Proceedings of the Workshop "Cereals straw and agricultural residues for bioenergy in European Union New Member States and Candidate Countries"

2 - 3 October 2007, Novi Sad, Serbia

Editors N. Scarlat, J. F. Dallemand, M. Martinov
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The mission of the Institute for Environment and Sustainability is to provide scientific-technical support to the European Union’s Policies for the protection and sustainable development of the European and global environment.
Preface

The Workshop "Cereals Straw and Agricultural Residues for Bioenergy in New Member States and Candidate Countries" was held on 2-3 October 2007 in Novi Sad, Serbia. The Workshop was organised by the Joint Research Centre (Institute for Environment and Sustainability, "Quality and Performance of Biofuels" Action of the Renewable Energies Unit), in co-operation with the Faculty of Technical Sciences (Department for Biotystems Engineering) of the University of Novi Sad, and the Academy of Sciences and Arts of Vojvodina, Serbia. The Workshop followed a previous seminar on "Sustainable Bioenergy Cropping Systems for the Mediterranean", held in Madrid, Spain, on 9-10 February 2006 and an Expert Consultation on "Cereals Straw Resources for Bioenergy in the European Union", held in Pamplona, Spain, on 18-19 October 2006.

The Novi Sad Workshop addressed the use of crop residues and especially of cereals straw for bioenergy production in European Union New Member States (NMS), Candidate Countries (CC) and Potential Candidate Countries (PCC). A better understanding of the situation on cereal straw and crop residues production and competitive use in NMS, CC and PCC was needed to assess their availability and potential for the use for energy production. The Workshop aimed at collecting more information on the availability and possible use of cereal straw and agricultural residues, status, problems and barriers for implementation, as well as perspectives for development. A list of critical issues to be addressed was proposed and the participants answered questions related to the specific situation in their region and country: basic resources, environmental limits, competitive uses.

The discussions focussed on the implications of using straw for energy on soils and agriculture. Straw is presently mainly used for animal bedding, horticulture, mushroom production and soil fertility. The use of straw for bioenergy can be a good option if it does not affect soil properties, soil organic matter and soil productivity. Straw ploughing in soil influences virtually all soil properties and can lead to some benefits on soil structure, organic matter content, biodiversity, erosion resistance, drought resistance, on cultivation, but can have also some negative effects such as diseases. Some environmental risks caused by the removal of the residues from the field (erosion in sloping and low fertility areas, etc.) were also discussed. The implications of straw removal on soil physical properties, water storage, and soil biology or erosion risk must be considered. In order to use straw for bioenergy, it is necessary to assess the removal rate which can be allowed whilst maintaining soil organic matter, soil properties and fertility. The opinion was expressed that the residues left in the field (roots and stalks) after harvesting might be enough to respond to the environmental requirements.

The meeting participants brought data on the cereal straw production and availability for energy, after considering the current use in other sectors. There are differences in the area cultivated with cereals and yields in EU NMS, CC and PCC, due to different specific geographic and climatic conditions. Yields of cereals are lower than in other EU countries, due to reduced use of fertilizers and pesticides, small scale farms, insufficient machinery and unfavourable climate. This shows that there is quite a big potential to increase the grain production and, consequently the amount of straw available.

Useful data were presented on the competitive uses of cereal straw, which in all these countries are quite important: for animal bedding (cattle, horses), mushroom production, etc. Some data were reported on the available residues from orchards and vineyards, which could be an important source of energy, which has not really been included so far in the assessment of resources availability.
Acknowledgements

The Workshop "Cereals Straw and Agricultural Residues for Bioenergy in New Member States and Candidate Countries" was held in Novi Sad, Serbia on 2-3 October 2007. The organisers of the meeting were N. Scarlat (Renewable Energies Unit, Institute for Environment and Sustainability, Joint Research Centre, European Commission) and M. Martinov (University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia).

The Proceedings were prepared by N. Scarlat and J.-F. Dallemand and the organisers acknowledge the input from all the participants (see detailed list in Annex). Special thanks to M. Martinov (University of Novi Sad, Faculty of Technical Sciences), and M. Tesic (Academy of Sciences and Arts of Vojvodina, University of Novi Sad) for their contribution to the preparation of the meeting and the organisation of the technical visit. Special thanks also to D. Powlson (Rothamsted Research, Harpenden, United Kingdom), whose contribution has been highly appreciated.

This meeting was possible thanks to the support of H. Ossenbrink (Renewable Energies Unit, Institute for Environment and Sustainability, Joint Research Centre, European Commission) within the framework of the activities of the Biofuels Action. The digital version of the Proceedings can be found on the Biofuel website (http://re.jrc.ec.europa.eu/biof/).
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Current activities, recent developments and trends for bioenergy and biofuels in EU

Nicolae Scarlat, Jean-Francois Dallemand, Robert Edwards

Quality and Performance of Biofuels
Renewable Energies Unit

The Institute for Environment and Sustainability

...a Research Based Policy Support Provider

IES Mission Statement

The mission of the Institute for Environment and Sustainability is to provide scientific-technical support to the European Union's Policies for the protection and sustainable development of the European and global environment.
**Renewable Energies Unit**

**Core task**
Scientific support for EU policies on renewable energies and energy efficiency for a sustainable energy supply with emphasis on
- Research on Photovoltaic Solar Electricity
- Monitoring the implementation of renewable energy sources
- Assessment of Biofuels

**Activities**
- Performance and Reliability testing of new Photovoltaic Devices
- EU reference system for Renewable Energies and Energy Efficiency
- European Resources and Environmental Impacts of Biofuels

It maintains in-house research on carefully selected, forward-looking fields which need further European efforts to increase share of Renewable Energies in the competitive market.

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**BioF objectives and activities**

**Study sustainability of biofuels from EU and emerging countries**

1. **Availability vs. cost for EU-sourced feedstock for biofuels and bioenergy**
   - agricultural crops and residues
   - forest residues and extra fellings
   - energy crops
   - biogas: manure, wastes, crops, municipal waste

   Includes:
   - soil carbon + degradation constraints
   - water availability

2. **Imported biofuels and feedstocks**
   - Resource assessment in emerging countries
     Potential production and growth rates
     e.g. sugar cane in Brasil, oilseeds in S-E Asia
   - Environmental Impact outside EU
     - carbon stocks, soil, water and biodiversity
     - bioenergy sustainability standards
BioF objectives and activities

3. GreenHouse Gas performance and cost of biofuels
   - "JEC" WTW study: costs of road fuel substitution and CO₂ abatement
     - update and expand
     - new biofuels pathways and processes
     - compare different uses of biomass
   - Methodology:
     - publish rigorous methodology guidelines
     - simplified version GHG certification of biofuels

4. Wider impact of biofuels/bioenergy policy - cost/benefit analysis
   Effect on:
   - food prices
   - oil prices
   - by-products markets: animal feed, glycerine
   - EU imports/exports

Well-to-Wheels study (JRC-EUCAR-CONCAWE)
   = Life-cycle analysis restricted to quantitative aspects:
     Green-House Gas
     fossil energy
     total energy
     direct costs for given availability.
   = Well-to-Tank + Tank-to-Wheels

Why another Life-Cycle Analysis Study?
   - LCA studies disagree, mostly because of methodology and assumptions about by-product use.
   - Most LCAs cannot be compared:
     - methodology differences (/errors !)
     - not transparent
RESULTS DEPEND ON THE PROCESS AND BY-PRODUCT USE:

Sustainability Certification of Biofuels

Why carbon and sustainability certification?
- Serious concerns about:
  - real GHG biofuels performances
  - negative environmental effects
  - effects on food security of supply (and prices)
- High complexity of biofuels pathways and feedstock
- High differences and uncertainties between GHG performances of biofuels

- Sustainable development - meeting the present needs through adequate management and conservation of the natural resources, without compromising the ability of future generations to meet their own needs.
Main concerns of biofuels production

Environmental
- Land use change, deforestation
- Loss of natural habitats and biodiversity
- Soil erosion, degradation and soil nutrient depletion
- Use of GMOs instead of native species
- Depletion and pollution of water sources
- Emissions to air

Economic:
- Economic prosperity of local communities
- Employment
- Competition for raw material with food production

Social concerns
- Property rights and rights of use
- Labour conditions and worker rights
- Human safety and health

Certification framework
Certification-to ensure that biofuels are produced in a sustainable manner—economically viable and without environmental degradation, or social inequity
- Sustainability certification
  - environment
  - economic
  - social
- GHG certification for quantifying GHG savings (carbon intensity)
- Chain of custody certification-info on the origin and supply chain
Existing certification schemes

Agriculture: EUREP GAP, SAN - voluntary certification of agricultural products meeting certain guidelines for sustainability

Forestry: FSC, PEFC certification of sustainable forest management including economic, environmental and social aspects.

New initiatives for biofuels certification

- Roundtable on Sustainable Palm Oil (RSPO) social, economic, ecological and general criteria on the entire supply chain for palm oil.
- Roundtable on Sustainable Soy (RTRS) - Basel Criteria for responsible Soy - economically viable, socially equitable and environmentally sustainable.
- Better Sugarcane Initiative (BSI) - principles and standards for ‘better sugarcane’ with respect to its environmental and social impacts.
- UK Renewable Transport Fuel Obligations (RTFO) - linking biofuels certificates with GHG savings and sustainability reporting scheme
- Roundtable on Sustainable Biofuels (RSB) standards for the sustainability (environment, social, GHG and implementation) of biofuels (EPFL, Lausanne, Switzerland).
- Certification of Sustainable biomass production in The Netherlands including GHG balance and sustainability criteria

Networking

- Workshop on "Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries", 2 - 3 October 2007, Novi Sad, Serbia, in cooperation with University of Novi Sad.
- Expert consultation on "EU Forest-based biomass for energy: cost/supply relations and constraints" 18-19 September 2007, Joensuu, Finland, with Metla, European Forest Institute.
RES policy framework

RES White Paper (1997)
- To achieve a share of renewable energy from 6% to 12% of the total energy consumption in EU by 2010


RES Electricity Directive (2001)
- To establish a framework to increase the share of renewables electricity from 14% to 22% of gross electricity consumption by 2010

- To achieve a share of 5.75 % of biofuels for transport in the total amount of fuels in Europe by 2010


Renewable energy targets 2010
- RES share of 12 % in total primary energy consumption
- RES electricity share of 21 % in gross electricity consumption
- Biofuels share of 5.75 % in transport fuel consumption

Renewable energy mandatory targets for 2020
- Renewable energies share of 20 % in overall EU energy consumption
- Binding minimum target of 10 % share of biofuels in overall EU transport consumption
- GHG emissions reduction of 20 %

Renewable energy today
- About 14 % of all EU electricity supply is generated by RES
- About 10 % of heat demand is supplied by RES
- About 1.4 % of transport fuel demand by renewable energy sources
**Difficulties of meeting RES targets**

- High costs of renewables—external costs not considered for fossil fuels
- Decentralised nature of RES application
- Administrative barriers and discriminatory rules for grid access
- Inadequate information available
- Expressing RES targets against primary energy—disadvantages for wind, solar and hydro energy
- Increased energy consumption, invalidating RES progress

**RES heating**
- Not single market for renewable heating
- Market is not regulated
- Difficulties for monitoring of sales

**RES deployment** depends on a coherent, predictable, supportive political & legal framework.

**White Paper—Targets 1995…2010**

- Electricity Generation by Renewable Electricity Sources [TWh]
- Current trend in biomass use for energy and Biomass Action Plan
Renewable energy sources in EU in 2005

Share of renewable energies in primary energy consumption in EU in 2005 [%]

- Latvia: 45.6%
- Sweden: 44.2%
- Finland: 42.7%
- Austria: 40.1%
- Denmark: 39.8%
- Portugal: 37.7%
- Slovenia: 37.6%
- Estonia: 36.5%
- Lithuania: 35.4%
- Spain: 34.3%
- France: 32.7%
- Italy: 32.5%
- Greece: 32.3%
- Poland: 30.9%
- Slovak Republic: 30.7%
- Hungary: 30.5%
- Germany: 29.9%
- Czech Republic: 29.7%
- Ireland: 29.5%
- Belgium: 29.3%
- Cyprus: 29.1%
- Malta: 28.9%
- EU: 28.7%

Share of different resources in the renewable primary energy production in EU in 2005

- Biomass: 66.1%
- Geothermal: 5.5%
- Hydro power: 22.2%
- Wind power: 5.5%
- Solar: 0.7%

