



# Summary of the Activities of the RN Thematic Group in 2016

*ERNCIP Thematic Group  
Radiological and Nuclear  
Threats to Critical  
Infrastructure*

Harri TOIVONEN, HT Nuclear Ltd, Finland

2016

The research leading to these results has received funding from the European Union as part of the European Reference Network for Critical Infrastructure Protection project.

# Summary of the Activities of the RN Thematic Group in 2016

This publication is a Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication.

**JRC Science Hub**

<https://ec.europa.eu/jrc>

JRC105547

PDF

ISBN 978-92-79-65733-7

doi:10.2760/89876

---

Luxembourg: Publications Office of the European Union, 2016

© European Union, 2016

The reuse of the document is authorised, provided the source is acknowledged and the original meaning or message of the texts are not distorted. The European Commission shall not be held liable for any consequences stemming from the reuse.

How to cite this report: Toivonen H., *Summary of the Activities of the RN Thematic Group in 2016*,

doi:10.2760/89876

All images © European Union 2016

## Contents

Abstract .....	2
1 General Description of the RN Thematic Group.....	3
1.1 Purpose .....	3
1.2 Links to EU Policy .....	4
2 Objectives 2016 .....	5
3 Implementation of Work Programme 2016 .....	6
3.1 Way of Working .....	6
3.2 Liaison .....	6
4 Results and Deliverables .....	7
4.1 List-mode Data Acquisition .....	7
4.2 Robotics.....	8
4.3 Reachback.....	9
5 Work Programme 2017 – 2018 .....	11
Appendix 1: ERNCIP RN Thematic Group R&D Proposal for H2020 Call ....	12

## Abstract

A summary of the activities of the RN Thematic Group of ERNCIP in 2016 is reported. The Group organized its work in three sub-topics: awareness raising on a new standard on list-mode data acquisition, robotics in RN field and reachback (expert support to field teams). The work of the Group is based on the Work Programme 2016 developed at the end of March 2016.

In March 2016, the International Electrotechnical Commission (IEC) accepted the proposal to develop a new international standard (IEC 63047) for list-mode data acquisition. The pre-normative research for this standard was provided by the ERNCIP RN Thematic Group. A field trial was organized for the robotics. It produced valuable feedback to understand the technological and information gaps between robotics community and radiological experts. These gaps need to be acknowledged towards efficient field cooperation and standardized operations. The work on reachback focused on cooperation with the Global Initiative to Combat Nuclear Terrorism to organize a joint workshop on roles and responsibilities of the technical reachback. The agenda was designed and the time of the event was fixed to 28-30 March 2017.

The activities of the Group in 2016 are documented in four ERNCIP outputs produced in 2016, including this report summarising the Group's work in 2016. In addition, two flyers, fact sheets were produced to promote awareness raising of the list-mode data acquisition standard and the ERNCIP initiative on joint formats and protocols for the communication between the frontline officers and the technical reachback.

## 1 General Description of the RN Thematic Group

The ERNCIP network has been established to improve the protection of critical infrastructures in the EU. ERNCIP therefore works in close cooperation with all types of CIP stakeholders, focusing particularly on the technical protective security solutions. Within this context the RN Thematic Group deals with radiological and nuclear threats, their prevention, detection and mitigation of consequences.

The primary aim of the RN Thematic Group is to advance common technology standards and harmonised processes that will improve the detection of RN substances in Europe. The work aims to lead to proposals for European or International Standards. In addition, the Group identifies safety and security gaps, produces initiatives for improvements through documents for the production of harmonised guidance or proposals aimed at operators.

### 1.1 Purpose

The RN Thematic Group works on the radiation measurement standards, the standardisation of deployment protocols, the certification of radiation detectors, response procedures and communication to the public, in the accidents or in the event of criminal or unauthorised acts involving nuclear or other radioactive material out of regulatory control (MORC). The work is closely related to the opportunity, opened up by current developments in technology, to utilise the remote support of field teams (reachback) for radiation detection.

The work of the Group is shared out across three sub-groups, tackling the three areas of List-mode, Robotics and Reachback.

**List-mode** is data acquisition based on digital electronics. Time-stamped list-mode data format produces significant added value compared to the more conventional spectral data format. It improves source localisation, allows signal-to-noise optimisation, noise filtering, with some new gamma and neutron detectors requiring list-mode data to function. The list-mode approach also allows precise time synchronisation of multiple detectors enabling simultaneous singles and coincidence spectrometry such as singles gamma and ultraviolet (UV)-gated gamma spectrometry, among other applications.

