) and other stakeholders is a good way to involve them in the success of the project. Similarly, networking with other signatories developing or implementing a CAP, will provide additional value towards meeting the targets by exchanging experience and best practices, and establishing synergies.

Box 38. Tips for putting the CAP into practice

— Adopt a Project Management approach: deadline control, financial control, planning, deviations analysis and risk management. Use a quality management procedure;

— Divide the project into different parts and select persons responsible;

— Strengthen horizontal cooperation between different policy-areas and mainstream climate actions into existing strategies;

— Prepare specific procedures and processes aimed at implementing each part of the project;

— Plan the follow-up with the stakeholders establishing a calendar of meetings in order to inform them;

— Anticipate future events and take into account negotiation and administrative steps to be followed by the Public Administration;

— Propose, approve and put into operation a training programme at least for those persons directly involved in the implementation;

— Motivate and offer training and support to the involved team.

7 Monitoring and reporting

Monitor the evolution and impacts of the actions included in the CAP and updating it regularly allows to ensure continuous improvement in the process. GCoM signatories must submit a progress report every second year following the submission of the CAP for evaluation and monitoring.

Box 39. Monitoring and reporting

— It is mandatory to:

— Submit monitoring reports every two years after submitting the action plan(s);

— Provide information about the implementation status of each action/action area/sector contained in the action plan;

— Update and resubmit the action plan(s) when there are significant changes to the existing plan(s).

— It is recommended to:

— Report the implementation cost for each action.

The reporting requirements include timelines for different elements of reporting. The following table (**Table 48**) shows the overall reporting time for the GCoM in India, coherent with GCoM recommendations (see all the recommendations of the GCoM Framework in 2). Year 0 corresponds to the year in which the local authority commits formally to join the initiative by signing the [commitment letter or replace with the correct term used in the region/country]. Starting from then, they will be asked to submit the first group of documents the latest two years after; while in year 3 they must submit the CAP. Currently, there are two official reporting platforms in the GCoM framework: MyCovenantand the CDP/ICLEI Unified Reporting System.

Table 48. Reporting elements and corresponding timelines for GCoM signatories.

Reporting element	YEAR	YEAR	YEAR	YEAR	YEAR	YEAR
Baseline Emissions Inventory			X			
Risk and vulnerability assessment			X			
Targets and goals (mitigation and adaptation)			X			
Access to Energy assessment			X			
Climate action plan(s) (mitigation and adaptation,				X		
Progress report						X*

* Every two years after submitting the CAP.
Source: JRC own elaboration.

Every four years, the progress reports should include an updated CO_2 emission inventory called a *Monitoring Emission Inventory* (MEI) developed according to the same methods and data sources of the BEI to ensure comparability. Ideally, local authorities compile CO_2 emissions inventories on an annual basis. If that frequency over-burdens human or financial resources, local authorities may carry out inventories after longer intervals and/or with simpler methodologies. Through the reporting, a deeper understanding of the results delivered by the CAP is provided and corrective and preventive measures can be defined if required.

8 Financing Sustainable Energy and Climate Action Plans

8.1 Initial Considerations

CAP(s) elaboration and implementation require tailored dedicated financing. The achievement of the sustainable targets often implies big investments at local and national level. To deliver such investments, local authorities face the challenge of accessing to finance. Moreover, LAs should take this challenge with holistic approaches in identifying both the kind of support required within the CAP process and available schemes and mechanisms. The need of financing support may arise for different stages of the CAP process: capacity buildings and trainings, technical and legal studies, feasibility assessments, assistance with financial studies for actions and their implementation. The C40 report (2018) (Moro et al., 2018) shows how the type of assistance needed by cities to advance in the implementation of climate related projects not only focuses on financial modelling and development of bankable projects. On the contrary, it ranges from capacity development activities (such as capacity building, best practices, finance training) to implementation (such as organisational structuring, risk management, operational study), from technical studies (impact assessment, socio-economic) to feasibility studies, from legal studies to financing studies and stakeholder engagement. These financing options are oriented at supporting capacity building of actors involved in the process, who will then be able to seek and apply for funding autonomously. Therefore, local authorities should at first identify at which stage of the process and for which activity they need financial support. Subsequently, available schemes, financial mechanisms and resources at the local, regional, national and international level should be defined. The role played by LAs is more important in the region due to the scarcity of resources, economic circumstances and high vulnerabilities faced in the territory. Therefore, efforts should be continuously made to find and to secure appropriate alternative sources of funding throughout elaboration and implementation.

A lack of bankable projects and difficulties matching such projects to appropriate sources of funding are limiting sustainable and climate resilient development of Indian cities.

IUC India has produced a Manual for Financing Sustainable and Climate Resilient Urban Development in India([169]) with the aim to develop an approach to identify and pursue viable financing mechanisms for sustainable and climate resilient projects in Indian cities. Successful implementation also requires firm, long-term funding commitments. Local authorities should identify the required economic resources to finance the actions planned in their CAP and the relative timeframes. Different and specific short-term, medium-term and long-term funding options are available for implementing the variety of actions planned. Scarcity of financial resource increases the possibility of opting for energy-efficiency projects with short paybacks, but with low reductions in energy consumption and CO_2 emissions or quick adaptation effect. This approach will not capture the real potential savings available through the implementation of the actions. As a consequence, the choice of the appropriate funding options in terms of both the timeframe and the required kind of support is of utmost importance for the successful implementation of the plan and for the achievement of the mitigation and adaptation targets. Moreover, when considering the costs of CAP actions, local authorities should keep in mind the co-benefits to health, quality of life, employment, attractiveness of the city, reduction of vulnerabilities etc. which have an associated financial value.

Multiple funding sources are needed to fund climate change responses in cities since available resources may not be sufficient. Local authorities' budget is only one component of the financing structure. Due to the great involvement of stakeholders, CAP implementation will also require a strong institutional coordination to ensuring coherent and effective budgeting. In this context, local authorities may have to take into consideration the role of private actors in developing climate related projects. CAP actions could be partially co-financed by the private sector and part of the projects may receive grants support.

Box 40. Key definitions

Funding: refers to how a project is paid for over time.

Financing: refers to how debt or equity is raised to pay for immediate capital investment.

([169]) https://iuc.eu/index.php?id=615

This section will attempt to describe the most common financing mechanisms and funding opportunities available to the GCoM signatories in India. Links and examples are provided as a general guidance to local authorities and stakeholders. However, due to their intrinsic diversity and the dissimilar economic situation, some options will be more suitable to some cities than others.

8.2 Challenges for local authorities

Numerous barriers impede the development and implementation of sustainable actions in cities. Local authorities may face a number of challenges when considering the implementation of the actions planned in their CAP. Some common barriers faced by Local Authorities when dealing with financing mechanisms and funding opportunities are listed below.

- Local Authorities lack knowledge of all the options of financing schemes available. There are existing initiatives that try to tackle this problem by providing comprehensive information about the different financing options available.
- Local Authorities financial autonomy. Frequently LAs lack knowledge regarding the share of tax revenues transferred to the local authority. This also extends to a lack of mandate and systems in place to facilitate financial autonomy.
- Absence of capacity to present projects that can be financed. Local Authorities do not possess the proper manpower, professional training and experience to choose the most suitable instrument, to prepare application for the funding, to make the project eligible. The access to financing instruments, especially non-grant instruments, for climate action is often challenged by the difficulty in demonstrating the 'bankability' of the planned investments. Moreover, time constraints seriously challenge local authorities in developing documents for submission. There are funding opportunities oriented to increase the technical skills on this aspect and to support in the preparation of applications and documents.
- Local Authorities may face political constraints before accessing climate finance. Political instability may lead to delays in prioritisation of actions to be financed and in the application for funds.
- Climate investments are often small or scattered to attract investors. Moreover, these programs are hardly designed to be financially viable and replicable. Options to aggregate small projects should be explored.
- Lack of trust impeding private sector investment. Private sector involvement could be fostered by transparency and clearly defined risks. In parallel, LAs show low or no trust in private sector, which ends up with a scarce private involvement in action planning and implementation.
- Weak institutions and legal frameworks and underdeveloped capital markets harm the access of LAs to long-term finance. Financial intermediaries, including national, regional and international development banks, can play an important role in promoting urban finance, basing upon the experience of developed countries.

8.3 Financing Mechanism

Investment projects in the area of climate and energy for cities show many similarities in principles and models with other (more traditional) investment projects. Understanding these aspects would be an important step for local authorities who will have to decide the most effective approach to implement the actions contained in their CAP(s). More advanced tools are available, and depending on the local context these mechanisms may have significant potential to finance actions. Moreover, through the development of tailored market mechanisms the private sector is more involved and incentivised to invest in the climate action. However, due to the complexity of these instruments, special consideration should be given in the planning and implementation phases, to avoid potential pitfalls with adverse effects on the local population. The paragraphs below describe frequent mechanisms that can be used to support key actions in cities.

8.3.1 Local Authorities' own financial resources

Municipal budget is a short-term funding option for local climate action. These resources may come from grants (national or external), local taxes (houses, business, income-producing sources), borrowing in terms of debt financing and loans. However, these last options are limited due to the lack of an adequate legal framework, difficulties for local authorities to be solvent and transparency issues. Green bonds and climate bonds are spreading among local authorities as a viable tool to sustain local climate projects. Municipal taxes can be used to support climate change action. Moreover, the big changes for African cities development call for the renewal of local taxation. Local authorities in India have the limited authority to determine characteristics of local taxes. Many of these are, on the contrary, determined at state level. In most cases, the state services do not have contractual relations with the local communities for which they are supposed to work. As a consequence, it is central to raise awareness of the importance of strengthening the financial autonomy of local authorities through local taxation. Improving fiscal decentralization and local autonomy strengthen the administrative capacity to face the most alarming challenges in various contexts ([170]).