Share of renewable energies in gross electricity consumption in EU in 2005 [%]

- Austria: 44.2%
- Sweden: 43.8%
- Latvia: 42.7%
- Finland: 42.5%
- Denmark: 40.1%
- Slovenia: 37.7%
- Estonia: 36.5%
- Lithuania: 35.4%
- Spain: 34.3%
- Portugal: 32.7%
- Italy: 32.5%
- Greece: 32.3%
- Poland: 30.9%
- Slovak Republic: 30.7%
- Hungary: 30.5%
- Germany: 29.9%
- Czech Republic: 29.7%
- Ireland: 29.5%
- Belgium: 29.3%
- Cyprus: 29.1%
- Malta: 28.9%
- EU: 28.7%

Share of different resources in the renewable electricity production in EU in 2005

- Hydro power: 66.4%
- Wind power: 16.3%
- Solar: 0.3%
- Biomass: 15.8%
- Geothermal: 1.2%

Gross electricity production from solid biomass in EU in 2005 [TWh]

- Finland: 11.1 TWh
- Sweden: 10.9 TWh
- Germany: 9.1 TWh
- Netherlands: 6.4 TWh
- UK: 6.2 TWh
- Italy: 4.5 TWh
- Austria: 4.3 TWh
- Denmark: 3.9 TWh
- France: 3.8 TWh
- Spain: 3.4 TWh
- Portugal: 3.0 TWh
- Poland: 2.9 TWh
- Belgium: 2.6 TWh
- Hungary: 2.1 TWh
- Czech Republic: 1.9 TWh
- Slovenia: 1.5 TWh
- Slovak Republic: 1.5 TWh
- Ireland: 1.3 TWh

Energy production from biomass in 2005

- Electricity only
- CHP

Gross heat production from biomass in EU in 2005 [toe]

- Sweden: 1.8 toe
- France: 1.6 toe
- Finland: 1.5 toe
- Germany: 1.4 toe
- Austria: 1.3 toe
- Italy: 1.2 toe
- UK: 1.1 toe
- Czech Republic: 1.0 toe
- Poland: 1.0 toe
- Slovenia: 0.9 toe
- Hungary: 0.8 toe
- Belgium: 0.7 toe
- Netherlands: 0.6 toe
- Slovakia: 0.6 toe
- Ireland: 0.5 toe

Source: EuroObserv ER
Liquid biofuels production in EU

Bioenergy pathways

agriculture

forestry

domestic & industrial waste

resource

conversion technology

utilisation

oil crops

sugar & starch crops

solid biomass

wet biomass

estification

hydrolysis/fermentation

pyrolysis

gasification

combustion

anaerobic fermentation

liquid biofuels for transport (ethanol, FAME, DME, etc.)

Electricity

heat

steam

cogeneration

Electricity

estification

hydrolysis/fermentation

pyrolysis

gasification

combustion

anaerobic fermentation

liquid biofuels for transport (ethanol, FAME, DME, etc.)

EU 15

EU10

Source: EurObserv'ER
Straw potential in EU
- abundant throughout Europe
- easily available resource
- available scalable technology

however...
- high capacity installations only in DK, UK and ES
- slow transfer of know-how to other regions
- little information below national level
- factors are site sensitive

Straw plants
- 11 Plants in Denmark
- Ely (38 MW) power station, UK
- Sangüesa (25 MW), Spain

GIS-based assessment of cereal straw energy in the EU

Objectives
Inventory of straw from wheat and barley in EU25+2
- actual production
- environmental constraints
- competitive use
- availability for energy

Suitability for large scale electricity generation
- example of Ely power station (UK, 38MW)
- economics
- suitability maps
- localization/optimization
Straw inventory
Straw from wheat & barley in 2003 (1000 tones/region)

Straw available for energy (1000 tones/region)

Density of straw for energy

Assumptions:
• yearly consumption 200 000 ton + 50% reserve
• transport distance up to 50km

EU could host up to 67 “Ely clones” (38 MW)
FR: 28  PL: 2
UK: 15  IT: 1
DK: 7   SE: 1
DE: 6   SK: 1
ES: 5   CZ: 1
Total capacity: 2.5 GW
Straw energy utilized: 230 PJ (LHV thermal)
(out of a total available 820PJ)

BUT... straw-collection logistics needs to be assessed
for each potential location
Aspects of using straw for energy

Resources
- Straw availability depends on the agricultural markets, climatic conditions
- Sustainability of straw removal is important
- Vulnerability to market change, short term weather and long-term climate change
- Local sustainability of straw removal
- Competitive use – traditional use – energy use
- Trade

Logistics
- Transport logistics crucial
  - Limit the plant size to ~50 MWel
  - Size is site-specific - optimal 10-15 MW max. 36 MW
- Storage is an important aspect- large storage areas required
- Large volumes involved as only 2 month harvest window for straw
- Limitations due to low heat demand, grid connection - rural sites, limited grid capacity

Technical issues
- Available technology, demonstrated, high plant availability
- CHP should be preferred where heat demand is high: in industry and district heating
- Local heating boilers is a cheap and practic way to use straw
- Co-firing could be an option
- Feedstock quality impacts plant operation.
- Necessary to standardize the fuel input

Economic issues
- Costs for collection, transport, storage
- Conversion vs. size
- Competition with other use may offer better prices to farmers
- Development of support schemes are needed
Using straw for energy - implications for soils & agriculture

David Powlson
Lawes Trust Senior Fellow, Rothamsted Research, UK

Climate change

“The greatest long-term challenge we face”
- Tony Blair, former UK Prime Minister

“A greater threat than terrorism”
- David King, UK Government Chief Scientific Adviser
Responses

- Decrease CO$_2$ emissions from fossil fuels
- Decrease trace GHG emissions
  - N$_2$O, CH$_4$
To decrease CO$_2$ emissions:

- Energy saving
- Lifestyle changes
- Renewable energies (electricity, heating, transport)
- Carbon sequestration (biological, geological)

Renewable energies

Bioenergy
Types of bioenergy

- Agricultural crops used for energy instead of food (bioethanol, biodiesel)
  - “1st generation bioenergy crops”
- Dedicated biomass crops
  - “2nd generation bioenergy crops”
- Crop residues and other “wastes” incinerated for electricity or CHP
- Anaerobic digestion of animal slurry
- Photosynthetic algae in solution culture

Bioenergy crops – “1st generation”

- Bioethanol
- Biodiesel
Using agricultural crops for energy (bioethanol, biodiesel)

Advantages
- Easy to grow – farmers familiar with crops
- Easy processing
- Produce liquid transport fuels
- No major infrastructure changes
- Soil requirements - as for food
- Environmental impacts - as for food

Disadvantages
- *Little CO₂ saving!*
  - CO₂ emissions from N fertilizer production
  - energy for processing
  - N₂O from soil where N applied
- Impacts on world food supplies
- Perverse incentives – e.g. clearing forests to grow palm oil – extra CO₂ emissions!
Bioenergy crops – “2nd generation”

Dedicated biomass crops – mainly perennials

Willow

Miscanthus giganteus

Perennial energy grasses growing in Dundee – Topgrass project (DTI/Defra)

Miscanthus

Switchgrass

Reed canary grass
Co-firing:
Drax coal-fired power station, UK

- Miscanthus
- Wood chips

**LIHD** = low-input high-diversity grassland biomass

Crop residues for bioenergy:

**Cereal straw**

**Ely, UK**

**Sanguesa, Spain**


North American examples
Fate of straw:

- Burn in the field
- Incorporate into soil
- Animal bedding
- Surface mulching in horticulture
- Industrial uses, e.g. fibreboard
- Energy

Some organic C returned to soil
Straw -

- Convenient for bioenergy. But …
- One of few options for maintaining OM content of arable soils
- EU Commission identifies OM decline as a threat to soils in Europe
- Nutrient removal - K

RothC simulations

Silty clay loam

Removing straw leads to gradual decline in SOC
Soil organic matter (SOM) matters!

- Influences virtually all soil properties
  eg, physical structure, ease of cultivation, ease of root growth, erosion, nutrients, biodiversity ("soil quality")
- Generally, more is better!
- Additional environmental benefit
  locking up (sequestering) C from atmosphere

Caution!

But not so simple.....!

- **TOTAL** soil organic matter content changes *slowly* in response to straw or other organic additions (years – decades).

- But individual **FRACTIONS** and soil **FUNCTIONS** associated with OM change *faster* and *proportionately more* than total.
• Evidence that small change in total C has larger proportional influence on soil physical properties
  – Energy for tillage
  – Aggregate stability
  – Water infiltration rate
• Evidence from
  – Farmer assessments
  – Research - Broadbalk long-term experiment
UK Defra project

Objectives included:

• Record farmer’s assessment of management benefits from increased SOM (often resulting from straw incorporation)
  – interviewed 110 farmers.
• Estimate financial of value on SOM based on farmer’s estimates of management benefits.

Farmer measurements/observations on SOM impacts

Some evidence that farmers could detect changes caused by increased SOM sooner than by traditional “scientific” measurements

Main benefits:
• Cultivation, soil structure, crop establishment, drought resistance, earthworms, less fertilizer

Some negatives:
• Diseases
What determines SOM economic value?

Most important factors:

- Soil type
- Value of crops benefiting from SOM
- Costs of animal manure application
- Price of straw if sold (animal bedding, energy)

Net value of SOM management: €8-80/ha/yr

Considerable assumptions and uncertainties!
- Highly dependant on nature of enterprise
- Intangibles (e.g. timeliness, flexibility) may be more significant

Plough draught

- Small increases in SOM led to decrease in energy required for cultivation
- SOM favoured by increased crop residues (N fertilizer and straw incorporation)

Watts, Clark, Poulton, Powlson, Whitmore (2006)

*Soil Use and Management* 22, 334-341
Broadbalk
- Winter wheat (continuous & rotation)
  Started 1843

Draught Forces & Energy

Doppler radar sensor
(forward speed)

Strain gauged frame
(to measure draught forces)

Laser proximity sensors
(depth & front furrow width)

Draught Force
### Specific draught measurements: Broadbalk Experiment, Rothamsted

![Diagram of specific draught measurements at Broadbalk Experiment, Rothamsted](image)

Watts, Clark, Poulton, Powlson, Whitmore. 

### Broadbalk – SOC and specific draught

<table>
<thead>
<tr>
<th>Treatment</th>
<th>SOC %</th>
<th>Specific draught, $S$ kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>0.84</td>
<td>88</td>
</tr>
<tr>
<td>FYM</td>
<td>2.80 ($\uparrow233%$)</td>
<td>75 ($\downarrow15%$)</td>
</tr>
<tr>
<td>NPK</td>
<td>1.08 ($\uparrow29%$)</td>
<td>77 ($\downarrow12%$)</td>
</tr>
</tbody>
</table>

Watts, Clark, Poulton, Powlson, Whitmore. 
“Labile C” – easily oxidisable – about 10% of total C (microbial biomass + metabolites)

- Increased by straw incorporation and N fertilizer application (larger yields, larger residue returns)
- “Labile C” – correlated with:
  - Increased aggregate stability
  - Increased water infiltration rate


---

Rothamsted, Broadbalk Experiment

![Graph showing relationship between labile C and total C with mean weight diameter (MWD)]

Fig. 2. Linear relationships of total N ($N_T$), labile C ($C_L$), non-labile C ($C_{NL}$) and total organic C ($C_T$) with mean weight diameter (MWD) for the Broadbalk Wheat Experiment for the low C treatments. (*"P < 0.01; "P < 0.05."

*Aggregate stability related to “labile C” — increased by straw and N fertilizer*

Water infiltration rate related to “labile C”
- increased by straw and N fertilizer

Other benefits from straw addition to soil

- Source of organic N (very slowly available)
- Immobilisation of N in short term:
  - would expect some decrease in nitrate leaching
  - but very limited direct evidence of significant effect
- Source of K
- Potential to decrease soil erosion
Potential for soil erosion – southern Spain.
(Rotation: wheat – spring crop); long periods of bare soil.
• Soil sustainability
• Water quality – phosphate, sediments

Climate change impacts.
• Bare soil exposed to increasingly intense winter rainfall.
• More spring crops under climate change?

Soil erosion decreased by:
• Minimum tillage
• Straw on soil surface

Malagon long-term experiment, University of Cordoba.
Use straw for bioenergy?