The work on list-mode data format standards instigated by this Group continues primarily in the EURAMET EMPIR 14SIP07 – DigitalStandard project. This project builds upon the pre-normative work of this Group, and is specifically dedicated to the development of a draft international standard, including tools to support its implementation, under the auspices of the IEC Technical Committee 45 “Nuclear Instrumentation”.

**Robotics** for radiological applications refers to remote-controlled radiation measurements and sampling using unmanned air, under water or ground vehicles. There are no standards for sampling or taking measurements when searching for MORC, or responding to other incidents such as reactor accidents or explosions.

Unmanned vehicles can operate in areas with high radiation or danger of explosives. They can also be used for monitoring the movements of a threat object in hostile environments by gathering real-time data from multiple mobile sensor sources. Remote controlled radiation measurement and sampling techniques need to be developed for this kind of situations.

***Reachback*** is the expert support of field teams. An efficient Concept of Operations is based on moving data instead of people or samples, achieving a faster and better response with fewer people.

The conventional means to undertake in-field analysis is:

1. Frontline officers or first responders operate detection equipment.
2. If anomalous radioactivity is detected, secondary measurements are performed, and if required, experts (a Mobile Expert Support Team) are invited to the location with more sophisticated equipment and know-how.

However, analysis of collected data can more safely and thoroughly be done at distance from an incident. As an alternative, frontline officer and first responder can be equipped with spectrometers that are gain-stabilized, easy to use and able to send the recorded high-quality data wirelessly to a database which can be located far away from the field mission itself (cross-border support). In the analysis centre, experts follow and interpret the measurements in near real-time and provide advice to the Command and Control, or directly to the frontline officer. Defined formats and protocols are needed for efficient communication between frontline officers and a reachback centre, but there are no standards related to remote support of field teams.

At the time of writing, the RN Thematic Group [11 documents](#) (published reports and fact sheets) are available on the ERNCIP website on list-mode data acquisition (4), robotics (3) and reachback (4).

## 1.2 Links to EU Policy

The work of the RN Thematic Group directly supports the priorities of the European Union in two areas:

1. Enhancing the EU's internal security;
2. Facilitating the development of a single market for European security industry.

The EU Internal Security Strategy ([Action 2](#)) draws attention to the need to enhance capabilities against CBRNE (chemical, biological, radiological, nuclear, explosives) threats, including developing minimum detection and sampling standards. This is elaborated in the [CBRN Action Plan, 4.5](#), which details detection as one of the priorities, [Actions H.23, H.24 and RN.25](#).

The EU Security Industrial Policy Action Plan ([4.1.1. Action 1](#)) concludes that the European security industry suffers from market fragmentation, and to move closer to a single market needs European-wide standardisation of, and certification schemes for, security products.

To this effect, the work underway in the framework of the European Standardisation Organisations, under the banner of DG Enterprise and Industry's (now DG GROW) [Mandate 487](#) is aimed at more harmonised European security standards. In the preparatory work under the CBRNE part of Phase 2, the task to standardise the data format for list-mode data acquisition is highly prioritised at the international level, as was shown by the decision-making process to start the development of an IEC standard for list mode data acquisition (see Chapter 4.1).

## 2 Objectives 2016

The work of the RN Thematic Group was carried out based on the following objectives included in the work programme 2016:

1. List-mode:

To continue to promote the EMPIR DigitalStandard project and to present the work at suitable scientific conferences or workshops. Communicate the benefits of digital data acquisition system to vendors, system-level manufacturers and end users.

2. Robotics:

To support the development of European robotics/RN detection exercises, trials and/or competitions using the Group's work on RN scenarios, with the aim that existing and future standards shall be introduced into the field of robotics.

3. Reachback:

To raise awareness within EU Member States through international organizations (GICNT and IAEA) and through direct contacts on the benefits of information sharing nationally, regionally and internationally through expert support (reachback) for prevention and detection of, or response to, nuclear security events.

## 3 Implementation of Work Programme 2016

The RN Thematic Group experts carried out the activities of the work programme, mostly on a volunteer basis. All the activities were implemented with the active participation and administrative assistance of the ERNCIP Office.