8.3.2 Grant programs

Investment grants or interest rate subsidies are often provided by governments to support the upfront cost of energy efficiency projects that may entail too high investment costs and long amortisation periods. Investment subsidies increase the financial rate of return on investment, increasing investors' demand for investment. In addition, investment subsidies improve cash flow and thus increase investors' access to debt finance (Bertoldi et al., 2010).

Public grant programmes are used in order to support Energy Efficiency projects that contribute to energy and social policies and meet other public policy goals. The advantage of public grant programmes is that subsidies can be an important factor in raising the general awareness and trust in sustainable projects.

On the contrary, the great disadvantage is that in times of squeezed budgets, it is often difficult to put aside the necessary budget for subsidies to realise the policy goals. This often places subsidy programs in a stop-and-start operational mode, which may actually delay project implementation encouraging potential project proponents to wait for better grant conditions or for the next funding call (Bertoldi et al., 2010). Grants have the advantage of not requiring highly developed financial markets and are used for small scale projects, which have been identified as two of the main barriers for mitigation and adaptation actions implementation.

8.3.3 Soft loans

Soft loan schemes which offer below market rates and longer payback periods, and loan guarantees, which provides buffer by first losses of non-payment, are mechanisms whereby public funding facilitates/triggers investments in EPC. They give long-term financial coverage to help bridge the pre-commercialisation financing gap for EE projects by direct subsidies on interest payments, by risk premiums (e.g. an IFI or a state can guarantee a certain amount of loans), or by capital gains to a revolving fund. They are commonly used for energy efficiency measures. Loan conditions include:

- extended payback periods,
- low or zero interest rates,
- short-term interest deferral periods, and/or
- inclusion of payback grace periods ([171]).

8.3.4 Green Bonds

Bond markets can be a source of low-cost capital for cities and municipalities. Green bonds are bonds where revenues are allocated to "green" projects. In particular, these bonds have emerged as a financing tool for climate change mitigation and adaptation actions within cities ([172]). Local authorities have begun to emerge as strategic issuers of green bonds in the United States, Europe, and South Africa, as they represent a low-cost and long-term source of capital to finance climate mitigation and adaptation infrastructure requirements. A green municipal bond is a fixed-income financial instrument for raising capital through the debt capital market. As with any other bond, the bond issuer raises a fixed amount of capital from investors over an established period of time (the “maturity”), repays the capital (the “principal”) when the bond matures, and pays an agreed-upon amount of interest (“coupons”) during that time.

([170]) https://ukdiss.com/examples/decentralization-local-governance-india.php

([171]) Bertoldi, P. and Rezessy, S. (2010). Financing energy efficiency: forging the link between financing and project implementation. [online] Ispra: Joint Research Centre of the European Commission. Available at: http://www.konvencijazupanov.eu/IMG/pdf/Financing_energy_efficiency.pdf

([172]) How to Issue a Green Muni Bond - Climate Bonds Initiative. Available at: https://www.climatebonds.net/resources/publications/how-to-issue-a-green-muni-bond

Box 41. Green Bonds in India

In India, one of the fastest-growing green bonds market in Asia – the first half of 2019 had $10.3bn of green bond transactions, as per the Economic Survey 2019-20. As noted previously, green bonds are like any other bonds but whose proceeds have been earmarked for specific "green" i.e. climate-friendly projects or assets. There are three broad types of green bonds – organization-guaranteed bonds, asset-backed bonds, and hybrid bonds – based on the source of repayment for the lenders and the available recourse in case of a default.
To enhance the transparency and integrity of the green bonds market globally, there are a set of voluntary process guidelines – the Green Bond Principles (GBP) – issued by the International Capital Market Association ([173]).

https://greencleanguide.com/everything-you-need-to-know-about-green-bonds-in-india/

The key difference between a green bond and a regular bond is that the former is explicitly labelled as "green" by the issuer, and a commitment is made to use the proceeds of the green bond to exclusively finance or re-finance projects with an environmental benefit. Eligible projects include, but are not limited to, renewable energy, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, clean transportation, clean water, and various climate adaptation projects (Saha and d'Almedia, 2017).

8.3.5 Public-private partnerships (PPPs)

Governments have difficulties in meeting the demand for services and implementing climate projects by acting alone. As a consequence, cooperation between the local authority, local investors, and local citizens are deemed to be vital factors of success for realizing ambitious projects in the adaptation and mitigation framework. The public-private partnership (PPP) is one of such collaboration, based on the awareness that both the public and private sectors can benefit by combining their financial resources, know-how and expertise. PPPs are a concession mechanism whereby the local authority acquires financing from the private sector, with certain obligations. Numerous stakeholder groups have a legitimate interest in sustainable actions development. The leadership of local authorities usually have a crucial role in forging partnerships and pooling resources across the public and private sectors. When identifying all the stakeholders that might contribute to the partnership, their level of participation and potential conflicts of interest must be taken into account.

Effective cooperation between local government, businesses and the community is always difficult to achieve because of the wide range of participants involved, the low level of trust that often exists between potential partners and the lack of predictability in the process. The transparency in the process is determinant for successful PPP ([174]).

As an enabler, local authorities have the capacity to steer policies in support of niche innovations that are new to the market as well as technologies that offer multiple social benefits. For instance, public administration promotes the construction of a zero-emission swimming pool, or a district heating and cooling installation, by allowing a private company to run it revolving the profits on the initial investment. In India, the PPP route was established two decades ago. Now, with new government initiative the PPP has again come with better risk sharing matrix between private and public.

A regulation and legal frameworks within which stakeholders play the role are key elements that may ensure the quality and the success of the partnership. Moreover, this kind of contract should be flexible to cater for the needs of the private company (for example to extend the contract in case of unexpected payback delays). A frequent due diligence is also recommended in order to follow up the evolution of incomes ([175]). The Ministry of Finance of Government of India centralizes the coordination of PPPs, through its Department of Economic Affairs' (DEA) PPP Cell has established Indian PPP Toolkit([176]) to provide expert guidance, dependable counsel

([173]) https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/
([174]) UNDP. Public Private Partnership for urban environment. http://pppue.undp.2margraf.com/en/01_2.htm
([175]) Successful worldwide Public-Private Partnerships example can be found in the document "Public-Private Partnerships: Local Initiatives 2007" on www.theclimategroup.org/assets/resources/ppp_booklet.pdf
([176]) https://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/India_SolidWasteMgmt_PPP_Tookit-Volume-I_EN.pdf

and a compilation of best practices to assist Indian State legislatures as they consider whether and how to pursue PPPs in their States.

Box 42. PPP Toolkit

PPPUE is the global facility developed by developed by UNDP that developing countries use to obtain support in their efforts to define, promote and implement Public Private Partnerships to reduce poverty by increasing the access of the urban poor to basic services. The programme offers a flexible portfolio of demand driven services built on the basis of a strong partner network and results at the country level

The Tools for Pro Poor PPP at the local level are aimed at members of local level government, business and community organisations interested in an innovative approach to the problems of service delivery, especially to the poor. The toolkit has been developed as a working manual to be added to and modified as required by users to enhance its functionality. It has been prepared with the extensive involvement of people involved in PPPUE's projects and programmes around the world. These contributions have been invaluable and have served to ensure that the text presents a globally applicable entry point to PPPs while simultaneously remaining open to modification with locally appropriate contextual materials.

Source: http://pppue.undp.2margraf.com/en/05.htm

8.3.6 Revolving funds

Revolving funds are intended to establish sustainable financing for a set of investment projects. The fund may include loans or grants and have the ambition of becoming self-sustainable after its first capitalisation. The funds remain available to finance continuing operations, because they are replenished with the revenues earned. These funds are very important when liquidity is scarce. They can be established as a bank account of the owner or as a separate legal entity. The interest rate generally applied in the capitalisation of revolving funds is lower than the market one. Typically, several parties are involved and the owners can be public or private companies, organisations, institutions or authorities. The operator of the fund can either be its owner or an appointed authority. External donors and financiers provide contributions to the fund in the form of grants, subsidies, loans or other types of repayable contributions. The borrowers can either be the project owners or contractors. The advantage of revolving funds is that they are less dependent on external investors. If they are operated effectively, revolving fund can contribute to a permanent financing structure for energy efficiency investments, which is separate from political influence. A revolving fund can complement to an ESCO. In India, Water for Asian Cities (WAC) Programme, a collaborative initiative between UN-HABITAT and Asian Development Bank (ADB) is supporting the implementation of the water and sanitation related targets in Asian cities and promoting new/innovative investments in the urban water and sanitation sector. In India, WAC is supporting the four cities of Bhopal, Gwalior, Indore and Jabalpur in the state of Madhya Pradesh, India with the revolving fund financial support of ADB for the improvement and expansion of urban water and sanitation services ([177]).

8.3.7 Crowdfunding

Crowdfunding distinguishes itself from more traditional mechanisms, in which a small number of investors provide large sums of money to finance sustainable development projects. In crowdfunding, the approach is subverted. It is based on individuals' efforts to support other's initiatives or projects by investing small sums of money. The main channel to gather money is internet: projects seeking funding are displayed in an online accessible portal. Once the project reaches the funding target, it can be commissioned to provide returns to investors. Crowdfunding is at an a early stage, but it has potentials for supporting sustainable projects at the city level, since it is an easy to set-up mechanism and allows to overcome some of the most common finance-related barriers ([178]). In North America and Europe, crowdfunding has emerged as a promising alternative for entrepreneurial finance. Crowdfunding platforms are increasingly targeting the development and commercialization of clean technologies in developing countries. The Africa crowdfunding market is active

([177]) https://unhabitat.org/sites/default/files/2020/09/guidelines_on_revolving_funds_for_community.pdf
([178]) Ferrer Nuñez J. (2013).Financing Models for smart cities-Smart Cities stakeholder platform.

and growing. However, there is still room to leverage the full range of options for this financing tool. To increase the potential of success of crowdfunding campaigns, the choice of the platform, the level of commitment in the project and the support from business incubators may be taken into account ([179]). Beyond monetary gains, crowdfunding help to increase the visibility and transparency of a company, which in turn increases its perceived trustworthiness with customers, investors and partners. Equity-based Crowdfunding is not legal in India, whereas other types are legal. Crowdfunding is governed by SEBI (Securities and Exchange Board of India) in India ([180]).