- Assess number of years when straw could be removed whilst maintaining SOM
  - Affects area required to supply power plant
- Remember nutrient removal – K
- Consider implications for soil physical properties, on- and off-site
  - tillage, surface capping, seedling emergence, water storage, soil biology, erosion risk
- Straw burning power plants – may permit development of biomass crops – increasing security and continuity of biomass supply
- Consider mix of straw and biomass crops for energy – rather than straw alone
Cereal/Soybean Straw and other Crop Residues Utilization as Fuel in Serbia – Status and Prospects –

Prof. Dr. Milan Martinov, Prof. Dr. Milos Tesic
Faculty of Technical Sciences, Novi Sad

1. Introduction
2. Crop residues, arts and potentials
3. Soil amelioration
4. Current utilization
5. Visions and prospectus
1. INTRODUCTION

Fossil fuels consumption in Serbia, 11.8 mil. toe* of primary energy per annum.

Biomass total potential – 2.7 million toe.

Crop residues biomass – 1.4 million toe.

About 4.5 million ha of agricultural land, and about 3.5 million ha of sowing land.

Field production about 2.6 million ha, 20% big farms.

Two groups of farms, big, over 200 ha, small (up to 50 ha), and medium (50 to 200 ha) – S&M. Different production technology, different energy needs and approach to energy production and utilization.

*) 1 toe – ton of oil equivalent = 41 860 MJ
2. CROP RESIDUES, STATUS AND POTENTIALS

Significant agricultural residues of field production in Serbia:

- cereal straw
- maize stover and cobs
- soybean straw
- oil rape straw

Crop residues yields

The production technology and grain yield of big and small and medium (S&M) farms is different, i.e. higher at big farms.

Harvestable straw for all cereals is approximately the same, according to farmers data about 3 t/ha for big farms, and 2.5 t/ha at S&M farms. The same holds for soybean, and slightly higher for oil rape.

Sunflower crop residues harvestable yield is approximately twice higher than the grain yield, i.e. about 5 t/ha (Martinov, 1982).

Maize stover harvestable yield is about 60% of the grain yield. Average 5 t/ha for big and 4 t/ha for S&M farms.

The maize cobs yield is in the range 15 to 18% of the grain yield (Martinov and Topalov, 1984). This is on average approximately 1 t/ha, for most big and S&M farms (big farms have higher yield but only seed production was considered, and this yield is comparable with that of S&M farms).
Restrictions

Both big and S&M farms apply the so-called conservation tillage, whereby all crop residues remain in soil. Conservation tillage is applied on about 30% of fields, and this share shows growing tendency.

Maize stover can be harvested only until the second half of October, i.e. Later on, it is too soiled and too wet. That means, only early hybrids can be harvested. Their share is estimated to be about 20% for big and 15% for S&M farms. There is no mature technique for stover harvesting.

Dominate maize harvesting procedure for S&M farms is picking/husking of maize ears, and natural drying. Maize cobs are available in the farmers’ yard after drying and shelling, end of February. The share of this technology is assessed to be 70%. Big farms use same technology for seed production. This is about 10% of the total. Maize cobs are available already in October, November, and can be used for drying of maize ears.

There is no procedure and machinery for harvesting of sunflower crop residues.

Other utilization

Most significant use of diverse straws is for animal bedding. The share of the so-used straw is calculated to be approximately 5% for big and 10% for S&M farms. Soybean and oil rape straw is exceptionally used for this purpose.

Maize stover is used as cattle fodder. It is not used on big farms and part used at S&M farms is assessed at 10%.

In some cases storage and transportation losses have been calculated, as well as the other minor non-energy utilizations.
Comments and perspectives

Total amount of biomass usable for energy purposes is more than 3.7 million tons. Calculating 3 kg of biomass for 1 kg of oil of primary energy, the equivalent is 1.23 million toe. Together with pruning and other agricultural residues this is about 1.4 million TOE, as calculated in previous studies of biomass potentials, or 11.8% of total fossil fuel primary energy used per annum.

Trends of production are also given in the table. Considerable rise is expected for rape oil, due to new factory of biodiesel. The rise of maize and soybean production is also expected due to better prices, production of bio ethanol.

Over 80% is located at S&M farms. This category should be more targeted in the future.
3. SOIL AMELIORATION

Agronomists do not support removal of crop residues from the fields, in Serbia as in the other countries (Kastori and Tesic, 2005). On the other hand there are no experimental data on the effects of biomass removal on soil fertility reduction. Through roots, stubble and harvesting residues more than two thirds of residual biomass remain in the soil. The current practice in the country is also burning of crop residues. This is prohibited by law, but widely applied.

The removal of nutrients has also been evaluated as negative, but most of them can be brought back by spreading of coarse combustion ash of biomass.

Influence of biomass removal in big scale should be further investigated, but it seems that the presented amount should not have negative effects on soil and ecology. This is especially the case for maize, as the most popular crop.

4. CURRENT UTILIZATION

Tab. 2  Assessment of currently used crop residues in Serbia

<table>
<thead>
<tr>
<th>Crop residue</th>
<th>Big farms, 1,000 t</th>
<th>S&amp;M farms, 1,000 t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal straw</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Maize stover</td>
<td>–</td>
<td>60</td>
</tr>
<tr>
<td>Maize cobs</td>
<td>10</td>
<td>900</td>
</tr>
<tr>
<td>Soybean straw</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>1,170</td>
</tr>
</tbody>
</table>

1,350

Only about 36% of available crop residues used, 87% by S&M farms owners and other users in their vicinity.
### Tab. 3 Example of straw use as a fuel in one big farm with 7,000 ha

<table>
<thead>
<tr>
<th>Unit</th>
<th>Heating area, m²</th>
<th>Required boiler power, kW</th>
<th>Installed boiler power, kW</th>
<th>Manufacturer</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martinci</td>
<td>2.528</td>
<td>500</td>
<td>250+150</td>
<td>Ekoprodukt</td>
<td>Straw</td>
</tr>
<tr>
<td>Lačarack</td>
<td>972</td>
<td>194</td>
<td>300</td>
<td>Ekoprodukt</td>
<td>Straw</td>
</tr>
<tr>
<td>Veliki Radinci</td>
<td>1.425</td>
<td>285</td>
<td>400</td>
<td>Terming</td>
<td>Straw</td>
</tr>
<tr>
<td>Sr. Mitrovica</td>
<td>1.637</td>
<td>327</td>
<td>300</td>
<td>Terming</td>
<td>Straw</td>
</tr>
<tr>
<td>Svinjogojska farma</td>
<td>7.827</td>
<td>1564</td>
<td>750</td>
<td>Nigal</td>
<td>Straw</td>
</tr>
<tr>
<td>Bosut</td>
<td>210+316</td>
<td>42+36</td>
<td>120</td>
<td>Ekoprodukt</td>
<td>Straw</td>
</tr>
<tr>
<td>Divoš</td>
<td>817</td>
<td>163</td>
<td>80</td>
<td>Terming</td>
<td>Straw</td>
</tr>
<tr>
<td>Sremska Rača</td>
<td></td>
<td></td>
<td>35</td>
<td>Stadler</td>
<td>Wood, coal</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15.714</strong></td>
<td><strong>3.112</strong></td>
<td><strong>2.685</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### The list of major domestic producers of biomass facilities

<table>
<thead>
<tr>
<th>No</th>
<th>Manufacturer</th>
<th>Web</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TERMIN D.O.O.</td>
<td><a href="http://www.terminkula.co.yu">www.terminkula.co.yu</a></td>
<td>Straw and maize cobs boilers 40–1100 kW</td>
</tr>
<tr>
<td>2</td>
<td>SUKOM D.O.O.</td>
<td><a href="http://www.sukom.co.yu">www.sukom.co.yu</a></td>
<td>Straw boilers 100–1000 kW</td>
</tr>
<tr>
<td>3</td>
<td>PODVIS-TERM A.D.</td>
<td><a href="http://www.podvisterm.co.yu">www.podvisterm.co.yu</a></td>
<td>Straw boilers 30–1800 kW</td>
</tr>
<tr>
<td>4</td>
<td>METALAC A.D.</td>
<td><a href="http://www.inter-mehanika.com">www.inter-mehanika.com</a></td>
<td>Straw boilers 20–80 kW</td>
</tr>
<tr>
<td>5</td>
<td>KIRKA-SURI D.O.O.</td>
<td><a href="http://www.kirka.co.yu">www.kirka.co.yu</a></td>
<td>Straw boilers, medium and big, over 1 MW</td>
</tr>
<tr>
<td>6</td>
<td>TEHINSERV</td>
<td></td>
<td>Straw boilers 25–120 kW</td>
</tr>
<tr>
<td>8</td>
<td>NIGAL D.O.O.</td>
<td></td>
<td>Big straw boilers and hot air generators, over 500 kW</td>
</tr>
<tr>
<td>9</td>
<td>EKO PRODUKT</td>
<td></td>
<td>Straw boilers 120–400 kW</td>
</tr>
<tr>
<td>10</td>
<td>TERMOHORT</td>
<td><a href="http://www.termomont.co.yu">www.termomont.co.yu</a></td>
<td>Small and medium straw boilers</td>
</tr>
<tr>
<td>11</td>
<td>ALFA PLAM</td>
<td><a href="http://www.alfa-plam.co.yu">www.alfa-plam.co.yu</a></td>
<td>Biomass stoves</td>
</tr>
<tr>
<td>12</td>
<td>RAZVOJ</td>
<td></td>
<td>Biomass boilers 40 kW to 1 MW</td>
</tr>
<tr>
<td>13</td>
<td>TERMOPLIN D.O.O.</td>
<td><a href="http://www.termaplin.co.yu">www.termaplin.co.yu</a></td>
<td>Biomass boilers and hot air generators(driers)</td>
</tr>
<tr>
<td>14</td>
<td>RADIJATOR INJENJERING</td>
<td><a href="http://www.radijator.co.yu">www.radijator.co.yu</a></td>
<td>Biomass boilers 18–250 kW</td>
</tr>
<tr>
<td>15</td>
<td>ZIVANKO ARNAUTOVIC</td>
<td></td>
<td>Biomass hot air generators 20–55 kW</td>
</tr>
<tr>
<td>16</td>
<td>INOMAG</td>
<td></td>
<td>Biomass boilers</td>
</tr>
<tr>
<td>17</td>
<td>RADIJATOR</td>
<td></td>
<td>Biomass boilers, small and medium</td>
</tr>
<tr>
<td>18</td>
<td>DP ZASTAVA-METAL</td>
<td></td>
<td>Biomass boilers 32–63 kW</td>
</tr>
<tr>
<td>19</td>
<td>MEGAL A.D.</td>
<td><a href="http://www.megal.co.yu">www.megal.co.yu</a></td>
<td>Biomass boilers and stoves 18–140 kW</td>
</tr>
<tr>
<td>20</td>
<td>MILAN BLAGOJEVIC A.D.</td>
<td><a href="http://www.mbs.co.yu">www.mbs.co.yu</a></td>
<td>Biomass stoves</td>
</tr>
<tr>
<td>21</td>
<td>ABC Proizvod</td>
<td><a href="http://www.abcproizvod.co.yu">www.abcproizvod.co.yu</a></td>
<td>Biomass boilers 25–130 kW</td>
</tr>
</tbody>
</table>
Problem: Low efficiency and high pollutant emission

Tab. 4 Example of boiler testing results (Brkic and Martinov, 2006)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Declared power, kW</th>
<th>Measured power, kW</th>
<th>η, %</th>
<th>λ</th>
<th>CO₂, %</th>
<th>CO₂, mg/Nm³</th>
<th>NO₂, mg/Nm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratstvo I</td>
<td>40</td>
<td>41.9</td>
<td>54</td>
<td>2.8</td>
<td>1.7-3.6</td>
<td>5.7-11.6</td>
<td>2.28-5.91</td>
</tr>
<tr>
<td>Bratstvo II</td>
<td>360</td>
<td>145-317</td>
<td>64-72</td>
<td>1.3-2.7</td>
<td>2.5-15.5</td>
<td>2.8*</td>
<td>0-4.8*</td>
</tr>
<tr>
<td>Nigal</td>
<td>750</td>
<td>299-530</td>
<td>43-69</td>
<td>2.8-7.9</td>
<td>2.4-6.5</td>
<td>1.8-2.8</td>
<td>1.7-2.43</td>
</tr>
<tr>
<td>Razvoj</td>
<td>400</td>
<td>249-369</td>
<td>63</td>
<td>2.1-4.8</td>
<td>1.5-5.9</td>
<td>3.1-15.3</td>
<td>2.0-5.2</td>
</tr>
<tr>
<td>Šukom</td>
<td>250</td>
<td>171-232</td>
<td>31-67</td>
<td>1.8-8.8</td>
<td>1.8-11.0</td>
<td>1.6-9.0</td>
<td>34.9-7</td>
</tr>
<tr>
<td>Terming</td>
<td>500</td>
<td>59-170</td>
<td>50-73</td>
<td>1.3-3.5</td>
<td>5.5-14.4</td>
<td>4.0-6.4</td>
<td>1.7</td>
</tr>
</tbody>
</table>

η – energy efficiency, λ – air excess ratio, (*) in %

Domestic developments

Scheme of developed small straw conventional bales boiler
Demerits of oil boiler:
- high emission of pollution
- difficult to handle
- high fuel costs

Merits of biomass boiler:
- high efficiency
- low emission
- easy to handle

Biomass competitive in comparison with heating oil!
Pilot plant, about 1 MW thermal power boiler, for soybean straw round bales

New boiler of this type, for big rectangular bales of soybean straw, 1.2 MW, under construction. It should serve as demonstration plant used for heating of greenhouse.