Primarily, the activities of the experts focused on research and analysis of the relevant issues, resulting in the preparation of reports documenting the findings of the analysis, conclusions, and recommendations as appropriate.

### 3.1 Way of Working

The RN Thematic Group prepared a work programme with detailed objectives, tasks and deliverables. Progress of the tasks was monitored by the coordinator, with issues arising to be discussed at Thematic Group meetings. In order to minimize travelling, one of the sub-group meetings was organized adjacent to a full Group meeting. The coordinator prepared the agendas for each meeting, and formally documented the key points of discussion and all actions agreed at each meeting. In 2016 the following meetings took place:

#### *Task leaders*

- 17-18 March 2016, Ispra – Planning meeting

#### *Full Thematic Group*

- 16 - 17 November 2016, Ispra

#### *Sub-groups*

- 20-23 June 2016, Robotics sub-group, Eggendorf, Austria
- 19 October 2016, Reachback sub-group, Bucharest
- 16 November 2016, Robotics sub-group, Ispra.

The coordinator ensured that tasks were completed according to the agreed work programme, and that the reports were of sufficient quality for publication.

### 3.2 Liaison

Communication and coordination with CEN about the subject matter and related procedures was included in the work activities by inviting the representative of NEN to the RN Thematic Group meeting in November 2016.

Liaison with H2020-funded projects was established to ensure the findings of the Thematic Group are re-used, and that duplication of effort is avoided. The main effort was placed in the cooperation with the C-BORD programme where data management and reachback plays important role. The Coordinator was invited to the Advisory Group of the project to promote reachback initiative developed in the framework of the ERNCIP.

On request, the RN Thematic group prepared an R&D proposal for DG HOME to be considered in Horizon 2020 call (see Appendix 1).

## 4 Results and Deliverables

### 4.1 List-mode Data Acquisition

In March 2016, the International Electrotechnical Commission (IEC) accepted the proposal to develop a new international standard for list-mode data acquisition. The work has been included in the work programme of IEC/TC 45 "Nuclear instrumentation", and was assigned to WG 9 "Detectors and systems". The project received the number IEC 63047. The pre-normative research for this standard has been provided by the RN Thematic Group in the frame of mandate M/487, in which CEN/TC 391 assigned the highest priority to the standardisation of the list-mode data format.

The research initiated within the ERNCIP framework has led to the establishment of a consortium of four European National Metrology Institutes receiving funding from the H2020 European Metrology Programme for Innovation and Research (EMPIR), administered by Euramet. JRC-Geel takes part as an unfunded partner in the DigitalStandard consortium. A liaison category A was established between JRC and IEC/TC 45. Jan Paepen (JRC-Geel; RN TG member) was appointed as liaison officer and IEC project leader for the development of the international standard IEC 63047. This work originated from the ERNCIP RN Thematic Group and is now included in the JRC work programme. The Group continues to promote the list-mode standard at relevant conferences, workshops and other events (see below, Dissemination of results).

JRC-Geel organised a workshop on 15-17 June, 2016, to discuss the new standard with equipment manufacturers, IEC appointed experts and EMPIR DigitalStandard consortium partners. The aim of the workshop was to optimise the benefits of the standard and to accommodate the needs of the primary implementers of the standard. The standard was discussed in depth. Several technical issues were resolved and later implemented in the draft, which was submitted to the IEC/TC 45 secretariat for circulation as first Committee Draft to the National Committees. The IEC/TC 45 member committees have until 20 January, 2017, to comment on the draft. Comments will be discussed and decided upon at the next IEC/TC 45/WG 9 meeting in Brussels on 24 April, 2017.

Collaboration agreements were set up between JRC-Geel and five manufacturers of digital data acquisition instruments, who replied to a call for expression of interest, published in the Official Journal of the EU. To facilitate the commenting process, JRC-Geel developed encoding and decoding software for writing and reading data in the draft IEC 63047 format. Manufacturers have the opportunity to test and discuss the implementation of the draft during laboratory tests, planned at the JRC-Geel EUFRAT facilities in February 2017. Results will be published in an open-access scientific paper.