8.3.8 Third-party financing

The third- party financing (TPF) is a mechanism that allows another party (as ESCOs) to provide the capital and take the financial risk. It is perhaps the easiest way for municipalities to undertake ambitious projects (such as comprehensive building energy retrofits). High financing costs may be expected to reflect the fact that the debt is registered on another entity's balance sheet. The interest rate is, however, only one factor among many that should be considered to determine the suitability of a third-party financing vehicle. In the region, almost all the countries have allowed for third party access (Bertoldi et al., 2010). Third party funding can be valuable in reducing litigation risk and exposure, if one has a strong case. Litigation funding cannot help in saving arbitration costs. The Supreme Court of India recently validated the concept of litigation funding.

8.4 Energy services companies (ESCOs)

Energy Service Companies (ESCOs) are one of the most well-defined third-party financing mechanisms for energy-related initiatives. ESCOs provide the opportunity to reduce greenhouse gas emissions through increased energy efficiency in a variety of sectors. ESCO remuneration is based on the amount of energy saved through the project, thereby the ESCO usually finances the energy-saving projects without any up-front investment costs for the local authority. The energy savings achieved during the contract period recovers the investment costs and pays a profit. The contract guarantees the local authority a certain energy savings and saves the city investment in an unknown field. Once the contract has expired, the city owns the efficient project.

In India Bureau of Energy Efficiency (BEE) does empanelment of ESCOs through a process of grading carried out by SEBI Accredited rating agencies CRISIL/ CARE Advisory Research & Training Ltd /ICRA Analytics Ltd. indicating capability in implementation of energy efficiency projects through performance contracting based on availability of technical manpower, financial strength, market position etc ([181]). Currently, 127 ESCOs are empanelled by BEE. The energy efficiency market in India is estimated to be worth INR 150,000 Crore equivalent to US$ 25 billion, out of which only 5% potential has been tapped by ESCOs so far. Accordingly, a significant Energy Efficiency potential is left untapped in India and ESCOs are supposed to be the main vehicle to harness this potential.

ESCOs often offer a performance "guarantee", which can take several forms. The guarantee can revolve around the actual flow of energy savings from a retrofit project. Alternatively, the guarantee can stipulate that the energy savings will be sufficient to repay monthly debt service costs. Measurements and verification of the energy savings are decisive for all the parts involved. Energy Performance Contracting (EPC) is a contractual arrangement between a beneficiary and an Energy Service Company about energy efficiency improvements or renewables installations. Normally an ESCO implements the measures and offers the know-how and monitoring during the whole term of the contract. Essentially the ESCO will not receive its payment unless the project delivers energy savings/production as expected (Bertoldi, Rezessy 2005).

8.5 Financing and funding opportunities

External funding is available and International Financing Institutions (IFIs) on sustainable projects are active in the region. Several multilateral funds are available in the region for both mitigation and adaptation projects ([182]).

([179]) The World Bank (2016). Climate Technology Program - In Brief n°1. Available at: www.infodev.org
([180]) https://www.sebi.gov.in/sebi_data/attachdocs/1403005615257.pdf
([181]) https://www.beeindia.gov.in/content/escos-0
([182]) Further insight can be found in IFI, 2018. www.ifc.org

Countries may access GCF resources through multiple entities simultaneously. The GCF overall aim is to reach a shift to low-emission and climate-resilient development, by taking into account the needs of nations that are particularly vulnerable to climate change impacts. The Fund allows the engagement of both the public and private sectors in transformational climate-sensitive investments. A guide on how to access the GCF (GCF 101) is available on the website (https://www.greenclimate.fund/gcf101).

An example for a DFI financed fund is the Climate Investment Funds (CIF). It is funded by the World Bank and the regional development banks, including the ADB, NABARD. The CIFs include a Clean Technology Fund (CTF) and a Strategic Climate Fund (SCF). The Clean Technology Fund promotes scaled-up financing for demonstration, deployment and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emissions savings.

Two examples of funds financed by multilateral donors are the Global Environment Facility Trust Fund (GEFTF) (https://www.thegef.org/) and the Global Energy Efficiency and Renewable Energy Fund (GEEREF) (https://geeref.com/). The GEFTF is one managed by the GEF aiming at helping emerging and developing countries to achieve the goals sets by the United Nations Framework Convention on Climate Change (UNFCCC) and supporting them in climate change mitigation and adaptation. The GEEREF is financed by the European Union, Germany and Norway. It works as a Public-Private Partnership (PPP) to support small and medium size enterprises (SMEs) that invest in energy efficiency and renewable energy.

The Adaptation Fund gives developing countries full ownership of adaptation projects, from planning through implementation, while ensuring monitoring and transparency at every step. The Fund was established under the Kyoto Protocol of the UN Framework Convention on Climate Change and is financed in part by government and private donors, and also from a two percent share of proceeds of Certified Emission Reductions (CERs) issued under the Protocol's Clean Development Mechanism projects.
The Adaptation Fund was established to finance concrete adaptation projects and programmes in developing countries that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is supervised and managed by the Adaptation Fund Board (AFB). The Adaptation Fund Board Secretariat provides research, advisory, administrative, and an array of other services to the Board. The World Bank serves as trustee of the Adaptation Fund on an interim basis.

AF-funded projects are implemented around the world through accredited National Implementing Entities, Multilateral Implementing Entities and Regional Implementing Entities. The Fund also has a growing Readiness Programme that provides capacity-building workshops, small technical assistance grants and south-to-south cooperation to facilitate accreditation of new implementing entities and reach more vulnerable communities with urgently needed climate adaptation solutions. All funding applicants must submit project proposals through a National Implementing Entity, a Regional Implementing Entity, or a Multilateral Implementing Entity. Proposals also require endorsement by the Designated Authorities of the country in which the proposed activities would take place. More information available at: https://www.adaptation-fund.org/about/.

India is taking an innovative approach to combatting climate change by establishing six small-scale Adaptation Fund projects on the ground in diverse regions of the country across a variety of adaptation sectors.

Developed through the Fund's national implementing entity in India, the National Bank for Agriculture and Rural Development (NABARD), and implemented together with local organizations, projects are taking place from the north-western Himalayas, to the central Madhya Pradesh region, to the eastern region, to Rajasthan in the west and the eastern and southern coasts. They are tackling sectors tailored to the local adaptation need, from climate-smart agriculture to food security, fisheries, forestry, managing coastal zones, and collecting and conserving water ([183]).

([183]) https://www.adaptation-fund.org/adaptation-fund-project-story-india/

9 Conclusions and final recommendations

The Global Covenant of Mayors for Climate and Energy (GCoM) is nowadays the world's largest urban initiative, involving more than 11.000 local and regional authorities worldwide, toward a carbon-neutral and resilient future. The initiative facilitates and accelerates the implementation of effective actions to fight climate change. JRC, as the scientific body supporting the initiative, has the mandate of developing adapted guidance materials for local authorities joining the initiative in the different regions of the world. With this aim, the present guidebook provides support to Indian local authorities signing the GCoM and committing to developing and implementing actions at the local level to decrease their total GHG emissions in their territories as well as increasing their resilience and ensure sustainable, secure, and affordable access to Energy. This document covers the main steps of the process in detail focusing on the specific aspects of the Indian context: how to integrate this globally harmonized approach to the national climate framework.

Joining the GCoM means for Indian municipalities the possibility of benefiting from a long experience in local climate action, and the support of a global net, leveraging the achievement of national and global climatic objectives. However, the development and implementation of a Local Action Plan (CAP) need significant time, human resources, and technical expertise and this guidebook aims at facilitating the best integration of all these factors. Section 1, 2, and 3 contains the basics for successful development and implementation

of the CAP, which goes beyond the elaboration of the document itself. This requires a real political commitment, the involvement of the key stakeholders, a reorganization of the Local authority (LA) structure and the will to embrace a sustainable approach in the long term.

One of the main challenges for Indian LAs is the gathering of robust qualitative and quantitative data needed to build the assessments on mitigation (Baseline emission inventory BEI), Adaptation (Risk and Vulnerability Assessment RVAs) and Access to energy Assessment (AEA). The assessment of the initial situation is the key step for understanding where and how the LAs would like / could go by 2030. Section 4 of the guidebook aims at supporting Indian LAs providing specific methodologies and links to repositories where the information needed can be found, calculated, or downscaled to the local level.

Section 5 and 6 guide Indian LAs in setting targets based on the results of the assessment phase, as well as define feasible and effective actions in the sectors of activity of the LA and how to prioritize and best implement them. The engagement of relevant actors from the early stage of the planning would be paramount to achieving effective development and implementation. The guidebook provides specific recommendations to ensure robust participation and engagement of all social sectors and stakeholders.

The last sections of the guidebook tackle the most important factors leading a LA to effective implementation of the plan: the monitoring and financing planning of the CAP. LAs have been often finding this aspect quite awkward and challenging. For this reason, this guidebook includes a comprehensive section providing an overview of the existing financing mechanisms and available funds in India to address the main barriers local authorities face when dealing with the implementation of their actions. Suggestions and recommendations to guide local authorities in the choices of tools and promotion of investments are provided. Indian LAs will use this information for decision-making towards achieving their goals.