5. VISIONS AND PROSPECTS

Wider use of crop residues can be expected first after introduction of subsidies and other financial supports

Simultaneous development of rural areas –societal, economic and demographic effects

CHP and tree-generation

Co-firing

Biodiesel

Bio-ethanol
Small and medium farms produce over 70% of total agricultural residues. They already use crop residues as a fuel for household heating. The facilities should be more efficient and have lower emission of pollutants.

In this sector utilization of crop residues is traditional, but the is very low. Profitable use is possible in many cases, also without subsidies.

Most dominant fuel are maize cobs.

Contemporary facilities are urgently needed.

It is unrealistic to expect merger of few households to use district heating.

Development of local specific low-cost facilities is needed.

Typical project can be

**Energetically and environmentally improved maize harvesting and drying technology in SEE**

Big farms already now use crop residues as energy source for different purposes; further growth is expected, especially if the subsidies are to be introduced. They are also capable to invest in CHP. The problem is inhomogeneous form of bales (conventional, round and big rectangular bales of different dimensions), and unstable prices of crop residues.

Big farms are suitable for demonstration plants.

Good future for soybean and rape straw.

Technology from EU applicable in the future.
REFERENCES


Sergej Usťak: Biomass as a renewable source of energy in the Czech Republic

The map of the Czech Republic
The targets of the current Czech National Programme for Energy Efficiency and Renewable and Secondary Energy Sources for the year 2010 are:

1) Production of electricity from renewable sources in the amount 8% (EU-21%) of the gross electricity consumption;

2) Share of renewable energy sources in the total primary energy consumption at the level 6% (EU-12%) of the total primary energy consumption;

<table>
<thead>
<tr>
<th>Source of energy</th>
<th>Share of total primary energy sources, %</th>
<th>Share of total electricity production, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>48,3</td>
<td>59,3</td>
</tr>
<tr>
<td>Oil *</td>
<td>19</td>
<td>0,03</td>
</tr>
<tr>
<td>Natural gas *</td>
<td>19</td>
<td>4,63</td>
</tr>
<tr>
<td>Nuclear</td>
<td>9,3</td>
<td>30,1</td>
</tr>
<tr>
<td><strong>Renewable sources of energy (RES)</strong></td>
<td>4,31</td>
<td>4,17</td>
</tr>
<tr>
<td>others</td>
<td>0,09</td>
<td>1,77</td>
</tr>
</tbody>
</table>

* - imported sources
** - share of gross electricity consumption - 4,91 %
2006: Renewable energy share of gross electricity consumption (GEC - approx. 71,7 TWh per year): 4,91 % or 3,52 TWh;

Renewable energy share of total electricity production (TEP - approx. 84,4 TWh per year): 4,17 % or 3,52 TWh;

Renewable energy share of primary energy sources (PES - approx. 1 903 PJ per year): 4,31 % or 82 PJ;

Structure of renewable energy sources (RES, 4,31 % of total PES in 2006) in the Czech Republic (% of RES):

- Household biomass: 0,97%
- Rest biomass: 3,24%
- Water: 3,23%
- Biowaste: 0,22%
- Biogas: 0,16%
- Liquid biofuels: 11,21%
- Geothermal: 48,99%
- Wind: 31,16%
- Solar: 0,83%
Currently biomass is the most important source of renewable energy in the Czech Republic!!!

In the Czech Republic households are the main consumer of RES - renewable energy sources (about a half of total renewable energy). The main source of household energy is solid biomass for the purposes of heat generation, first of all firewood and wood residues, which are obtained by purchase by the sellers of fuels or self collection or by the businesses handling with this resource originated from forest, from the maintenance of city and village green etc.
### Number of domestic installations burning or co-burning biomass fuel in Czech Republic (MPI-2005)

<table>
<thead>
<tr>
<th>Installations</th>
<th>Total amount</th>
<th>For biomass</th>
<th>For coal and biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen-stoves</td>
<td>75 500</td>
<td>56 500</td>
<td>19 000</td>
</tr>
<tr>
<td>Heating boilers</td>
<td>284 000</td>
<td>105 900</td>
<td>178 100</td>
</tr>
<tr>
<td>Heating and hot water boilers</td>
<td>116 500</td>
<td>47 100</td>
<td>69 400</td>
</tr>
<tr>
<td>Local heaters</td>
<td>126 200</td>
<td>66 200</td>
<td>60 000</td>
</tr>
<tr>
<td>Hot water boilers</td>
<td>21 600</td>
<td>17 300</td>
<td>4 300</td>
</tr>
<tr>
<td>Hearthstones</td>
<td>66 900</td>
<td>66 900</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td><strong>690 700</strong></td>
<td><strong>359 900</strong></td>
<td><strong>330 800</strong></td>
</tr>
</tbody>
</table>

### Development of household biomass consumption in CZ during 2003-2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Solid biomass, millions t</th>
<th>Energy of biomass, PJ</th>
<th>Achieved heat, PJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>2,65</td>
<td>34,5</td>
<td>21,8</td>
</tr>
<tr>
<td>2004</td>
<td>2,83</td>
<td>36,8</td>
<td>23,3</td>
</tr>
<tr>
<td>2005</td>
<td>2,85</td>
<td>37,1</td>
<td>23,5</td>
</tr>
<tr>
<td>2006</td>
<td>3,09</td>
<td>40,1</td>
<td>25,4</td>
</tr>
</tbody>
</table>
Czech Republic has relatively good condition for wood biomass production due to the large areas of forest:

<table>
<thead>
<tr>
<th>Total area, millions ha</th>
<th>Forest, millions ha</th>
<th>Forest on total area, %</th>
<th>Coniferous, millions ha</th>
<th>Deciduous, millions ha</th>
<th>Average age of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.89</td>
<td>2.58</td>
<td>32.8 %</td>
<td>1.98</td>
<td>0.58</td>
<td>63</td>
</tr>
</tbody>
</table>

Development of wood exploitation and fire wood deliveries in CZ during 2001-2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Wood, millions m³</th>
<th>Fire wood, millions m³</th>
<th>Wood, millions t</th>
<th>Fire wood, millions t</th>
<th>Forest waste, millions t</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>14.4</td>
<td>--</td>
<td>8.62</td>
<td>--</td>
<td>1.29</td>
</tr>
<tr>
<td>2002</td>
<td>14.5</td>
<td>--</td>
<td>8.72</td>
<td>--</td>
<td>1.31</td>
</tr>
<tr>
<td>2003</td>
<td>15.1</td>
<td>1.09</td>
<td>9.08</td>
<td>0.65</td>
<td>1.36</td>
</tr>
<tr>
<td>2004</td>
<td>15.6</td>
<td>1.19</td>
<td>9.36</td>
<td>0.71</td>
<td>1.40</td>
</tr>
<tr>
<td>2005</td>
<td>15.5</td>
<td>1.23</td>
<td>9.31</td>
<td>0.74</td>
<td>1.40</td>
</tr>
<tr>
<td>2006</td>
<td>17.7</td>
<td>1.35</td>
<td>10.61</td>
<td>0.81</td>
<td>1.59</td>
</tr>
</tbody>
</table>

* - without bark
The potential of forest biomass of Czech Republic consists of wood residues from the wood-processing industry, thinning, pruning and firewood.

<table>
<thead>
<tr>
<th>Potential</th>
<th>energy (PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>77.6</td>
</tr>
<tr>
<td>Available</td>
<td>44.8</td>
</tr>
<tr>
<td>Real consumption of biomass by households in 2006</td>
<td>40.1</td>
</tr>
</tbody>
</table>

The potential for increase of forest biomass consumption by households in CZ is very low!

Three options available:
1) export of wood biomass;
2) extension of production and use of short rotation coppice woods;
3) extension of production and use of standardised biofuels (pellets and briquettes) with use of agricultural biomass (i.e. energy crops and agricultural residues).
**Balance of briquettes and pellets in CZ in 2005-2006 (in tons) and price**

<table>
<thead>
<tr>
<th></th>
<th>Briquettes</th>
<th>Briquettes</th>
<th>Pellets</th>
<th>Pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Capacity</td>
<td>144 415</td>
<td>149 448</td>
<td>49 016</td>
<td>118 250</td>
</tr>
<tr>
<td>Production in CZ</td>
<td>102 303</td>
<td>113 969</td>
<td>20 875</td>
<td>53 283</td>
</tr>
<tr>
<td>Import</td>
<td>975</td>
<td>3052</td>
<td>0</td>
<td>188</td>
</tr>
<tr>
<td>Export</td>
<td>81 335</td>
<td>81 910</td>
<td>11 686</td>
<td>24 382</td>
</tr>
<tr>
<td>Delivered on the home market</td>
<td>46 155</td>
<td>32 763</td>
<td>13 912</td>
<td>28 872</td>
</tr>
<tr>
<td>From large consumers</td>
<td>23 599</td>
<td>5 784</td>
<td>9 223</td>
<td>21 017</td>
</tr>
<tr>
<td>From small consumers</td>
<td>2 426</td>
<td>26 979</td>
<td>3 617</td>
<td>7 855</td>
</tr>
<tr>
<td>Price (incl. 19% VAT), EUR/t</td>
<td>155 average</td>
<td>(107-225) min-max</td>
<td>150 average</td>
<td>(125-190) min-max</td>
</tr>
</tbody>
</table>

**Balance of energy biomass utilisation in CZ in 2006**

<table>
<thead>
<tr>
<th>Fuel - kind of biomass</th>
<th>Fuel for electr., kt</th>
<th>Fuel for heat, kt</th>
<th>Fuel in total, kt</th>
<th>Fuel in total, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chips or wastes</td>
<td>250</td>
<td>881</td>
<td>1 131</td>
<td>19,0</td>
</tr>
<tr>
<td>Cellulose leach</td>
<td>185</td>
<td>884</td>
<td>1 069</td>
<td>17,9</td>
</tr>
<tr>
<td>Fire-wood</td>
<td>0</td>
<td>54</td>
<td>54</td>
<td>0,9</td>
</tr>
<tr>
<td>Agricultural crops</td>
<td>62</td>
<td>12</td>
<td>74</td>
<td>1,2</td>
</tr>
<tr>
<td>Briquettes and pellets</td>
<td>16</td>
<td>8</td>
<td>24</td>
<td>0,4</td>
</tr>
<tr>
<td>Total</td>
<td>513</td>
<td>1 840</td>
<td>2 353</td>
<td>39,5</td>
</tr>
<tr>
<td>Energy biomass use in households</td>
<td>3 088</td>
<td>517</td>
<td>5 958</td>
<td>100</td>
</tr>
<tr>
<td>Export of wood fuel</td>
<td>517</td>
<td>8,7</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
## Heat generation from different types of biomass without households in the year 2006