*Dissemination of results - awareness raising on the new standard in workshops and seminars*

- Jan Paepen. Technical Meeting on Radiation Detection Instruments for Nuclear Security: Current Status, Future Needs, and Improvements, IAEA, Vienna, Austria, 4-8 April 2016.
- Jan Paepen. CENELEC/TC 45B meeting, AFNOR, Saint-Denis, Paris, France, 13-14 April 2016.
- John Keightley. CCRI (II) KCWG, BIPM, Sevres, Paris, France, March 2016.
- Harri Toivonen. GammaSpec 2016 – Nordic Seminar on Gamma-Ray Spectrometry, Rømskog, Norway, 13-14 Sep 2016.

- John Keightley. ICRM RMT WG meeting, NPL, Teddington, UK, 22 September 2016.
- John Keightley. ICRM LSC meeting, ENEA, Rome, Italy, 7-8 November 2016.
- John Keightley. ICRM Life Sciences WG meeting, ENEA, Rome, Italy, 10-11 November 2016.
- John Keightley. CCRI (II) KCWG (II), BIPM, Sevres, Paris, France, 16-17 November 2016.

#### *Publications*

- ERNCIP Office. IEC Standard for List-mode Data Acquisition in Nuclear Measurements, March 2016. Fact sheet, available at [ERNICIP download area](#); or displaying also abstracts, see [Radiological and Nuclear Threats to Critical Infrastructure](#).

## **4.2 Robotics**

### *Robotics trial on radiological and nuclear measuring and mapping*

There is significant potential in the use of unmanned remote controlled vehicles in sampling and measurements in radiological incidents. There are no standardised sampling and measurement methods using these types of vehicles. Common standards would simplify the use of remote controlled vehicles in an emergency scenario and would thus be very valuable in critical infrastructure protection.

In 2016, the RN Thematic group prepared a comprehensive report on the state-of-the-art of the unmanned systems that have potential to be used for radiation measurements and sampling (see below, publications). Search and rescue robotics is the domain that is closest to the robots applicable to the radiation measurement scenarios.

The Group identified a huge gap between what the research and development community is able to deliver, the existing industry state of the art and the user requirements. This includes the complete absence, non-observance or non-compliance of standards, best practices and norms.

The Group prepared a scenario for the European Land Robot Trial (ELROB 2016). This was worldwide the first time ever that so many different heterogeneous robotic teams participated in a completely RN related trial with live radiation sources. The group was able to enforce many international standards. This is a good step forward for further improvements such as the implementation of data format standards IEC 63047 and IEC 62755.

Lessons learned from ELROB 2016 are:

- Unawareness of the RN field needs in robotics community (academic)
- Lack of knowledge in RN sensor handling and measuring
- Lack of possibilities for testing (e.g. strong sources)
- Lack of inexpensive and simple robust RN sensors
- Lack of standards and harmonisation

From these findings, it is clear that there is an urgent need for dedicated RN robotics activity:

- Start robotics community building and raise awareness
- Implement standards (e.g. IEC 63047, IEC 62755, etc.)
- Supply robotics community with professional and regular real world tests

### *Standardization activities - IEC TC45/PT63048*

In October 2015, Korea submitted a New Work Item Proposal to the IEC/TC 45 "Nuclear Instrumentation" for the development of a new International Standard "General requirements for remote and unmanned automatic devices for nuclear and radiological applications". The proposal was accepted and included in the TC 45 work programme with the number IEC 63048. The work was allocated to a new project team, PT 63048. Frank Schneider, ERNCIP RN TG group member, was appointed as expert by the German national committee of TC 45 to participate in the development of the new standard. The project team is currently preparing a draft, which will be circulated to the national committees for comments by the end of 2016.

#### *Publications*

- Frank E. Schneider, Bastian Gaspers, John Keightley, Juha Röning, Jan Paepen. The unmanned systems trial for radiological and nuclear measuring and mapping. Draft October 2016 (in process of being published).

### **4.3 Reachback**

In 2016, the work on reachback focused on raising awareness of the importance of a unified expert support system for Europe. The awareness raising efforts of the RN Thematic Group were linked to on-going international programmes on nuclear security. The Group was in close co-operation with the Detection Group of the Global Initiative to Combat Nuclear Terrorism (GICNT) to organize joint actions.

The main effort was the preparative work to organize a joint international workshop on the roles and responsibilities of technical reachback in nuclear security with the aim to agree on joint formats and protocols to standardize information sharing and data management. In addition to GICNT, the RN Thematic Group was in touch and in cooperation with the JRC-Karlsruhe and the IAEA regarding the development efforts on Expert Support (reachback). It was concluded that all parties have similar interests, and the best way forward is a close cooperation to formulate a road map, starting with a tangible effort to organize the reachback workshop in 28 -30 March, 2017 in Ispra.