To conclude, this document is a useful tool for Indian LAs supporting authorities in achieving their climate targets and goals through the successful elaboration and implementation of their CAP compliant with the global reporting requirements but adapted to their specific circumstances. The guidebook provides as well successful good practice examples to motivate and, hence, build upon the already achieved results to shape an aware community committed to a path towards sustainability.

References

Abdullaha, S., Jeanty, W. 2009. Demand for Electricity Connection in Rural Areas: The case of Kenya. BATH ECONOMICS RESEARCH PAPERS 26/09. Department of Economics

Achinas, S., Achinas, V., Euverink, G., 2017. A Technological Overview of Biogas Production from Biowaste, Engineering 3 (3), pp. 299-307.

AfDB / OECD / UNDP, 2016. African Economic Outlook 2016. Special Theme: Sustainable Cities and Structural Transformation.

Aghajanzadeh, A., Wray, C. and McKane, A., 2015. Opportunities for Automated Demand Response in California Wastewater Treatment Facilities, Berkeley National Laboratory, Berkeley, California, USA

Agrawal B, Tiwari GN., 2010. Life cycle cost assessment of building integrated PV thermal (BIPVT) systems. Energy and Buildings 42, pp. 1472–1481.

Ahlborg, H., Boräng, F., Jagers, S. C., Söderholm, P. (2015). Provision of electricity to African households: The importance of democracy and institutional quality. Energy policy, 87, pp. 125-135.

Alfaro, J., Miller, S. 2014. Satisfying the rural residential demand in Liberia with decentralized renewable energy schemes. Renewable and Sustainable Energy Reviews 30, pp. 903–911

Al-Waelia, A., Sopiana, K., Kazem, H., Chaichan, M., 2017. Photovoltaic/Thermal (PV/T) systems: Status and future prospects, Renewable and Sustainable Energy Reviews 77, pp. 109–130.

Arnstein, S.R., 1969. A Ladder of Citizen Participation. Journal of the American Planning Association, 35, pp. 216–224. doi:10.1080/01944366908977225

Bazilian, M., Nakhooda, S., Van de Graaf, T., 2014. Energy governance and poverty. Energy Research & Social Science 1, pp. 217–225. doi:10.1016/J.ERSS.2014.03.006

Bertoldi, P. and Rezessy, S. 2010. Financing energy efficiency: forging the link between financing and project implementation. [online] Ispra: Joint Research Centre of the European Commission. Available at: http://www.konvencijazupanov.eu/IMG/pdf/Financing_energy_efficiency.pdf

Bertoldi P. (editor), Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030, EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79- 96848-8, doi:10.2760/68327, JRC112986

Bertoldi P. (editor), Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA), EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96929-4, doi:10.2760/118857, JRC112986

Bertoldi P. (editor), Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – PART 3 – Policies, key actions, good practices for mitigation and adaptation to climate change and Financing SECAP(s), EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96927-0, doi:10.2760/58898, JRC112986.

Bertoldi, P., Rivas Calvete, S., Kona, A., Hernandez Gonzalez, Y., Marinho Ferreira Barbosa, P., Palermo, V., Baldi, M., Lo Vullo, E. and Muntean, M., Covenant of Mayors: 2019 Assessment, EUR 30088 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-10721-7, doi:10.2760/49444, JRC118927.

Bhatia, M., Angelou, N., 2015. Beyond Connections : Energy Access Redefined (ESMAP Technical Report; 008/15). Washington, D.C.

Bobbio, L. (2019) Designing effective public participation, Policy and Society, 38(1), 41-57, DOI: 10.1080/14494035.2018.1511193

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., Yanda, P., 2007. Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanso.

Bruno, J., Ortega-López, V., Coronas, A, 2009. Integration of absorption cooling systems into micro gas turbine trigeneration systems using biogas: Case study of a sewage treatment plant, Applied Energy 86, pp. 837-847.

Castán Broto, V., Stevens, L., Ackom, E., Tomei, J., Parikh, P., Bisaga, I., Seng To, L., Kirshner, J., Mulugetta, Y., 2017. A research agenda for a people-centred approach to energy access in the urbanizing global south. Nature Energy 2, pp. 776–779. doi:10.1038/s41560-017-0007-x

Dalberg Advisors, Lighting Global, 2018. Off-Grid Solar Market Trends Report 2018. International Finance Corporation, Washington, D.C.

Dickson, E., Baker, J.L., Hoornweg, D., Asmita, T., 2012. Urban risk assessments: understanding disaster and climate risk in cities (urban development).

Duić, N., Krajačić, G., Graça Carvalho, M., (2008). Renew Islands methodology for sustainable energy and resource planning for islands, Renewable and Sustainable Energy Reviews 12(4), pp. 1032-1062.

Ellis J. 2010. Energy Service Companies (ESCOs) in Developing Countries. International Institute for Sustainable Development, Winnipeg, Canada

Eriksen, S.H., Kelly, P.M., 2007. Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment. Mitigation and Adaptation Strategies for Global Change, 12, pp. 495–524. doi:10.1007/s11027-006-3460-6

Escudero, S., Savage, R., Kravva, V., Steeds, E., 2017. Future Energy Scenarios for African Cities: Unlocking Opportunities for Climate Responsive Development. European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF), Eschborn, Germany.

European Commission (EC), Directorate-General Research and Innovation, European Missions: 100 Climate-Neutral and Smart Cities by 2030. Info Kit for Cities. Available at: https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_eumission-climate-neutral-cities-infokit.pdf

Field, C.B., Barros, V., Stocker, T.F., Dahe, Q., 2012. Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. Cambridge University Press.

Field, C.B., et al., 2014. Technical Summary, in: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 35–94.

Guimarães Pereira, Â., & Völker, T., Chapter 8: Engaging with citizens, in Science for Policy Handbook. European Commission (EC) Directorate-General Joint Research Centre, 2020. Available at: https://ec.europa.eu/jrc/communities/sites/default/files/science_for_policy_handbook_fin.p

Hansen S., Langlois, P., Bertoldi, P. 2009. ESCOs Around the World: Lessons Learned in 49 Countries.

Haas, R., Lettner, G., Auer, H., Duic, N., 2013. The looming revolution: How photovoltaics will change electricity markets in Europe fundamentally, *Energy* 57, pp. 38-43

ICLEI - Local Goverments for Sustainability, UN Habitat, UNEP, 2009. Sustainable Urban Energy Planning: a handbook for cities and towns in developing countries.

ICLEI - Local Goverments for Sustainability, 2015. Dialogue report: 100% renewable energy in cities, in: Cites and Regions Pavilion – TAP 2015 | COP21. Renewable Cites, Local Governments for Sustainability (ICLEI) and World Future Council, Le Bourget, Paris.

IEA - International Energy Agency, 2009. Cities, Towns and Renewable Energy. Agency, International Energy. doi: https://doi.org/https://doi.org/10.1787/9789264076884-en

IEA - International Energy Agency, 2017. Energy Access Outlook 2017. From Poverty to Prosperity : World Energy Outlook Special Report. Paris (France).

IFI- International Finance Corporation, 2018. Climate Investment Opportunities in Cities. An IFC Analysis. Washington, D.C. 20433, www.ifc.org

IPCC, 2006. 2006 IPCC guidelines for national greenhouse gas inventories. Institute for Global Environmental Strategies Hayama, Japan.

IPCC, 2007. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change, 2007. Cambridge University Press, Cambridge.

IPCC, 2014a. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandre. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014b. Summary for policymakers, in: Field, C.B., Barros, V.R., Mastrandrea, M.D., Mach, K.J., Abdrabo, M.-K., Adger, N., Anokhin, Y.A., Anisimov, O.A., Arent, D.J., Barnett, J. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.

Kelly, A., Marvin, S. (1995). Demand-side management in the electricity sector: Implications for town planning in the UK. Landuse Policy, 12, pp. 205-221

Kern K., Alber, G., 2009. Governing Climate Change in cities: Modes of urban climate governance in multi-level systems. In: The international conference on Competitive Cities and Climate Change, Milan, Italy, 9 - 10 October, 2009. - Paris : OECD - pp. 171 - 196.

Kollmann, R., Neugebauer, G., Kretschmer, F., Truger, B., Kindermann, H., Stoeglehner, G., Ertl, T., Narodoslawsky, M., 2017. Renewable energy from wastewater - Practical aspects of integrating a wastewater treatment plant into local energy supply concepts, *Journal of Cleaner Production* 155 (1), pp. 119-129.

La Greca P., Martinico F. 2018. Shaping the Sustainable Urban Mobility. The Catania Case Study. In: Papa R. Fistola R. Gargiulo C., Smart Planning: Sustainability and Mobility in the Age of Change. GREEN ENERGY AND TECHNOLOGY, Basel: Springer International Publishing.

Latunussa C, Mancini L, Blengini G, Ardente F, Pennington D. (2016). Analysis of material recovery from photovoltaic panels. EUR 27797. Luxembourg (Luxembourg): Publications Office of the European Union; doi:10.2788/786252

Lou, X., Nair, J., 2009. The impact of landfilling and composting on greenhouse gas emissions – A review, Bioresource Technology 100, pp. 3792-3798.

Manzano-Agugliaro, F., Taher, M., Zapata-Sierra, A., Juaidi, A., Montoya, F., 2017. An overview of research and energy evolution for small hydropower in Europe, Renewable and Sustainable Energy Reviews 75, pp. 476-489.

Mobilise your city project: http://mobiliseyourcity.net/ Moro, A.; Walker, O.; Hooks, A., 2018. Analysis: The demand for financing climate projects in cities. This report, co-authored by the C40 Cities Finance Facility, CDP, and in collaboration with the Global Covenant of Mayors for Climate and Energy.

Morrissey, J., 2017. The energy challenge in sub-Saharan Africa: A guide for advocates and policy makers Part 2: Addressing energy poverty. Oxfam Research Backgrounder series.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J., Urquhart, P., 2014. Africa, in: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199–1265.