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chips or wastes</td>
<td>881</td>
<td>9,0</td>
<td>7 918</td>
<td>7 032</td>
<td>886</td>
<td>11,2</td>
</tr>
<tr>
<td>Cellulose leach</td>
<td>884</td>
<td>8,7</td>
<td>7 656</td>
<td>7 100</td>
<td>556</td>
<td>7,3</td>
</tr>
<tr>
<td>Fire-wood</td>
<td>54</td>
<td>10,3</td>
<td>556</td>
<td>556</td>
<td>0</td>
<td>0,0</td>
</tr>
<tr>
<td>Agricultural crops</td>
<td>12</td>
<td>10,0</td>
<td>123</td>
<td>64</td>
<td>59</td>
<td>47,8</td>
</tr>
<tr>
<td>Briquettes and pellets</td>
<td>8</td>
<td>14,3</td>
<td>117</td>
<td>72</td>
<td>44</td>
<td>38,0</td>
</tr>
<tr>
<td>Total</td>
<td>1 840</td>
<td>8,9</td>
<td>16 370</td>
<td>14 825</td>
<td>1 545</td>
<td>9,4</td>
</tr>
</tbody>
</table>

## Power generation from different types of biomass without households in the year 2006

<table>
<thead>
<tr>
<th>Fuel - kind of biomass</th>
<th>Fuel consumption (kt)</th>
<th>Fuel energy (TJ)</th>
<th>Power generation (MWh)</th>
<th>Net consumption. (MWh)</th>
<th>Delivery to electricity network (MWh)</th>
<th>Direct deliveries (MWh)</th>
<th>Ratio of delivery : total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chips or wastes</td>
<td>250</td>
<td>2 247</td>
<td>272 725</td>
<td>78 257</td>
<td>190 673</td>
<td>3 794</td>
<td>71,3</td>
</tr>
<tr>
<td>Cellulose leach</td>
<td>185</td>
<td>1 600</td>
<td>350 028</td>
<td>331 976</td>
<td>0</td>
<td>18 051</td>
<td>5,2</td>
</tr>
<tr>
<td>Agricultural crops</td>
<td>62</td>
<td>619</td>
<td>84 465</td>
<td>7 822</td>
<td>76 040</td>
<td>603</td>
<td>90,7</td>
</tr>
<tr>
<td>Briquettes and pellets</td>
<td>16</td>
<td>222</td>
<td>23 850</td>
<td>1 599</td>
<td>19 033</td>
<td>3 217</td>
<td>93,3</td>
</tr>
<tr>
<td>Total</td>
<td>513</td>
<td>4 560</td>
<td>731 068</td>
<td>419 654</td>
<td>285 746</td>
<td>25 665</td>
<td>42,6</td>
</tr>
</tbody>
</table>

Average market price (incl. 19 %VAT and 10 % profit) in Czech Republic:
- of cereal and rape straws packed into huge bags - 40-55 EUR/t or 2,7-3,7 EUR/GJ
- of wood chips - 50-70 EUR/t or 3,8-4,7 EUR/GJ;
- of briquettes and pellets - 120-180 EUR/t or 6,7-10 EUR/GJ
### Key consumers of different types of biomass in CZ

<table>
<thead>
<tr>
<th>Fuel - kind of biomass</th>
<th>Fuel in total, kt</th>
<th>Fuel in total, %</th>
<th>Key consumers - Czech energy producers</th>
</tr>
</thead>
</table>
| Wood chips or wastes   | 1 131             | 48.1             | 1) CEZ, (4 power plants: Hodonín, Tisová I., Poříčí II., Dvůr Králové); 2) 4 companies: Plzenska teplerenska, Dalkia CR, TEDOM and IROMEZ. The share of all others is less than 30 %.
| Cellulose leach        | 1 069             | 45.4             | Excl. group of paper and cellulose producers: two the biggest are 1) Mondi Packaging Paper CR Steti, and 2) Biocel Paskov. |

Total: 2 353, 100.0

### Key consumers of different types of biomass in CZ

<table>
<thead>
<tr>
<th>Fuel - kind of biomass</th>
<th>Fuel in total, kt</th>
<th>Fuel in total, %</th>
<th>Key consumers - Czech energy producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire-wood</td>
<td>54</td>
<td>2.3</td>
<td>Only small heat producers</td>
</tr>
<tr>
<td>Agricultural crops</td>
<td>74</td>
<td>3.2</td>
<td>The heat producers are medium public boilers (use near 16 % of biomass) and the power producers are big power plants (CEZ, Dalkia, IROMEZ, TEDOM) - use together 84 % of biomass.</td>
</tr>
<tr>
<td>Briquettes and pellets</td>
<td>24</td>
<td>1.0</td>
<td>Near 70 % is used by bigger consumers (co-generation of power and heat) and 30 % by small heat producers.</td>
</tr>
</tbody>
</table>

Total: 2 353, 100.0
<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (ha)</th>
<th>% of arable land*</th>
<th>Yields (t/ha)</th>
<th>ratio of straw/resid : grain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>grain</td>
<td>straw or residues</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>779 241</td>
<td>25,39</td>
<td>4,81</td>
<td>3,75</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>71 569</td>
<td>2,33</td>
<td>3,46</td>
<td>2,77</td>
</tr>
<tr>
<td>Winter barley</td>
<td>131 099</td>
<td>4,27</td>
<td>4,04</td>
<td>3,64</td>
</tr>
<tr>
<td>Spring barley</td>
<td>368 278</td>
<td>12</td>
<td>3,86</td>
<td>2,32</td>
</tr>
<tr>
<td>Oats</td>
<td>58 978</td>
<td>1,92</td>
<td>3,04</td>
<td>3,65</td>
</tr>
<tr>
<td>Triticale</td>
<td>49 668</td>
<td>1,62</td>
<td>3,95</td>
<td>3,56</td>
</tr>
<tr>
<td>Rye (winter and spring)</td>
<td>44 093</td>
<td>1,44</td>
<td>3,92</td>
<td>3,8</td>
</tr>
<tr>
<td>Mustard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunflower for grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize for grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunflower for grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other crops in total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic cereals in total</td>
<td>1 502 926</td>
<td>49,0</td>
<td>3,87</td>
<td>3,36</td>
</tr>
<tr>
<td>Rape</td>
<td>298 058</td>
<td>9,71</td>
<td>2,56</td>
<td>3,47</td>
</tr>
<tr>
<td>Mustard</td>
<td>41 066</td>
<td>1,34</td>
<td>0,95</td>
<td>2,18</td>
</tr>
<tr>
<td>Maize for grain</td>
<td>71 027</td>
<td>2,31</td>
<td>6,69</td>
<td>6,57</td>
</tr>
<tr>
<td>Sunflower for grain</td>
<td>34 284</td>
<td>1,12</td>
<td>2,18</td>
<td>6,1</td>
</tr>
<tr>
<td>Other crops in total</td>
<td>444 435</td>
<td>14,5</td>
<td>3,10</td>
<td>4,58</td>
</tr>
<tr>
<td>Fodder crops at arable land - in hay</td>
<td>582 236</td>
<td>18,97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay from grasslands</td>
<td>883 296</td>
<td>28,78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All crops in total</td>
<td>3 412 893</td>
<td>82,4</td>
<td>3,57</td>
<td>3,83</td>
</tr>
</tbody>
</table>

*the official area of total arable land in the Czech Republic is 3,06 mil. ha
Different types of potential for the use of straw and residual biomass in CZ

<table>
<thead>
<tr>
<th>Source of agricultural biomass</th>
<th>Total biomass output, kt</th>
<th>Total energy output, PJ</th>
<th>Max. enviro-suitable, %</th>
<th>Available, %</th>
<th>Max. enviro-suitable, PJ</th>
<th>Available, PJ</th>
<th>Real (2006), PJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw of cereals</td>
<td>5 009</td>
<td>75,1</td>
<td>40</td>
<td>20</td>
<td>30,1</td>
<td>15,0</td>
<td>0,80</td>
</tr>
<tr>
<td>Straw of rape and mustard</td>
<td>1 124</td>
<td>16,9</td>
<td>100</td>
<td>50</td>
<td>16,9</td>
<td>8,4</td>
<td>0,20</td>
</tr>
<tr>
<td>Residues of maize and sunflower</td>
<td>676</td>
<td>10,1</td>
<td>60</td>
<td>30</td>
<td>6,1</td>
<td>3,0</td>
<td>0,05</td>
</tr>
<tr>
<td>Hay of fodder crops at arable land</td>
<td>3 356</td>
<td>50,3</td>
<td>80</td>
<td>40</td>
<td>40,3</td>
<td>20,1</td>
<td>0,05</td>
</tr>
<tr>
<td>Hay from permanent grasslands</td>
<td>2 544</td>
<td>38,2</td>
<td>100</td>
<td>50</td>
<td>38,2</td>
<td>19,1</td>
<td>0,01</td>
</tr>
<tr>
<td>All crops in total</td>
<td>12 711</td>
<td>191</td>
<td>131</td>
<td>65,7</td>
<td>1,11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions:

1) For generation of heat and power with energy biomass burning and co-combustion, the most suitable is utilisation of straw of cereals and straw of rape and mustard. The total available potential for basic cereal straw is 1 million t of biomass or 15 PJ of energy and for rape and mustard straw is 0,56 million t or 8,4 PJ (in sum 23,4 PJ of energy).

2) The other types of agricultural energy biomass (hay of grasslands, hay of fodder crops from arable land, residues of maize and sunflower) are not suitable for direct burning, but they are suitable for biogas production.
Conclusions:

3) Current intensive development of biogas production in the Czech Republic, which started two years ago due to the new Czech law for support of renewable electricity production, allows the extension of agricultural energy biomass production and utilisation.

4) The available potential of residues of maize and sunflower and fodder crops (from grasslands and arable land) is very significant. In total it is 6,6 million t of energy biomass or 42,2 PJ.

5) Moreover, much higher is the potential of biomass for biogas production (first of all maize for silage, which is cultivated in CZ on area of about 220 thousand ha with a production of about 6,6 million t).
Potential use of straw and agricultural residues for bioenergy in Slovenia

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Workshop
Novi Sad, 2nd-3rd October 2007

Potentials of cereal straw and crop residues in SLOVENIA

Resources cereal straw and crop residues?

POTENTIAL PRODUCTION

- Potentials: 95,000 ha of cereals (incl. 35,000 ha wheat, 13,300 ha barley and 42,700 ha grain maize, (EUROSTAT, 2003).
- According to the SI Yearbook 2006 (data for 2005) wheat production covered 30,095 ha, barley covered 15,451 ha, grain maize covered 42,396 ha, while rape production for bioenergy increased to 7,000 ha in 2007.
- Very problematic and maybe important crop residues are hops straw (well concentrated on 1,453 ha) and residues from wine production (16,428 ha concentrated mainly in three regions).
STRAW + RESIDUES PRODUCTION

Total straw production
- from wheat is 140,000 t,
- from barley 50,000 t and
- from grain maize 350,000 t

Total 540,000 t

- straw residues from hops about 22,500 t and
- about 70,000 t of residues from wine production (all data are presented on dry basis). Residues from industry are not included because until now they were used mostly for compost.

For wheat and maize, we calculated harvest index from 0.50 to 0.55 with regard to differences among varieties (low – early mature to high – late mature plants) and dry basis of yield.

USED STRAW

- Total 0.6 million livestock units (LSU), cattle 0.3 LSU, sheeps 0.01 LSU.
  - Cattle population: No. 452,517 in 2005 (1/4 use straw, 1 kg per day = 42,000 t)
  - Pigs: No. 457,432 in 2005 (1/8 use straw, 0.5 kg per day = 10,000 t)
  - Horses: 16,879 in 2003 i.e. 9.000 t straw (1.5 kg per day)
  - Sheeps: 7,700 t (0.1 kg per day)
  - Horticulture / mushrooms production: 500 t

- Total use of straw is 61,100 t per year.
Status or present utilization of cereal straw and crop residues in Slovenia

- Status or present utilization of cereal straw and crop residues
- No existing uses for energy
- What are the competitive use
  - Left in the field: 156,000 t straw
  - Cattle production - used as litter (61,000 t), straw is incorporated into organic matter with pig slurry and cattle liquid manures.
- Available for energy: 323,000 t straw

Environmental issues related to cereal straw and crop residues utilisation (i)

Local sustainability of straw removal
- Local community – draft based on Law of Environment and Aarhus Convention made by Environmental Societies includes very strict rules about use of energy and especially management of the projects. For example, the biogas stations were object to extensive public discussions.

- The second problem are small farms (61,000 holders, with an average of 7.3 ha per holding, 5% of farms have a size under 5 ha, 47% farms between 6-20 ha, and just 4% farms are larger than 31 ha).