The first draft of the workshop agenda was drafted in a planning meeting. The meeting took place in Bucharest on 18 Oct, 2016, as a satellite meeting to a larger CICNT conference on nuclear security, thereby including relevant participants from the key organizations: JRC, GICNT, IAEA, CEA (France) and States Department (US). The outcome of the meeting was a first draft on the agenda covering four major topics:

1. Role of scientific and technical expert support in nuclear security detection architecture
2. Opportunities and challenges of technical reachback
3. Building on core components of technical reachback
4. Advanced technologies

In 2013 – 2015 the RN Thematic Group has written [three major publications](#) on the items above serving the conference agenda in the best possible manner. The complete process on the workshop preparation, including background material (read ahead), is covered in the publications of the RN Thematic Group 2016 (Kari Peräjärvi and Olof Tengblad, see below, Publications).

*Dissemination of results - awareness raising on reachback*

- Harri Toivonen and Kari Peräjärvi. Holistic Approach to Nuclear Security. Global Initiative to Combat Nuclear Terrorism, Nuclear Detection Working Group, Helsinki, 13-14 Jan 2016
- Kari Peräjärvi. Technical Meeting on Radiation Detection Instruments for Nuclear Security: Current Status, Future Needs, and Improvements. Chairperson of technical session 5: Functional and Performance Specifications of Radiation detection instruments; Vendor Presentations and Panel Discussion, IAEA, Vienna, Austria, 4-8 April 2016.
- Harri Toivonen. ERNCIP/IMPROVER Operators Workshop. Reachback: Information sharing to improve the resilience of society in the aftermath of a radiological/nuclear incident. Ispra, 27-28 April 2016.
- Harri Toivonen. ERNCIP: RN threats to critical infrastructure - Remote expert support to field operations in the event of nuclear disaster. 5<sup>th</sup> Meeting of the Community of Users on Safe, Secure and Resilient Societies - Focus on CBRNE. Brussels, 10 October 2016.  
The same presentation was given in
  - Bucharest for the participants of the Reachback planning meeting, 18 Oct 2016
  - Tallinn for the Estonian authorities, 13 Dec 2016.
- Harri Toivonen, Jan Paepen, Frank Schneider. Detection of Radiological and Nuclear Threats to Critical Infrastructure. ERNCIP Group of Experts meeting, Ispra, 2 -3 November 2016.
- Olof Tengblad and Harri Toivonen. Expert support of field teams. Poster. International Conference on Nuclear Security: Commitments and Actions. Vienna, 5 - 9 December 2016.

*Publications in 2016*

- ERNCIP Office. Expert support of field teams, April 2016. Fact sheet and poster, available at [ERNICIP download area](#).
- Olof Tengblad and Harri Toivonen. Reachback: Roles and responsibilities of law enforcement. Internal document Dec 2016.
- Kari Peräjärvi. Preparatory actions towards the JRC/GICNT Technical Reachback Workshop 2017. Internal document Dec 2016.

## 5 Work Programme 2017 – 2018

The RN Thematic Group prepared a proposal for the Work Package for 2017 and 2018 for the consideration of DG HOME, Innovation and Industry for Security for agreeing and allocation of budget.

The main objective is to work in nuclear security for the initiatives towards standardization of novel, advanced radiological and nuclear measurement techniques and related data management in the critical infrastructure protection.

Recently, the universities and the industry have developed new types of segmented radiological sensors which provide excellent possibilities to detect illicit trafficking and other criminal use of radioactive materials much more efficiently than is possible today with conventional sensors. The Group plans to identify these technologies and their properties to pave the way for their usage according to the new list-mode data acquisition standard that will be published early 2018. Of particular importance is the linkage of the list-mode data to reachback data management. These activities will be promoted in the international workshop on reachback, 28-30 March, Ispra.

At the time of writing, discussions on the ERNCIP CBRNE thematic groups work package for 2017 and 2018 are continuing between the ERNCIP Office and DG HOME.