OECD/IEA, 2017. Energy Access Outlook 2017. From Poverty to prosperity. IEA

OECD / IEA, 2017a. Energy Access Outlook: World Energy Outlook 2017 Special Report. Electricity Access Database [database].

OECD / IEA, 2017b. Energy Access Outlook: World Energy Outlook 2017. WEO Clean Cooking Access Database [database].

OECD & ECMT 2007. Annual Report 2007. Available at: https://www.oecd.org/newsroom/38528123.pdf

OECD, 2008. Handbook on constructing composite indicators: methodology and user guide. Organisation for Economic Co-Operation and Development (OECD), Paris (France).

OECD (2021), Evaluation Guidelines for Representative Deliberative Processes, OECD Publishing, Paris, https://doi.org/10.1787/10ccbfcb-en.

Pehnt, M., Cames, M., Fischer, C., Praetorius, B., Schneider, L., Schumacher, K., Voss, J., 2006. Micro cogeneration: towards decentralized energy systems. Springer-Verlag Berlin Heidelberg.

Prud'homme & Bocarejo, 2005. The London congestion charge: a tentative economic appraisal, Transport Policy, 12, issue 3, pp.279-287

Puzzolo, E., Pope, D., Stanistreet, D., Rehfuess, E.A., Bruce, N.G., 2016. Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. Environmental Research 146, pp. 218–234. doi: https://doi.org/10.1016/j.envres.2016.01.002

Quinn, A.K., Puzzolo, E., Dickinson, K., Sturke, R., Jack, D.W., Mehta, S., Shankar, A., Sherr, K., Rosenthal, J.P., 2018. An analysis of efforts to scale up clean household energy for cooking around the world. Energy for Sustainable Development 46, pp. 1–10. doi:10.1016/J.ESD.2018.06.011

Rao, ND, Pachauri, S. 2017, Energy Access and living standards: some observations on recent trends. Environment Research Letter, vol. 12, 2.

Rivas, S., Melica, G., Kona, A., Zancanella, P., Serrenho, T., Iancu, A., Koffi, B., Gabrielaitiene, I., Janssens-Maenhout, G., Bertoldi, P., 2015. The Covenant of Mayors: In-depth Analysis of Sustainable Energy Actions Plans. JRC, Luxembourg. doi:10.2790/043140

Rosenzweig, C., Solecki, W., Romero-Lankao, P., Mehrotra, S., Dhakal, S., Bowman, T., Ibrahim, S.A., 2015. ARC3. 2 Summary for City Leaders Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network.

Saha, d'Almedia, 2017. Green Municipal Bonds in Finance for City Leaders Handbook, 2nd Edition

Marco Kamiya, Le-Yin Zhang, (Editors). United Nations Human Settlements Programme. Available at: http://financeforcityleaders.unhabitat.org/

Shaheen, S., Guzman, S. and Zhang H., 2010. Bikesharing in Europe, the Americas, and Asia: Past, present, and future. Transportation Research Record

Sovacool, B., Florini, A., 2012. Examining the Complications of Global Energy Governance. Journal of Energy & Natural Resources Law, 30, 235–263.

The World Bank, 2017. World Development Indicators [database].

The World Bank, 2017b. State of Electricity Access report 2017. Washington DC 20433

The World Bank, 2017c. Global Tracking Framework 2017: Progress Towards Sustainable Energy. Washington (D.C.). doi:10.1596/978-1-4648-1084-8

The World Bank, 2010. Economics of adaptation to climate change: Synthesis report.

The World Bank, 2015. Progress Toward Sustainable Energy Framework 2015. The World Bank, Washington, D.C.

UN Habitat, 2011. Global report on human settlements 2011: Cities and climate change. United Nations Hum. Settlements Program, Earthscan.

UNFCCC, 2013. Reporting guidelines on annual inventories for Annex I Parties [WWW Document]. URL http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2

UNFCCC, 2017. Interim National Determined Contributions Registry [WWW Document]. URL http://www4.unfccc.int/ndcregistry/Pages/All.aspx

United Nations Conference on Trade and Development, 2017. The Least Developed Countries Report 2017. Transformational energy access. Geneva.

Urban Climate Change Research Network, 2015. Case Study Docking Station Overview. econd UCCRN Assessment Report on Climate Change and Cities (ARC3.2) [WWW Document]. URL http://uccrn.org/case-study-docking-station-overview/

Van Vossen, W., 2010. Sustainable landfilling in The Netherlands: Developments, Methodologies and Experiences, Österr Wasser- und Abfallw 62: pp. 141-148, *https://doi.org/10.1007/s00506-010-0201-6*

Wang, H.G., Montoliu-Munoz, M., Gueye, N.F.D., 2009. Preparing to Manage Natural Hazards and Climate Change Risks in Dakar, Senegal : A Spatial and Institutional Approach. World Bank, Washington, DC.

Weber, S., Sadoff, N., Zell, E., de Sherbinin, A., 2015. Policy-relevant indicators for mapping the vulnerability of urban populations to extreme heat events: A case study of Philadelphia. Applied Geography, 63, 231–243. doi:10.1016/J.APGEOG.2015.07.006

Westphal, M., Zhou, L., Satterthwaite, D., Martin, S., 2017. Powering Cities in the Global South: How Energy Access for All Benefits the Economy and the Environment. World Resources Institute, Washington (D.C.).

Wolf, M.-A., Pant, R., Chomkhamsri, K., Sala, S., Pennington, D., 2012. The International reference life cycle data system (ILCD) handbook-JRC reference reports.

Zamorano, M., Pérez, J., Pavés, I., Ridao, A., 2007. Study of the energy potential of the biogas produced by an urban waste landfill in Southern Spain. Renewable and Sustainable Energy Reviews, 11, pp. 909-922.

List of abbreviations and definitions

AC	Air Conditioning
AU	African Union
AFOLU	Agriculture Forestry and Other Land Use
BEI	Baseline Emission Inventory
CAP	Climate Action Plan
CCS	Carbon capture and storage
CH4	Methane
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_{2CHPE}	CO_2 emissions from electricity production in a CHP plant
CO_{2CHPH}	CO_2 emissions from heat production in a CHP plant
CO_{2CHPT}	total CO_2 emissions of the CHP plant
CO_2EH	CO_2 emissions related to heat that is exported outside of the territory of the LA
CO_{2-eq}	CO_2-equivalents
CO_2GEP	CO_2 emissions due to the production of certified green electricity purchased by the LA
CO_2IH	CO_2 emissions related to imported heat from outside the territory of the LA
CO_{2LPE}	CO_2 emissions due to the local production of electricity
CO_{2LPH}	CO_2 emissions due to the local production of heat
CoM SSA	Covenant of Mayors in Sub-Saharan Africa
CoM	Covenant of Mayors for Energy and Climate
COM-EF	CoM default Emission Factors data collection
CTC	Covenant Territorial Coordinators
DSO	Distribution system operator
EC	European Commission
EEA	European Environment Agency
EF	Emission Factor
EFDB	Emission Factor Database
EFE	Local emission factor for electricity
EFH	Emission factor for heat
ELCD	European Reference Life Cycle Database
EMEP	European Monitoring and Evaluation Programme
ENEL	Ente Nazionale per l'Energia Elettrica
EPLCA	European Platform on Life Cycle Assessment
ETS	European Union Greenhouse Gas Emission Trading System
EU	European Union
EU-28	European Union 28 Member States
EUROSTAT	Directorate-General of the EC providing statistical information to the institutions of the EU
GCoM	Global Covenant of Mayors

GEP	Green electricity purchases by the local authority
GHG	Greenhouse gas (only refers to N2O, CH_4, CO_2 in this report, if no explicit list)
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventory
GPG	Good practice guidance
GWP	Global Warming Potential
HDD	Heating Degree Days
HDDAVG	Heating Degree Days In An Average Year
ICLEI	Local Governments for Sustainability
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
LA	Local Authority
LAU	Local administrative unit
LCA	Life Cycle Assessment
LDC	Least developed countries
LED	Light emitting diodes
LEP	local energy production
LHC	local heat consumption
LHC_TC	temperature corrected local heat consumption
LPE	Local Production Of Electricity
LULUCF	Land Use Land Use Change and Forestry
MEI	Monitoring Emission Inventory
MEI	Monitoring Emission Inventory
MESHARTILITY	Measure and share data with utilities for the Covenant of Mayors
N_2O	Nitrous Oxide
NACE	Statistical classification of economic activities in the European Community
NAPA	National Adaptation Programme of Action
NCG	National Coordination Group
NCV	Net calorific value
NDCs	Nationally Determined Contributions
NEEFE	National or European Emission Factor for Electricity consumption
NUTS	Nomenclature of territorial units for statistics
OECD	Organisation for Economic Co-operation and Development
PCD	Political Commitment Document
PKM	Passenger-kilometre
PV	Solar photovoltaic installation
RES	Renewable energy sources
RVA	Climate Change Risk and Vulnerability Assessment

SDG	Sustainable Development Goals
SEACAP	Sustainable Energy Access and Climate Action Plan
TCE	Total electricity consumption in the territory of the local authority
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle-Kilometres Travelled

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Annexes

Annex 1. India's Intended Nationally Determined Contribution

Keeping in view its development agenda, particularly the eradication of poverty coupled with its commitment to following the low carbon path to progress and being sanguine about the unencumbered availability of clean technologies and financial resource from around the world, India hereby communicates its Intended Nationally Determined Contribution (INDC) in response to COP decisions 1/CP.19 and 1/CP.20 for the period 2021 to 2030:([184])

1. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
2. To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
3. To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level.
4. To achieve about 40 percent cumulative electric power installed capacity from nonfossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
5. To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.
6. To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
7. To mobilize domestic and new & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
8. To build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies.