How frequently one may take straw instead of incorporating it?
Rules exist in case of Integrated Crop Management (ICM), and additional rules are necessary.
Environmental issues related to cereal straw and crop residues utilisation (ii)

- formula based on soil, climate, technologies
  - In Slovenia more than 35 types and sub-types of soils with different, mainly bad, structure.
  - According to the Guidelines for Integrated Crop Management (ICM, part of Slovenian Environmental Programme in Agriculture) in case of content of the humus in the soil lower than 1.5% there exists a strong prohibition to take away the straw. Percentage of the fields with low level of humus is very high. On the other hand also burning the straw is strongly prohibited.
- effect on subsequent yields and fertiliser requirements
  - In Slovenia are often used fertilizers such as pig slurry and cattle liquid manures incorporated on the fields with cereal straw. Due to better C:N ratio is that the main way for increasing content of the humus in the soil and influence the soil structure. The straw in combination with liquid manure has a great effect on subsequent yields.
- other effects of incorporating straw
  - Increase of soil biodiversity.

Ongoing projects in Slovenia

- On going projects
  Bioenergy is based mainly on forest resources and production of rape seed. Three bio-power stations produce energy from pig slurry and maize silage, but not yet from straw and other crop residues.
  Practical problems in terms of resources, logistics, technology and economics: small farms; technology, logistics and economics unknown.
NEW PLANS

for bioenergy projects

- Research of utilization of different crops for bioenergy (incl. different oil crops, hemp ...), use of N-containing organic matter and C-organic compounds including straw for biofuels plants
- Bio oil and biodiesel production from rape seed and other oil crops.
Production of straw and other agricultural residues in Republic of Macedonia and possibilities for use as bio fuel

Ordan Cukaliev
Faculty for Agricultural Sciences and Food-Skopje

Workshop "Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries",
2-3 October 2007, Novi Sad, Serbia

Republic of Macedonia – general data

- Total area: 25,713 km²
- Population: 2 million
- Precipitation: 609 mm/year
- Runoff coeff.: 0.29
- Catchments:
  - Aegean (Vardar r. and tributaries): 22,319 km²
  - Adriatic (C. Drim & Ohrid, Prespa): 3,350 km²
  - Black Sea (Strumica): 44 km²
The Republic of Macedonia is a mountainous country with many lowlands. The average altitude of the whole territory is 850 meters. According to the Spatial Plan of the Country, 1.9% of the territory is covered by water (lakes), 19.1% are Plains and valleys, and the biggest part of 79% are hills and mountains.

Plains and valleys in Macedonia occupies a total area of 4,900 km² scattered throughout the country.

<table>
<thead>
<tr>
<th>Level of elevation</th>
<th>Area km²</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 200 m</td>
<td>744.10</td>
<td>2.89</td>
</tr>
<tr>
<td>200-500 m</td>
<td>5769.10</td>
<td>22.44</td>
</tr>
<tr>
<td>500-1000 m</td>
<td>11317.32</td>
<td>44.01</td>
</tr>
<tr>
<td>1000-1500 m</td>
<td>5741.68</td>
<td>22.33</td>
</tr>
<tr>
<td>1500-2000 m</td>
<td>1786.54</td>
<td>6.95</td>
</tr>
<tr>
<td>Over 2000 m</td>
<td>354.26</td>
<td>1.38</td>
</tr>
<tr>
<td>Total 44-2764 m</td>
<td>25713.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Hypsometric characteristics of Macedonia
## Climate

### Key Climatic Indicators at Major Meteorological Stations

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Station</th>
<th>Rainfall (mm/year)</th>
<th>Temp. (°C)</th>
<th>Wind (m/sec)</th>
<th>Sunshine (hours/day)</th>
<th>Cloudiness (0-10)</th>
<th>Air Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vardar</td>
<td>Gevgelija</td>
<td>667</td>
<td>14.0</td>
<td>1.8</td>
<td>6.5</td>
<td>4.4</td>
<td>70.8</td>
</tr>
<tr>
<td>Treska</td>
<td>Sol.Glava</td>
<td>640</td>
<td>9.0</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
<td>83.3</td>
</tr>
<tr>
<td>Pchinja</td>
<td>K.Palanka</td>
<td>617</td>
<td>10.0</td>
<td>2.3</td>
<td>6.3</td>
<td>5.3</td>
<td>68.2</td>
</tr>
<tr>
<td>Bregalnica</td>
<td>Ship</td>
<td>467</td>
<td>12.6</td>
<td>2.1</td>
<td>6.4</td>
<td>5.0</td>
<td>66.9</td>
</tr>
<tr>
<td>Crna</td>
<td>Prilep</td>
<td>535</td>
<td>11.1</td>
<td>1.6</td>
<td>6.3</td>
<td>5.0</td>
<td>67.5</td>
</tr>
<tr>
<td>Crn Drim</td>
<td>Ohrid</td>
<td>694</td>
<td>11.1</td>
<td>1.8</td>
<td>6.2</td>
<td>5.0</td>
<td>70.4</td>
</tr>
<tr>
<td>Strumica</td>
<td>Strumica</td>
<td>547</td>
<td>12.7</td>
<td>1.1</td>
<td>6.2</td>
<td>4.2</td>
<td>74.3</td>
</tr>
</tbody>
</table>

### Average temperatures

[Map of average temperatures]
Precipitation

Agroecological Indices

Drought index by de Martone (in vegetation) 1971-2000

Legend

1:1,000,000
Macedonian Agriculture

- Macedonian Agriculture is accounted for 13-15% of the GDP (only in production sector).
- Annual trade of agricultural products corresponds to over 500 millions US$.
- Land equipped for irrigation equals 123,000 hectares (with 30,000 ha actually irrigated).
- Labor force in Agriculture 23-25%.
- Arable land: 650 000 ha (80% private property, 20% former large farms).
### Agriculture – Land Use

<table>
<thead>
<tr>
<th>Land use</th>
<th>1990 – 1999 (ha)</th>
<th>2000 – 2005 (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable crop land</td>
<td>612,200</td>
<td>634,297</td>
</tr>
<tr>
<td>Irrigated</td>
<td>60,153</td>
<td>31,755</td>
</tr>
<tr>
<td>Rainfed</td>
<td>550,050</td>
<td>602,500</td>
</tr>
<tr>
<td>Pasture</td>
<td>630,000</td>
<td>707,263</td>
</tr>
<tr>
<td>Forest and woodland</td>
<td>997,374</td>
<td>934,128</td>
</tr>
<tr>
<td>Other land</td>
<td>331,926</td>
<td>191,349</td>
</tr>
</tbody>
</table>

### Use of arable land

<table>
<thead>
<tr>
<th>Year</th>
<th>Arable land and gardens</th>
<th>Sown Area</th>
<th>Nurseries</th>
<th>Fallow and uncultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>total</td>
<td>cereals</td>
<td>industrial crops</td>
</tr>
<tr>
<td>1998</td>
<td>533</td>
<td>358</td>
<td>222</td>
<td>42</td>
</tr>
<tr>
<td>1999</td>
<td>534</td>
<td>353</td>
<td>218</td>
<td>42</td>
</tr>
<tr>
<td>2000</td>
<td>498</td>
<td>350</td>
<td>221</td>
<td>34</td>
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<tr>
<td>2001</td>
<td>512</td>
<td>351</td>
<td>223</td>
<td>33</td>
</tr>
<tr>
<td>2002</td>
<td>480</td>
<td>321</td>
<td>196</td>
<td>31</td>
</tr>
<tr>
<td>2003</td>
<td>473</td>
<td>312</td>
<td>196</td>
<td>28</td>
</tr>
<tr>
<td>2004</td>
<td>481</td>
<td>304</td>
<td>191</td>
<td>27</td>
</tr>
<tr>
<td>2005</td>
<td>448</td>
<td>316</td>
<td>204</td>
<td>27</td>
</tr>
</tbody>
</table>
## Use of fertilizers and agro chemicals

<table>
<thead>
<tr>
<th>Year</th>
<th>Irrigated area in ha</th>
<th>Use of fertilizers in t</th>
<th>Use of Agro-chemicals in t</th>
<th>fertilizer use kg/ha</th>
<th>Agro-chemical use kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>45,095</td>
<td>16,416</td>
<td>308</td>
<td>27.45</td>
<td>0.52</td>
</tr>
<tr>
<td>2001</td>
<td>28,722</td>
<td>9,953</td>
<td>333</td>
<td>16.26</td>
<td>0.54</td>
</tr>
<tr>
<td>2002</td>
<td>21,448</td>
<td>10,593</td>
<td>245</td>
<td>18.36</td>
<td>0.42</td>
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<tr>
<td>2003</td>
<td>33,352</td>
<td>10,074</td>
<td>222</td>
<td>17.70</td>
<td>0.39</td>
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<tr>
<td>2004</td>
<td>15,075</td>
<td>9,931</td>
<td>273</td>
<td>17.73</td>
<td>0.49</td>
</tr>
<tr>
<td>2005</td>
<td>22,000</td>
<td>11,000</td>
<td>300</td>
<td>18.97</td>
<td>0.52</td>
</tr>
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</table>

## Cereal Production in ha

<table>
<thead>
<tr>
<th>Year</th>
<th>wheat</th>
<th>rye</th>
<th>barley</th>
<th>oats</th>
<th>maize</th>
<th>rice</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>121,669</td>
<td>5,845</td>
<td>49,988</td>
<td>2,374</td>
<td>37,488</td>
<td>3,871</td>
<td>221,235</td>
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<tr>
<td>2001</td>
<td>117,496</td>
<td>5,465</td>
<td>49,950</td>
<td>2,107</td>
<td>33,768</td>
<td>1,524</td>
<td>210,310</td>
</tr>
<tr>
<td>2002</td>
<td>102,774</td>
<td>3,945</td>
<td>49,883</td>
<td>2,589</td>
<td>34,873</td>
<td>1,868</td>
<td>195,932</td>
</tr>
<tr>
<td>2003</td>
<td>104,300</td>
<td>4,437</td>
<td>46,946</td>
<td>2,230</td>
<td>34,150</td>
<td>3,013</td>
<td>195,076</td>
</tr>
<tr>
<td>2004</td>
<td>101,607</td>
<td>4,546</td>
<td>44,975</td>
<td>2,408</td>
<td>32,913</td>
<td>2,888</td>
<td>189,337</td>
</tr>
<tr>
<td>2005</td>
<td>108,881</td>
<td>4,752</td>
<td>50,654</td>
<td>2,687</td>
<td>33,578</td>
<td>2,606</td>
<td>203,158</td>
</tr>
<tr>
<td>Average</td>
<td>109,455</td>
<td>4,832</td>
<td>48,733</td>
<td>2,399</td>
<td>34,462</td>
<td>2,628</td>
<td>202,508</td>
</tr>
</tbody>
</table>
Yield of Cereals in kg/ha

<table>
<thead>
<tr>
<th>Year</th>
<th>wheat</th>
<th>rye</th>
<th>barley</th>
<th>oats</th>
<th>maize</th>
<th>rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2,472</td>
<td>1,412</td>
<td>2,213</td>
<td>1,095</td>
<td>3,382</td>
<td>4,773</td>
</tr>
<tr>
<td>2001</td>
<td>2,132</td>
<td>1,749</td>
<td>1,855</td>
<td>1,120</td>
<td>3,563</td>
<td>5,204</td>
</tr>
<tr>
<td>2002</td>
<td>2,641</td>
<td>1,809</td>
<td>2,658</td>
<td>1,525</td>
<td>4,124</td>
<td>4,739</td>
</tr>
<tr>
<td>2003</td>
<td>2,177</td>
<td>1,365</td>
<td>1,789</td>
<td>1,085</td>
<td>4,051</td>
<td>4,293</td>
</tr>
<tr>
<td>2004</td>
<td>3,522</td>
<td>2,295</td>
<td>3,328</td>
<td>1,715</td>
<td>4,364</td>
<td>5,168</td>
</tr>
<tr>
<td>2005</td>
<td>3,081</td>
<td>2,005</td>
<td>2,719</td>
<td>1,553</td>
<td>4,491</td>
<td>5,270</td>
</tr>
<tr>
<td>Average</td>
<td>2,671</td>
<td>1,773</td>
<td>2,427</td>
<td>1,349</td>
<td>3,996</td>
<td>4,908</td>
</tr>
</tbody>
</table>

Conversion factors grain: straw


Spring wheat 1.33
Winter wheat 1.64.