## Appendix 1: ERNCIP RN Thematic Group R&D Proposal for H2020 Call

### □ The general scope

International terrorism is an increasing threat that has shocked European countries during the past year. As terrorist groups become more organized, better financed and more sophisticated, the threat of terrorist getting access to nuclear and other radioactive materials becomes ever more real. This has emphasized the need for the detection of materials out of regulatory control.

Technical solutions for the detection of nuclear and radioactive materials exist, but the detection systems are often complex and too expensive to be deployed in large quantities. The cheaper systems provide only a very limited amount of information, which leads into false alarms. This is especially problematic if the number of detectors is large and the detector are not operated by radiation experts. Solving these alarms manually is time consuming, expensive and often leads into decreased sensitivity. In the worst case, the alarming signals are completely overlooked.

### □ The specific challenge

The challenge of the required research is to develop cost-effective detection systems that can be deployed in large numbers as a network of sensors. The detection systems must provide enough information for rejecting false alarms and determining the right countermeasures. This enables autonomous decision-making, removing the need for costly and time-consuming secondary analysis made by experts. The required research includes development of:

- *High-resolution detectors* operating in room temperature are a key for cost-effective detection and analysis of gamma radiation. The discovery of Lanthanum Halides has led into development of several new high performance scintillator materials; LaBr<sub>3</sub>, CeBr<sub>3</sub>, and SrI<sub>2</sub>. A transparent ceramic material, CYGAG:Ce exhibits promising scintillation properties and offers the advantages in terms of chemical stability and robustness that a ceramic can offer compared to an inorganic crystal.
- *Multifunctional detectors* are capable of detecting gamma, particles and neutron radiation with a single detector unit. Detector can be made either by using novel scintillator materials with high cross-section for different types or radiation (such as Cs<sub>2</sub>LiLaBr<sub>6</sub>:Ce and CLYC, Cs<sub>2</sub>LiYCl<sub>6</sub>:Ce) or by combining two or more scintillator materials (Phoswich configuration) in a single unit.
- *Segmented detectors* give new imaging features that can help in detecting the angle of impact and thus the direction of the source relative to the detector.
- *Neutron spectrometers* open improved response for security applications such as better sensitivity to search directly for fissile material or indirectly other CBRNE materials through active interrogation.
- *Digital signal processing*, (and associated list-mode data storage) in combination to these novel detectors is a critical component to fully take advantage of the sensitivity to both gamma and neutron radiation as well as to take advantage of the imaging possibilities combining different materials in one detector.
- *Sensors*; As the peak wavelength of emission from novel scintillators can vary strongly, it will be necessary to explore the optimum coupling to high-performing photo-sensors, especially the solid-state replacements to the traditional PMtubes such as silicon drift detectors (SDD) and silicon photomultipliers (SiPM). These new sensors need less supply-voltage, are less bulky, weight less and are insensible to magnetic fields, and thus easier adapted to drones and automatic handling.

### □ The expected impact

The simultaneous detection of different radiation will improve the trigger system and lower the risk of false alarm. The directional detection possibility will speed up the search and localisation of hazardous radiation. Compact devices with low power consumption and of low weight are crucial for efficient use with unmanned vehicles.

***Europe Direct is a service to help you find answers  
to your questions about the European Union.***

**Freephone number (\*):  
00 800 6 7 8 9 10 11**

(\* The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

More information on the European Union is available on the internet (<http://europa.eu>).

## **HOW TO OBTAIN EU PUBLICATIONS**

### **Free publications:**

- one copy:  
via EU Bookshop (<http://bookshop.europa.eu>);
- more than one copy or posters/maps:  
from the European Union's representations ([http://ec.europa.eu/represent\\_en.htm](http://ec.europa.eu/represent_en.htm));  
from the delegations in non-EU countries ([http://eeas.europa.eu/delegations/index\\_en.htm](http://eeas.europa.eu/delegations/index_en.htm));  
by contacting the Europe Direct service ([http://europa.eu/europedirect/index\\_en.htm](http://europa.eu/europedirect/index_en.htm)) or  
calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (\*).

(\* The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

### **Priced publications:**

- via EU Bookshop (<http://bookshop.europa.eu>).

## JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.



**EU Science Hub**  
[ec.europa.eu/jrc](https://ec.europa.eu/jrc)



@EU\_ScienceHub



EU Science Hub - Joint Research Centre



Joint Research Centre



EU Science Hub

doi:10.2760/89876

ISBN 978-92-79-65733-7



Publications Office