([184]) https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

Annex 2. Recommendations for a GCoM Common Reporting Framework (CRF).

1. Global Covenant of Mayors Common Reporting Framework

   https://www.globalcovenantofmayors.org/wp-content/uploads/2019/04/FINAL_Data-TWG_Reporting-Framework_website_FINAL-13-Sept-2018_for-translation.pdf

2. Explanatory Note accompanying the Global Covenant of Mayors Common Reporting Framework

   https://www.globalcovenantofmayors.org/wp-content/uploads/2019/08/Data-TWG_Reporting-Framework_GUIDENCE-NOTE_FINAL.pdf

Annex 3. How to account indirect emissions from the consumption of electricity

3.1. Definition of local production of electricity

The methodology specifically developed in the frame of the GCoM allows defining and assessing the "Local production of electricity" (in MWh). The amount of electricity to be reported in as local electricity production will have a direct influence on the value of the local emission factor for electricity and consequently on the emissions associated with the local consumption of electricity.

The following selection criteria and method have been developed in order to identify the plants or installations that should be included in the calculation of the total LPE.

These selection criteria are based on the geographical location, source/type/size and the ownership/operation of the local electricity generation facility.

Consequently, the information on the total amount of electricity produced in all plants/units that meet the selection criteria and the associated GHG emissions are accounted for in the calculation of the local emission factor for electricity (EFE).

a) Geographical location of the plant/installation

The location of the energy plant/installation in the local territory is the first criterion. However it is not mandatory: electricity produced by installations/plants (refer to as "unit" hereafter) located outside the local territory can also be optionally included, if they are under the direct control of the LA (see point c). If the signatory decides to include plants located outside its territory as defined hereafter (which can make reaching the mitigation target easier or more difficult), it has to include all of them, as is the case with the ones located in its territory.

b) Source, type and size of local electricity production plant/installation

In order to calculate the total amount of LPE and associated GHG emissions to be accounted for in the calculation of the indirect emissions from electricity consumption, the local authority is recommended to include all the individual electricity generation plants in the local territory, (as well as any plant outside the local territory that is owned and/or operated by itself in section c), that meet the following criteria:

- Local electricity production from renewable sources in particular: wind, solar (solar thermal and solar photovoltaic), geothermal energy, ambient heat, hydropower, etc.) and combustible renewables (biofuels, bioliquids, biogas, solid biofuels and combustible wastes of renewable origin). The amount of energy from renewable sources corresponding to guarantees of origin/green certificates transferred to a third party, outside the local administrative boundaries, shall be deducted from the local energy production from renewable sources .
- Local electricity production from non-renewable sources:
  - all combined heat and power plants/installations,
  - all electricity-only plants/installations

c) Case of plants or installations (co-)owned and/or operated by the local authority

All plants/installations under the direct control of the local authority (operated and/or at least partly owned by the municipality) can be accounted for in the calculation of the LPE. This refers to any plant running on renewable or non-renewable energy sources as defined above, some of which are of particular interest for the municipality, such as plants consuming the municipal wastes or cogeneration plants providing heat for the municipal district heating network. The information on the electricity production can be assessed according to the responsibility of the LA and to the share of ownership of all partners (municipalities or commercial partners), following the approach detailed in Annex 5 which avoids double counting inside and outside the territory.

For renewables, the part of local production that is sold outside the local territory is excluded from the calculation of the local emission factor for electricity consumption.

In many cases, the information on local production ([185]) is directly available or assessable from the local (private or public) electricity provider, costumer and/or unit operator. For the large plants (such as CHPs), the

([185]) See also section 5.2 on data collection of energy consumed in the Building macro-sector.

information on the (distributed or centralised) local electricity production can usually be obtained via direct contact with the plant manager (municipal power agency or private company) or with the operators of the distribution network.

In other cases, the data can either be obtained through questionnaires to the local producers/suppliers (e.g., Energy communities) and/or costumers or be derived from statistics (e.g., number of permits delivered, if required; number of subsidies granted) related to the amount of installations and power. Energy market operators may also have data about entities that provide electricity to the grid (e.g., from the certified green electricity).

This list of the selected plants together with corresponding energy inputs, generated electricity and CO_2 emissions have to be updated all along the implementation process so as to account for the changes in local production of electricity and to avoid double counting across signatories. In case a given installation falls into different categories (included/optional/excluded) during the CAP implementation process, the local authority might need to recalculate the BEI/MEI(s) accordingly. This would be the case for instance of a small combustion installation, which would have grown above the 20 MW threshold and been excluded meanwhile by the signatory

In case of Combined Heat and Power (CHP) plants, the energy input has to be split between electricity and heat/cold production. The selection of the plants to be reported as local electricity production will have a direct influence on the value of the local emission factor for electricity and consequently on the emissions associated with the local consumption of electricity. Therefore, when building the subsequent MEI(s), consistency in the selection of production units is required to ensure that the local emission factor reflects the real changes in local electricity production. For example, for the installations running on renewable energy sources, all the additional units reported in MEI(s) should be new installations, installed after the baseline year.

A large portion of Greenhouse Gas emissions (GHG) from most companies comprise of consumption of electricity from the grid. In India, around 65% of electricity is coming from coal and other fossil fuel based thermal power plants. Electricity generated from these power plants contributes in GHG emissions. Therefore, electricity being consumed from the grid also contributes in the GHG emissions. GHG emission from the grid electricity consumption is categorized as energy indirect GHG emissions or scope 2 GHG emissions. Sourcing renewable energy helps to minimize such emissions related to consumption of electricity from the grid. Electricity generated by renewable energy based power plant avoids consumption that would otherwise have been produced by power plants that would emit GHGs due to combustion of fossil fuels. This is also the basis for Clean Development Mechanism (CDM) supervised by the United Nation's Framework Convention on Climate Change (UNFCCC).

The GHG emissions resulted from the generation of electricity is calculated as per the methodology developed by CDM – UNFCCC. In India, Central Electricity Authority (CEA), Government of India, prepares a database for GHG emission factor for the Indian grid annually([186]).

The Indian electricity system is divided into two grids, the Integrated Northern, Eastern, Western, and North-Eastern regional grids (NEWNE) and the Southern Grid. Each grid covers several states. For each of the two grids, the main emission factors are calculated in accordance with the relevant CDM methodologies. CEA keep on updating the database at the end of each fiscal year.

The database is an official publication of the Government of India. It is based on the most recent data available with the CEA. Therefore, it can be consider authentic and reliable.([187])

Source link for CEA EF Database: http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm

3.2. Indirect emissions from the consumption of electricity

In order to calculate the indirect CO_2 emissions to be attributed to the local production of electricity, EC JRC developed a specific methodology of estimating the local emission factor for electricity (EFE) taking into account the following components:

a) National emission factor for electricity consumption (NEFE)

([186]) https://cea.nic.in/cdm-co2-baseline-database/?lang=en
([187]) https://greencleanguide.com/how-to-calculate-ghg-emission-for-electricity-consumption-from-the-grid/

b) Indirect emissions from local electricity production (LPE)

c) Purchase and sale of Certified Electricity (CE)

a. National emission factors for electricity consumption

The National Emission Factor for Electricity (NEFE) shall be used as a starting point to determine the local emission factor for electricity.

b. Purchase and sale of certified electricity (CE)

Local authorities should report in the emission inventory i) any certified electricity (CE) purchased from outside and in addition ii) the amount of certified electricity generated within the local territory and sold to third parties outside its administrative boundaries.

Certified electricity is the electricity that is produced from renewable energy sources (for example certified electricity that meets the criteria for (international) renewable energy certificates, guarantee of origin of electricity, green certificates or similar):

Instead of purchasing the "mixed" electricity from the grid, the local authority/other local actors can decide to purchase certified electricity. The LA will report the amount of purchased electricity ($\sum \mathrm{CE}_{\mathrm{purchased}}$).

$\sum \mathrm{CE}_{\mathrm{purchased}} =$ Certified electricity purchased [MWh]

The amount of renewable energy produced by facilities that are located inside the local territory for which the guarantee of origin/green certificates of electricity produced from renewable sources is sold to third parties outside the administrative boundaries should not be accounted as local energy production ($\sum \mathrm{CE}_{\mathrm{sold}}$)

$\sum \mathrm{CE}_{\mathrm{sold}} =$ Electricity produced and certified by the guarantee of origin/green certificates which is sold to third parties [MWh]

Therefore, the amount of certified electricity that can be accounted for in the calculation of the local emission factor for electricity consumption results as follows:

$\sum \mathrm{CE}$: Certified electricity accounted in the inventory

$$\sum \mathrm{CE} = \sum \mathrm{CE}_{\mathrm{purchased}} - \sum \mathrm{CE}_{\mathrm{sold}} \qquad (2)$$

c. Calculation of local emission factor for electricity (EFE)

The local emission factor for electricity (EFE) to be reported as local emission factors should be calculated as follows:

In the case where the local authority would not be a net exporter of electricity (TCE ≥ LPE + GE) ([188])

$$\mathrm{EFE} = \frac{[(\mathrm{TCE} - \sum \mathrm{LPE} - \sum \mathrm{CE}) * \mathrm{NEFE} + \sum \mathrm{CO2}_{\mathrm{LPE}} + \sum \mathrm{CO2}_{\mathrm{CE}}}{\mathrm{TCE}} \qquad (3)$$

In the case where the local authority would be a net exporter of electricity (TCE < LPE + CE)

$$\mathrm{EFE} = \frac{\sum \mathrm{CO2}_{\mathrm{LPE}} + \sum \mathrm{CO2}_{\mathrm{CE}}}{\sum \mathrm{LPE} + \sum \mathrm{CE}} \qquad (4)$$

Where:

EFE = local emission factor for electricity consumption $[\frac{\mathrm{t\,CO_2}}{\mathrm{MWh}}]$

([188]) This formula neglects transport and distribution losses in and to the local territory, as well as auto- consumption of energy producers/transformers and tends to double count the local production already included in the NEFE. However, at the scale of the local authority, these approximations will have a minor effect on the local CO_2 balance and the formula may be considered as robust enough to be used in the context of the Covenant of Mayors.