Rice 2
wheat is 1.23
barley is 1.45
oats is 1.16
rye is 0.70
other cereals are 1.10.
Conversion factors grain: straw


Winter wheat and barley

straw = grain * 0.769 - 0.129 * arctan((grain - 6.7) / 1.5)

for Macedonian yield ratio grain: straw is 1.21.

for barley fits in low yield, high straw ratio end of the curve for Macedonia result is 1.19.

this relation gives grain straw ratio from 1.06 to 1.61 (increase with yield increasing.

Conversion factors grain: straw

Ratio biological yield : grain yield (own results).

Winter wheat 3.00 – 3.21 (depend on fertilizer rate).
Straw production in Republic of Macedonia is 531,226 t, mainly from winter wheat (66.6%) and barley (26.7%).
Straw use in Macedonia

Straw is most common bedding material for cattle in the country.

Number of cattle is 248,185 (2005).

Average straw used for bedding (estimated at 1.5 t/head/year) is 372,277 t/year.

Surplus of straw is 158,949 t/year.

Straw can be a valuable energy source in the country.

---

Vineyard area in ha

<table>
<thead>
<tr>
<th>Year</th>
<th>Total vineyard area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>26,530</td>
</tr>
<tr>
<td>2001</td>
<td>27,111</td>
</tr>
<tr>
<td>2002</td>
<td>26,194</td>
</tr>
<tr>
<td>2003</td>
<td>25,692</td>
</tr>
<tr>
<td>2004</td>
<td>24,777</td>
</tr>
<tr>
<td>2005</td>
<td>25,044</td>
</tr>
<tr>
<td>Average</td>
<td><strong>25,891</strong></td>
</tr>
</tbody>
</table>
Biomass from vineyard

Average vineyard area is 25,891 ha.


Pruning residues from vineyard are 4-8 t/ha.

Using average 6 t/ha pruning residues from vineyards are 155,346 (almost equal as straw surplus).

This biomass is almost not used.

<table>
<thead>
<tr>
<th>Year</th>
<th>Apples</th>
<th>Pears</th>
<th>Plums</th>
<th>Cherries</th>
<th>Sour cherries</th>
<th>Apricots</th>
<th>Peaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>3482</td>
<td>700</td>
<td>1707</td>
<td>168</td>
<td>1169</td>
<td>202</td>
<td>562</td>
</tr>
<tr>
<td>2002</td>
<td>3401</td>
<td>691</td>
<td>1617</td>
<td>167</td>
<td>1176</td>
<td>198</td>
<td>594</td>
</tr>
<tr>
<td>2003</td>
<td>3507</td>
<td>485</td>
<td>1467</td>
<td>161</td>
<td>1157</td>
<td>172</td>
<td>598</td>
</tr>
<tr>
<td>2004</td>
<td>4040</td>
<td>498</td>
<td>1463</td>
<td>170</td>
<td>1346</td>
<td>168</td>
<td>518</td>
</tr>
<tr>
<td>2005</td>
<td>4052</td>
<td>486</td>
<td>1436</td>
<td>176</td>
<td>955</td>
<td>161</td>
<td>522</td>
</tr>
<tr>
<td>Average</td>
<td>3696</td>
<td>572</td>
<td>1538</td>
<td>168</td>
<td>1161</td>
<td>180</td>
<td>559</td>
</tr>
</tbody>
</table>
Biomass from fruit production


Pruning residues in fruit trees vary from 1 kg/tree for some apple varieties up to 7 kg/tree for some plums and peaches. Similar coefficient are used in calculation of biomass production fro orchards (next slide).

Biomass production from orchards

<table>
<thead>
<tr>
<th></th>
<th>Apple</th>
<th>Pear</th>
<th>Plum</th>
<th>Cherry</th>
<th>Sour cherry</th>
<th>Apricot</th>
<th>Peach</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. trees</td>
<td>3696</td>
<td>572</td>
<td>1538</td>
<td>168</td>
<td>1161</td>
<td>180</td>
<td>559</td>
<td></td>
</tr>
<tr>
<td>kg/tree</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>4.5</td>
<td>4.5</td>
<td>8</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Biomass production in t</td>
<td>7392</td>
<td>1144</td>
<td>10766</td>
<td>756</td>
<td>5224</td>
<td>1440</td>
<td>3913</td>
<td>30635</td>
</tr>
</tbody>
</table>
Importance of Biomass

Biomass comprises all the living matter present on earth. It is derived from growing plants including algae, trees and crops or from animal manure.

The biomass resources are the organic matters in which the solar energy is stored in chemical bonds. Biomass has always been a major source of energy for mankind from ancient times. Presently, it contributes around 10-14% of the world’s energy supply.

Biomass is a carbon neutral resource in its life cycle and the primary contributor of greenhouse effect. Renewable biomass is being considered as an important energy resource all over the world. Biomass is used to meet a variety of energy needs, including generating electricity, fuelling vehicles and providing process heat for industries.
Biomass usage as a source of energy is of interest due to the following benefits:

- Biomass is a renewable, potentially sustainable and relatively environmentally friendly source of energy.
- A huge array of diverse materials are available from the biomass giving the user many new structural features to exploit.
- Increased use of biomass would extend the lifetime of diminishing crude oil supplies.
- Biomass fuels have negligible sulphur content and, therefore, do not contribute to sulphur dioxide emissions that cause acid rain.
- The combustion of biomass produces less ash than coal and the ash produced can be used as a soil additive on farms, etc.
- The combustion of agricultural and forestry residues and municipal solid wastes for energy production is an effective use of waste products.
- Biomass is a domestic resource which is not subject to world price fluctuations or the supply uncertainties as of imported fuels.
- Biomass provides a clean, renewable energy source that could improve our environment, economy and energy securities.
- Biomass usage could be a way to prevent more CO₂ production in the atmosphere as it does not increase the atmospheric CO₂ level.

Historically, the agricultural sector has been Turkey’s largest employer and a major contributor to the country’s GDP, exports and industrial growth.

As the country develops, agriculture declines in importance, however it still accounts for a relatively larger share of total output and employment than in many other countries.

Crops and livestock represent almost 90% of the agricultural sector in Turkey, with aquaculture contributing the rest.
Cereals, oily seeds and tuber crops are among the most widespread in Turkey.

Cereals are extensively grown in the central, eastern and southern parts of Turkey, whereas sunflower is prevalent in the region of Thrace (N-W Turkey).

Cotton and maize are the dominant crops in the south (the Cukurova and SE Anatolian regions), and the west (the Aegean region).

Tubers are widely produced in the Marmara (potatoes) and Central Anatolian (potatoes and sugar beet) regions.
Exploitation of Agricultural Residues in Turkey

Agricultural residues

The type and quantity of crops that form the basis of the agricultural sector in Turkey (wheat, barley, tobacco, cotton, rice, etc.) give rise to huge amounts of agricultural residues. The highest estimated amounts of residues are of wheat and barley followed by maize and cotton.

Residues left over the field after agricultural production. Cereal straw is used for various purposes such as animal feeding and animal bedding. Mainly residues from the production of industrial agricultural products are left over the field. The species are cotton stalk, corn stalk, sunflower stalk, straw and tobacco stalk etc.

Exploitation of Agricultural Residues in Turkey

Problems of agricultural residues

These residues are treated in an uncontrolled manner;

- either burnt in open-air fires or
- disposed of to decay.

Either case, they give rise to significant environmental impacts while at the same time useful resources are wasted in the expense of imported fuels.

Agricultural residues have been considered in three categories:

1) Annual crop residues that remain in the field after the crops are harvested. The main annual crops in Turkey are cereals, maize, cotton, rice, tobacco, sunflower, groundnuts, soybeans,

2) Perennial residues in Turkey that remain in the field after pruning of trees, shells, kernels etc.

3) Agro-industrial residues such as; cotton-ginning, seed oil industries, olive oil industries, rice industries, corn industries, wine and kernel factories.
Turkey is an energy importing country. More than about 60% of energy consumption in the country is met by imports. The share of imports continues to grow each year. Therefore, it is critical to supply its energy demand by using domestic non-renewable resources and renewable resources.

Coal is a major fossil fuel source for Turkey. Domestically produced coal accounted for about 24% of the country's total energy consumption, used primarily for power generation, steel manufacturing and cement production.

Turkey’s geographic location has several advantages for extensive use of most of the renewable energy sources. Turkey has substantial reserves of renewable energy resources. Renewable energy production represented about 14.4% of total primary energy supply (TPES). Main renewable energy resources in Turkey are: hydro, biomass, wind, geothermal and solar.

The project objective are:

- Mapping of the potential of agricultural waste
- Identification and assessment of legislative, institutional and administrative barriers to agricultural waste exploitation
- Technology review and assessment, in order to assess the different technological solutions available in the EU
- Preparation of an Action Plan
- Create an effective training infrastructure
- Setup investment support infrastructure
- Disseminate the results to a wide range of stakeholders using a variety of dissemination media.

Project team:

- University of Cukurova (leader, Turkey)
- TUBITAK (Turkey),
- EXERGIA (Greece),
- CRE (UK)
- VTT (Finland)
The quantities of residues from the annual and perennial crops cultivated in Turkey, in tons of dry matter per year, were calculated and estimated using data from local authorities of Ministry of Agriculture and Rural Affairs.

The total amount of crop residues was divided into theoretic and actual values.

### Total Annual Field Crops Production, Residues and Energy Values

<table>
<thead>
<tr>
<th>Crops</th>
<th>Residues</th>
<th>Production (tons)</th>
<th>Area (ha)</th>
<th>Total residues (tons)</th>
<th>Available residues (tons)</th>
<th>Availability (%)</th>
<th>Calorific value (MJ/kg)</th>
<th>Total calorific value (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Stalks</td>
<td>3,128,320</td>
<td>1,111,627</td>
<td>4,598,830</td>
<td>3,804,380</td>
<td>15</td>
<td>15.0</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td>Stems</td>
<td>1,111,627</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,061,040</td>
</tr>
<tr>
<td>Barley</td>
<td>Stalks</td>
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<td>209,875</td>
<td>606,911</td>
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<td>15.5</td>
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<td></td>
<td>Stems</td>
<td>209,875</td>
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<td></td>
<td>15</td>
<td></td>
<td>407,750</td>
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<td>Rapeseed</td>
<td>Stalks</td>
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<td>14,688</td>
<td>9,094</td>
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<td></td>
<td>Stems</td>
<td>5,425</td>
<td></td>
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<td></td>
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<td></td>
<td>16,820</td>
</tr>
<tr>
<td>Corn</td>
<td>Stalks</td>
<td>221,980</td>
<td>101,946</td>
<td>323,926</td>
<td>164,237</td>
<td>15</td>
<td>16.4</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td>52,260</td>
</tr>
<tr>
<td>Maize</td>
<td>Stalks</td>
<td>3,128,320</td>
<td>1,111,627</td>
<td>4,598,830</td>
<td>3,804,380</td>
<td>15</td>
<td>15.0</td>
<td>570</td>
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<tr>
<td></td>
<td>Stems</td>
<td>1,111,627</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>7,061,040</td>
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<tr>
<td>Peas</td>
<td>Stalks</td>
<td>756,450</td>
<td>203,000</td>
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<tr>
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<td>Stems</td>
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<td></td>
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<td>2,548</td>
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<tr>
<td>Millet</td>
<td>Stalks</td>
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<td>132</td>
<td>86</td>
<td>15</td>
<td>16.7</td>
<td>1,773</td>
</tr>
<tr>
<td></td>
<td>Stems</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td>245</td>
</tr>
<tr>
<td>Celery</td>
<td>Stalks</td>
<td>4,990</td>
<td>7,253</td>
<td>12,243</td>
<td>9,401</td>
<td>15</td>
<td>18.1</td>
<td>151,620</td>
</tr>
<tr>
<td></td>
<td>Stems</td>
<td>7,253</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td>131,820</td>
</tr>
<tr>
<td>Onion</td>
<td>Stalks</td>
<td>1,213,175</td>
<td>502,674</td>
<td>1,715,849</td>
<td>805,600</td>
<td>10</td>
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<td></td>
<td>Stems</td>
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<tr>
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<td>Stalks</td>
<td>29,032</td>
<td>16,532</td>
<td>45,564</td>
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<td>Carrot</td>
<td>Stalks</td>
<td>263,628</td>
<td>22,395</td>
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<td>Cabbage</td>
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<td>18,075</td>
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<td>12,035</td>
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<td>10</td>
<td></td>
<td>241,000</td>
</tr>
</tbody>
</table>
## Exploitation of Agricultural Residues in Turkey