TCE = Total electricity consumption [MWh] in the local territory

$\sum LPE$ = local electricity production from RES and non RES facilities [MWh]

$\sum CE$ = Certified electricity

$NEFE$ = national emission factor for electricity consumption $[t\ CO2/MWh]$

$\sum CO2_{LPE}$ = CO_2 emissions due to local energy production $[t\ CO_2]$

$\sum CO2_{CE}$ = CO_2 emissions [tCO2] due the purchase/sold of CE certified electricity. In the case that the standard approach is used, the emission factor for certified electricity is zero. If the LCA approach is used, the local authority has to estimate the LCA CO2CE either by requesting required information from the power provider or by using the CoM default factors provided for local renewable electricity generation if they are deemed suitable.

In the case of CHP plants, it is first required to distinguish between the energy input and emissions due to heat and electricity production.

3.3. How to allocate emissions in CHPs

Part or all of the heat used in the territory of the local authority may be generated in a combined heat and power (CHP) plant. It is essential to divide the emissions of a CHP plant between heat and electricity when filling the B online templates. The fuel use - and consequently, the associated emissions - can be allocated between heat and electricity generation by using the following methods proposed, based on the data availability:

I) The following method allocate the emissions based on the energy inputs required to produce separately (non in cogeneration) the same amount of outputs of heat and electricity (as in the CHP power plant output) as follows([189]):

$$CO2_{CHPH} = \frac{\frac{P_{CHPH}}{\eta_h}}{\frac{P_{CHPH}}{\eta_h}+\frac{P_{CHPE}}{\eta_e}} * CO2_{CHPT} \quad \text{(a)}$$

$$CO2_{CHPE} = CO2_{CHPT} - CO2_{CHPH} \quad \text{(b)}$$

where

$CO2_{CHPT:}$ total amount of CO_2 emissions in the CHP power plant [tCO_2]

$CO2_{CHPH}$: amount of CO_2 emissions from heat production [tCO_2]

$CO2_{CHPE}$: amount of CO_2 emissions from electricity production [tCO_2]

$P_{CHPE:}$ amount of electricity produced [MWh]

$P_{CHPH:}$ amount of heat produced [MWh]

η_e typical efficiency of separate electricity production.

η_h: typical efficiency of separate heat production. The recommended value to be used is 90 %.

([189]) see annexure 2 of European energy efficiency directive (212/27/EU)

Annex 4. Default Net calorific values (IPCC, 2006)

Fuel type	Net calorific value [TJ/Gg]	Net calorific value [MWh/t]
Crude Oil	42.3	11.8
Orimulsion	27.5	7.6
Natural Gas Liquids	44.2	12.3
Motor Gasoline	44.3	12.3
Aviation Gasoline	44.3	12.3
Jet Gasoline	44.3	12.3
Jet Kerosene	44.1	12.3
Other Kerosene	43.8	12.2
Shale Oil	38.1	10.6
Gas/Diesel Oil	43.0	11.9
Residual Fuel Oil	40.4	11.2
Liquefied Petroleum Gases	47.3	13.1
Ethane	46.4	12.9
Naphtha	44.5	12.4
Bitumen	40.2	11.2
Lubricants	40.2	11.2
Petroleum Coke	32.5	9.0
Refinery Feedstocks	43.0	11.9
Refinery Gas 2	49.5	13.8
Paraffin Waxes	40.2	11.2
White Spirit and SBP	40.2	11.2
Other Petroleum Products	40.2	11.2
Anthracite	26.7	7.4
Coking Coal	28.2	7.8
Other Bituminous Coal	25.8	7.2
Sub-Bituminous Coal	18.9	5.3
Lignite	11.9	3.3
Oil Shale and Tar Sands	8.9	2.5
Brown Coal Briquettes	20.7	5.8
Patent Fuel	20.7	5.8
Coke Oven Coke and Lignite Coke	28.2	7.8
Gas Coke	28.2	7.8
Coal Tar	28.0	7.8
Gas Works Gas	38.7	10.8
Coke Oven Gas	38.7	10.8
Blast Furnace Gas	2.47	0.7
Oxygen Steel Furnace Gas	7.06	2.0
Natural Gas	48.0	13.3
Municipal Wastes (non-biomass fraction)	10	2.8
Waste Oil	40.2	11.2
Peat*	9.76	2.7

These IPCC default Net calorific values (NCV) may be used for both stationary sources and road transport (see fuels in bold) when country-specific data are unavailable.

*Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels and CO2 emissions from combustion are included in the national emissions as for fossil fuels.

Annex 5. CO2 emission factors for fuels (IPCC, 2006)

Fuel type	CO_2 emission factor [kg/TJ]	CO_2 emission factor [t/MWh]
Crude Oil	73,300	0.264
Orimulsion	77000	0.277
Natural Gas Liquids	64200	0.231
Motor Gasoline	69300	0.249
Aviation Gasoline	70000	0.252
Jet Gasoline	70000	0.252
Jet Kerosene	71500	0.257
Other Kerosene	71900	0.259
Shale Oil	73300	0.264
Gas oil / diesel	74100	0.267
Residual Fuel Oil	77400	0.279
Liquefied Petroleum Gases	63100	0.227
Ethane	61600	0.222
Naphtha	73300	0.264
Bitumen	80700	0.291
Lubricants	73300	0.264
Petroleum Coke	97500	0.351
Refinery Feedstocks	73300	0.264
Refinery Gas	57600	0.207
Paraffin Waxes	73300	0.264
White Spirit & SBP	73300	0.264
Other Petroleum Products	73300	0.264
Anthracite	98300	0.354
Coking Coal	94600	0.341
Other Bituminous Coal	94600	0.341
Sub-Bituminous Coal	96100	0.346
Lignite	101000	0.364
Oil Shale and Tar Sands	107000	0.385
Brown Coal Briquettes	97500	0.351
Patent Fuel	97500	0.351
Coke oven coke and lignite Coke	107000	0.385
Gas Coke	107000	0.385
Coal Tar	80700	0.291
Gas Works Gas	44400	0.160
Coke Oven Gas	44400	0.160
Blast Furnace Gas	260000	0.936
Oxygen Steel Furnace Gas	182000	0.655
Natural Gas	56100	0.202
Municipal Wastes (non-biomass fraction)	91700	0.330
Industrial Wastes	143000	0.515
Waste Oil	73300	0.264
Peat*	106000	0.382

These IPCC default CO_2 emission factors may be used for both stationary sources and road transport (see fuels in bold) when country-specific data are unavailable. It is recommended to ensure that default emission factors, if selected, are appropriate to local fuel quality and composition.

*Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels and CO2 emissions from combustion are included in the national emissions as for fossil fuels.

Annex 6. End-of-life Management of Solar Photovoltaic Panels

Photovoltaics are set to play a key role in meeting the global need for clean and sustainable energy and in particular can held address the fast growing demand for energy in low income countries. The basic element of PV systems is the PV panel or module, comprising mostly glass, the PV active material, organic encapsulants, connectors and in some cases an edge frame. This package typically has useful operational life of 25 to 30 years.

Although the global market is still relatively young, its dynamic growth has led to the realisation that strategies are needed for dealing with large future volumes of end-of-life PV panels. There are two main considerations:

a) sustainable use of resources through reuse and recycling (in particular of precious and scarce metals such as silver, gallium, indium, and germanium, as well as of conventional material such as aluminium, glass and silicon), and

b) environmental concerns for incorrect disposal, in particular leaching of hazardous substances (e.g., lead for crystalline silicon photovoltaics and cadmium for some thin film products).

The 2016 IRENA-IEA-PVPS report [1] on end-of-life management provides a holistic view of the state of the art regarding decommissioning, repair, reuse, recycling and disposal from both a technical and regulatory perspectives. If you want to know more about what is being done at international level, the International Energy Agency Task 12 focuses among other activities on recycling of manufacturing waste and spent modules. Some good quality documents and reports are found on its website (http://www.iea-pvps.org/index.php?id=56).

Recycling

Up to now relatively few countries have addressed the issue of PV waste and recycling in in regulations. The EU is forerunner in the respect and since 2012 includes PV panels under its Waste Electrical and Electronic Equipment (WEEE) directive, which requires an 85% recovery rate of waste PV modules by mass. Regional schemes for collecting solar panels are in place. Although solar panel recycling presents technical challenges to separate multiple, extremely different materials, the technology has developed accordingly and the European solar panel recycling association PV Cycle boasts processes for recovering over 95 percent of a panel's materials.

Recycling technologies can be classified into bulk recycling (recovery of high mass fraction materials such as glass, aluminium and copper) or high-value recycling (recovery of both semi-conductor and trace metals). End-of-life crystalline silicon panels([190]), which currently make up well over 90% of the global market, are crushed or shredded and then glass and metals are separated. Pyrolysis at about 500°C is needed for the recovery of the silicon wafers from the modules and a chemical etching for the removal of metal coatings, antireflective coatings, and diffusion layers. For thin-film([191]) CIGS and CdTe modules, both bulk and high-value recycling is also possible. For example First Solar, the main producer of CdTe modules, claims that up to 90% of the semiconductor material can be reused in new modules and 90% of the glass can be reused in new glass products.

At present recycling faces significant economic challenges [1]. One factor is the lack of volume needed to achieve economies of scale. A more serious long term issue is that crystalline silicon the panels contain relatively few valuable materials, so the recycling cost is generally higher than the landfilling one. Thin-film module may offer more commercial scope given the presence of more valuable materials.

Disposal

Where recycling is not performed for reasons of cost-economics or lack of facilities, various materials from end-of-life PV panels or from the recycling process may need to be disposed of in appropriately design and manged landfills, subject to regulation and classification of hazardous content. PV panels are generally seen as inert waste, but given the presence of various trace metals in PV modules, there have been concerns about

([190]) A "crystalline silicon" solar panel or module typically has an area of about 1.5 m2 and is composed of approximately 60 interconnected silicon wafers, a backsheet, polymer encapsulation, front glass and a conjunction box. There may also be an aluminium or plastic edge frame. By weight, glass contributes approximately 80%. Other elements include: 5% silicon, 1% copper and less than 0.1% of silver, tin and lead

([191]) Thin-film refers to modules that are fabricated by deposition of active layers of a few micron thicknesses on a large area substrate, almost always glass. The glass makes up well over 90% of the mass. Cadmium telluride (CdTe) and Copper Indium Gallium Diselenide (CIGS) are the two main commercial products potential environmental impacts if module material were to be disposed of in unlined landfills. Studies have focussed in particular on leaching of lead from crystalline silicon module material and of cadmium from cadmium telluride thin film module material, exploring factors such as the acidity of the landfill environment, size of the module fragments etc. [3,4].

Summary points

- Given the key role of PV technology in future energy systems, all jurisdictions should PV end-of-life management aspects in regulatory schemes; experiences in Europe and other countries can provide useful examples. Collection schemes are an important part of such strategies given the distributed nature of PV deployment, especially in the urban environment.
- Reuse and recycling technology is available today although the short term lack of waste volume means that economies of scale often can't be realised.
- Disposal of materials from end-of-life PV panels or those remaining from the recycling process should be appropriately design and manged landfills, subject to regulation and classification of hazardous content.
- The PV sector should be encouraged to develop a sustainable product life cycle and industrial value chain, including repair, reuse, recycling and safe disposal of PV panels.

References

1. IRENA-IEA-PVPS, End-of-life management: Solar Photovoltaic Panels, June 2016, ISBN : 978-92-95111-99-8
2. I. D'Adamo, M. Miliacca, P. Rosa, Economic Feasibility for Recycling of Waste Crystalline Silicon Photovoltaic Modules, International Journal of Photoenergy Volume 2017, Article ID 4184676, doi.org/10.1155/2017/4184676
3. J. Nover, R. Zapf-Gottwick, C. Feifel, M. Koch, J. W. Metzger, and J. H.Werner, Long-term leaching of photovoltaic modulesJpn. J. Appl. Phys. 56, 08MD02 (2017).
4. P. Sinha, L. Trumbull,,S.Kaczmar, K.A. Johnson, Evaluation of Potential Health and Environmental Impacts from End-of-Life Disposal of Photovoltaics, from book "Photovoltaics: Synthesis, Applications and Emerging Technologies", Chapter: 2, Nova Science Publishers, Inc., 2014

Annex 7. End-of-Life Management of Batteries in the Off-Grid Solar Sector

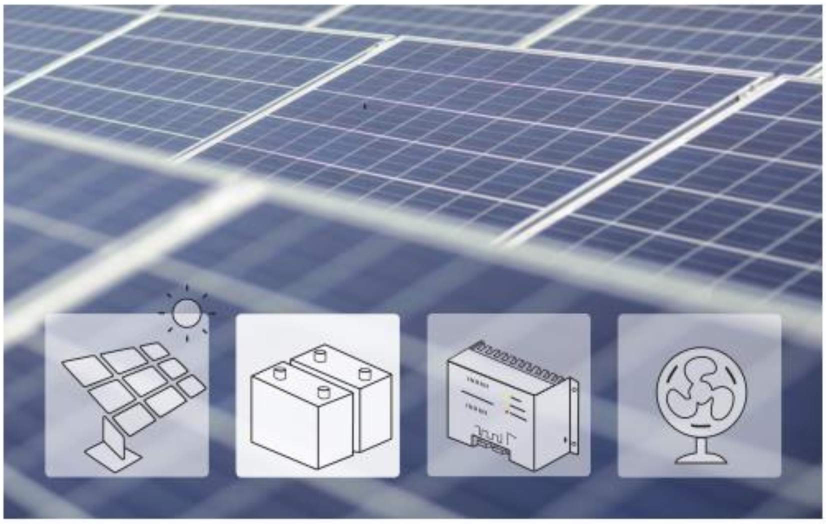
E-waste and battery waste are already known to be a challenge in many developing countries and emerging economies with serious hot spots in many urban areas where collection and recycling is often conducted by informal sectors with little regard to emission control and impacts on human and environmental health. If these challenges are not taken into account by energy-access projects, related problems might soon expand to rural communities. But this negative scenario should not be used as a reason to slow down energy access efforts.

The document "END-OF-LIFE MANAGEMENT OF BATTERIES IN THE OFF-GRID SOLAR SECTOR - How to deal with hazardous battery waste from solar power projects in developing countries?" introduces the realities of managing e-waste and battery waste in the context of developing countries, with a specific focus on energy access projects.

The document, published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, authored by Andreas Manhart, Öko-Institut e.V. Inga Hilbert, Öko-Institut e.V. Federico Magalini, Sofies and e dited by: Daniel Hinchliffe, Ellen Gunsilius (GIZ Sector Project), Caspar Priesemann (Energising Development (EnDev)) is available at: https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf

END-OF-LIFE MANAGEMENT OF BATTERIES IN THE OFF-GRID SOLAR SECTOR

How to deal with hazardous battery waste from solar power projects in developing countries?



Andreas Manhart, Inga Hilbert – Öko-Institut e.V.
Federico Magalini – Sofies

Developed in cooperation with GIZ sector project "Concepts for Sustainable Solid Waste Management" on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), and in cooperation with the multi-donor programme Energising Development (EnDev).

Annex 8. Resources for India Cities

1. The Committee on Solid Waste Management Rules and Plastic Waste Management Rules, 2016.

   http://moef.gov.in/wp-content/uploads/2017/06/Final-Report-on-the-Issues-related-to-SWM-and-PWM-Rules-2016.pdf

2. India's National Report 2018 submitted to UNCCD

   http://moef.gov.in/wp-content/uploads/2017/06/Indias-Report-Non-Editable_1.pdf

3. India's GHG Emissions Profile – Results of Climate Modelling Studies

   http://moef.gov.in/wp-content/uploads/2018/04/GHG_report_2.pdf

4. India's Forest and Tree Cover – Contribution as a Carbon Sink

   http://moef.gov.in/wp-content/uploads/2018/04/Contri_carbon_sink_2.pdf

5. Various annual reports by Ministry of Environment, Forest and Climate Change

   http://moef.gov.in/en/resource/annual-reports-of-the-ministry/

6. India's submissions to the United Nations Framework Convention on Climate Change

   http://moef.gov.in/wp-content/uploads/2018/04/UNFCCC_final_1.pdf

7. India's Fourth National Report to the Convention on Biological Diversity.

   http://moef.gov.in/wp-content/uploads/2018/04/India_Fourth_National_Report-FINAL_2.pdf

8. Governance for Sustainable Himalayan Ecosystem (G-SHE)

   http://moef.gov.in/wp-content/uploads/2018/04/G-SHE_Book_2.pdf

9. Results Framework Document – 2014-2015

   http://moef.gov.in/wp-content/uploads/2018/04/report_PMO_English.pdf

10. Climate Smart Cities Assessment Framework of Ministry of Housing and Urban Affairs

    https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf

    National Adaptation Fund For Climate Change

11. https://www.nabard.org/auth/writereaddata/File/Overall%20NAFCC%20Project%20Flyer.pdf

12. India Climate Change Knowledge Portal

    https://www.cckpindia. nic.in

13. National CDM Authority

    https://ncdmaindia.gov.in

14. Development of legal, Institutional and Financial Framework of National Program

    http://moef.gov.in/wp-content/uploads/2017/06/Development-of-legal-Instituitional-and-Financial-Framework-of-National-Program.pdf

15. Low Carbon Lifestyles

    http://moef.gov.in/wp-content/uploads/2017/06/Low-Carbon-Lifestyles_0.pdf

16. Climate Change and Cities

    https://www.wwfindia.org/about_wwf/reducing_footprint/cce/our_work/low_carbon_development_framework/sustainable_cities/

17. Climate Smart Cities

    https://www.giz.de/en/worldwide/75009.html

18. Making our cities smart and resilient

https://www.teriin.org/article/making-our-cities-smart-and-resilient

19. India Platform for GHG Emission Estimation and Analysis

    http://southasia.iclei.org/our-activities/our-pathways/low-emission-development/india-platform-for-ghg-emission-estimation-and-analysis.html

20. Climate Change Knowledge Portal: World Bank

    https://climateknowledgeportal.worldbank.org/country/india

21. State Action Plan on Climate Change

    http://moef.gov.in/en/division/environment-divisions/climate-changecc-2/state-action-plan-on-climate-change/

22. Following Indian States and Union Territories have their SAPCC :

i. Assam
ii. Andaman and Nicobar
iii. Andhra Pradesh
iv. Arunachal Pradesh
v. Bihar
vi. Chandigarh
vii. Chhattisgarh
viii. Delhi
ix. Gujarat
x. Haryana
xi. Himachal Pradesh
xii. Jammu & Kashmir
xiii. Jharkhand
xiv. Karnataka
xv. Kerala
xvi. Lakshadweep
xvii. Madhya Pradesh
xviii. Maharashtra
xix. Manipur
xx. Meghalaya
xxi. Mizoram
xxii. Nagaland
xxiii. Odisha CCAP 1 & CCAP 2
xxiv. Puducherry
xxv. Punjab
xxvi. Rajasthan
xxvii. Sikkim
xxviii. Tamil Nadu
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xxxi. Uttar Pradesh
xxxii. Uttarakhand
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