### Total Annual Fruits Production, Residues and Energy Values

<table>
<thead>
<tr>
<th>Crops</th>
<th>Residues</th>
<th>Production (tons)</th>
<th>Number of trees</th>
<th>Total Residues (tons)</th>
<th>Available Residues (tons)</th>
<th>Availability (%)</th>
<th>Calorific Value (MJ/kg)</th>
<th>Total Calorific Value (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Annual Fruits Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Exploitation of Agricultural Residues in Turkey</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td><strong>Apricots</strong></td>
<td>Tree pruning</td>
<td>1,328,486</td>
<td>174,373</td>
<td>11,280,137</td>
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<td><strong>Sour cherries</strong></td>
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<td>114,045</td>
<td>20,016</td>
<td>4,491,000</td>
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<tr>
<td><strong>Olives</strong></td>
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<td>371,488</td>
<td>820,836</td>
<td>794,034</td>
<td>20,49</td>
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<td>15,051,367</td>
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<tr>
<td><strong>Pears</strong></td>
<td>Tree pruning</td>
<td>8,256</td>
<td>28,089</td>
<td>20,108</td>
<td>19,249</td>
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<td>98,952</td>
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<tr>
<td><strong>Walnuts</strong></td>
<td>Tree pruning</td>
<td>115,498</td>
<td>3,377,864</td>
<td>20,580</td>
<td>19,119</td>
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<td>478,563</td>
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<tr>
<td><strong>Almonds</strong></td>
<td>Tree pruning</td>
<td>44,701</td>
<td>3,631,622</td>
<td>21,209</td>
<td>19,31</td>
<td></td>
<td>448,716</td>
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</tr>
<tr>
<td><strong>Hazelnuts</strong></td>
<td>Tree pruning</td>
<td>852,801</td>
<td>268,697,367</td>
<td>2,177,066</td>
<td>1,762,109,010</td>
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<td>33,165,500</td>
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</table>

### Exploitation of Agricultural Residues in Turkey

<table>
<thead>
<tr>
<th>Crops</th>
<th>Residues</th>
<th>Production (tons)</th>
<th>Number of trees</th>
<th>Total Residues (tons)</th>
<th>Available Residues (tons)</th>
<th>Availability (%)</th>
<th>Calorific Value (MJ/kg)</th>
<th>Total Calorific Value (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Annual Fruits Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Exploitation of Agricultural Residues in Turkey</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peach</strong></td>
<td>Tree pruning</td>
<td>1,411</td>
<td>8,942,009</td>
<td>14,811</td>
<td>28,62</td>
<td></td>
<td>9,463,919</td>
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<tr>
<td><strong>Lemons</strong></td>
<td>Peel</td>
<td>904,260</td>
<td>80</td>
<td>19,4</td>
<td>2,457,920</td>
<td></td>
<td>478,563</td>
<td></td>
</tr>
<tr>
<td><strong>Oranges</strong></td>
<td>Peel</td>
<td>2,596,052</td>
<td>2,596,052</td>
<td>20,108</td>
<td>19,31</td>
<td></td>
<td>448,716</td>
<td></td>
</tr>
<tr>
<td><strong>Mandarins</strong></td>
<td>Peel</td>
<td>1,381,835</td>
<td>11,848,275</td>
<td>20,108</td>
<td>19,31</td>
<td></td>
<td>5,346,612</td>
<td></td>
</tr>
<tr>
<td><strong>Grapes</strong></td>
<td>Peel</td>
<td>948,291</td>
<td>126,285</td>
<td>878,584</td>
<td>100</td>
<td>17,6</td>
<td>1,456,394</td>
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</tr>
</tbody>
</table>

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**Note:** The values in the table represent the total annual production, residues, and energy values for various crops in Turkey. The data includes the number of trees, production, and various energy values calculated based on available residues and calorific values.
Exploitation of Agricultural Residues in Turkey

Agricultural residues for bioenergy production in Turkey

- Cereal straw
- Corn residues
- Other agricultural residues

Cereal straw production in Turkey

- Total production
- Waste

- Wheat
- Barley
- Rye
- Oat
Exploitation of Agricultural Residues in Turkey

Possible Bioenergy Production from Agricultural Residues in Turkey

![Bar chart showing energy production (PJ/year) for field crop residues, fruit production residues, and animal waste.]

Regional Distribution of Agricultural Biomass Potential in Turkey

![Map showing regional distribution of agricultural biomass potential in Turkey.]
Exploitation of Agricultural Residues in Turkey

### Mediterranean Region

#### Field Crop Production

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production (tons)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>3,538,329</td>
<td>1,111,439</td>
</tr>
<tr>
<td>Maize</td>
<td>758,458</td>
<td>205,068</td>
</tr>
<tr>
<td>Barley</td>
<td>565,033</td>
<td>206,873</td>
</tr>
<tr>
<td>Cotton</td>
<td>440,354</td>
<td>161,547</td>
</tr>
</tbody>
</table>

#### Fruits Production

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Production (tons)</th>
<th>Fruit Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive</td>
<td>252,597</td>
<td>9,638,816</td>
</tr>
<tr>
<td>Orange</td>
<td>1,109,142</td>
<td>10,068,210</td>
</tr>
<tr>
<td>Lemon</td>
<td>4,486,934</td>
<td>4,844,293</td>
</tr>
<tr>
<td>Mandarin</td>
<td>431,161</td>
<td>4,765,416</td>
</tr>
<tr>
<td>Grey hurt</td>
<td>125,149</td>
<td>877,183</td>
</tr>
</tbody>
</table>

### Aegean Region

#### Field Crop Production

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production (tons)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobacco</td>
<td>251,286</td>
<td>136,264</td>
</tr>
<tr>
<td>Maize</td>
<td>227,737</td>
<td>686,260</td>
</tr>
<tr>
<td>Cotton</td>
<td>409,017</td>
<td>401,017</td>
</tr>
<tr>
<td>Barley</td>
<td>792,251</td>
<td>792,251</td>
</tr>
</tbody>
</table>

#### Fruits Production

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Production (tons)</th>
<th>Fruit Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive</td>
<td>996,787</td>
<td>51,723,577</td>
</tr>
<tr>
<td>Orange</td>
<td>142,239</td>
<td>3,067,707</td>
</tr>
<tr>
<td>Lemon</td>
<td>70,373</td>
<td>1,728,990</td>
</tr>
</tbody>
</table>

Field Crops (PJ) | Fruits (PJ)
--- | ---
57,0 | 8,0

Field Crops (PJ) | Fruits (PJ)
--- | ---
24,2 | 15,3
### Exploitation of Agricultural Residues in Turkey

#### Marmara Region

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production (tons)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>3,812,329</td>
<td>1,121,30</td>
</tr>
<tr>
<td>Sunflower</td>
<td>670,565</td>
<td>413,777</td>
</tr>
<tr>
<td>Maize</td>
<td>566,275</td>
<td>85,225</td>
</tr>
<tr>
<td>Barley</td>
<td>405,996</td>
<td>150,043</td>
</tr>
<tr>
<td>Millet</td>
<td>209,394</td>
<td>37,459</td>
</tr>
<tr>
<td>Oats</td>
<td>126,233</td>
<td>53,524</td>
</tr>
</tbody>
</table>

#### Central Anatolian Region

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production (tons)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>6,263,294</td>
<td>3,124,326</td>
</tr>
<tr>
<td>Barley</td>
<td>3,562,381</td>
<td>1,618,071</td>
</tr>
<tr>
<td>Rye</td>
<td>188,594</td>
<td>108,142</td>
</tr>
<tr>
<td>Sunflower</td>
<td>61,013</td>
<td>60,686</td>
</tr>
</tbody>
</table>

### Field Crop Production

**Marmara Region**

- Wheat: 3,812,329 tons, 1,121,30 ha
- Sunflower: 670,565 tons, 413,777 ha
- Maize: 566,275 tons, 85,225 ha
- Barley: 405,996 tons, 150,043 ha
- Millet: 209,394 tons, 37,459 ha
- Oats: 126,233 tons, 53,524 ha

**Central Anatolian Region**

- Wheat: 6,263,294 tons, 3,124,326 ha
- Barley: 3,562,381 tons, 1,618,071 ha
- Rye: 188,594 tons, 108,142 ha
- Sunflower: 61,013 tons, 60,686 ha

### Fruits Production

**Marmara Region**

- Olive: 170,667 tons
- Hazelnut: 115,156 tons

**Central Anatolian Region**

- Apricot: 50,527 tons
- Cherries: 35,927 tons
- Walnut: 15,864 tons
- Apricot: 49,185 tons
- Cherries: 34,927 tons
- Walnut: 14,864 tons

### Energy Potentials

**Marmara Region**

- Field crops: 41 PJ
- Fruits: 9.5 PJ

**Central Anatolian Region**

- Field crops: 31.3 PJ
- Fruits: 1 PJ
### Eastern Anatolian Region

**Field Crop Production**

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (ha)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1,037,619</td>
<td>1,525,730</td>
</tr>
<tr>
<td>Barley</td>
<td>404,766</td>
<td>627,955</td>
</tr>
<tr>
<td>Rye</td>
<td>13,464</td>
<td>20,896</td>
</tr>
</tbody>
</table>

**Fruits Production**

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Production (tons)</th>
<th>Fruit Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricot</td>
<td>324,888</td>
<td>7,020,869</td>
</tr>
<tr>
<td>Pistachio</td>
<td>20,453</td>
<td>618,430</td>
</tr>
</tbody>
</table>

### South-eastern Anatolian Region

**Field Crop Production**

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (ha)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1,157,940</td>
<td>287,376</td>
</tr>
<tr>
<td>Cotton</td>
<td>1,222,593</td>
<td>2,826,980</td>
</tr>
<tr>
<td>Barley</td>
<td>699,934</td>
<td>1,432,814</td>
</tr>
<tr>
<td>Maize</td>
<td>11,115</td>
<td>84,804</td>
</tr>
</tbody>
</table>

**Fruits Production**

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Production (tons)</th>
<th>Fruit Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive</td>
<td>75,962</td>
<td>4,115,667</td>
</tr>
<tr>
<td>Pistachio</td>
<td>34,213</td>
<td>26,633,575</td>
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<tr>
<td>Walnut</td>
<td>5,510</td>
<td>238,703</td>
</tr>
<tr>
<td>Almond</td>
<td>3,590</td>
<td>369,786</td>
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</table>
Exploitation of Agricultural Residues in Turkey

### Field Crop Production

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (ha)</th>
<th>Production (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1,074,920</td>
<td>2,323,452</td>
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<tr>
<td>Maize</td>
<td>218,562</td>
<td>619,981</td>
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<tr>
<td>Barley</td>
<td>260,665</td>
<td>606,462</td>
</tr>
<tr>
<td>Cezve</td>
<td>1,06,690</td>
<td>29,461</td>
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### Fruits Production

<table>
<thead>
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<th>Area (ton)</th>
<th>Fruit Trees</th>
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<tbody>
<tr>
<td>Hazelnut</td>
<td>537,111</td>
<td>247,423,170</td>
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<tr>
<td>Walnut</td>
<td>29,461</td>
<td>1,067,690</td>
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<tr>
<td>Cherries</td>
<td>11,468</td>
<td>501,828</td>
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</tbody>
</table>

### Regional Distribution of Animals in Turkey

**Mediterranean**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Cow</td>
<td>890,600</td>
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<tr>
<td>Sheep</td>
<td>1,858,400</td>
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<tr>
<td>Poultry</td>
<td>29,361,700</td>
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</table>

**Aegean**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>1,271,200</td>
</tr>
<tr>
<td>Sheep</td>
<td>2,906,500</td>
</tr>
<tr>
<td>Poultry</td>
<td>28,998,300</td>
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</tbody>
</table>

**Marmara**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>1,077,000</td>
</tr>
<tr>
<td>Sheep</td>
<td>2,211,200</td>
</tr>
<tr>
<td>Poultry</td>
<td>57,703,000</td>
</tr>
</tbody>
</table>

**Central Anatolian**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>1,840,600</td>
</tr>
<tr>
<td>Sheep</td>
<td>6,400,800</td>
</tr>
<tr>
<td>Poultry</td>
<td>37,442,400</td>
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</tbody>
</table>

**East Anatolian**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>2,472,900</td>
</tr>
<tr>
<td>Sheep</td>
<td>10,295,000</td>
</tr>
<tr>
<td>Poultry</td>
<td>14,018,400</td>
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</table>

**South-eastern Anatolian**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>664,500</td>
</tr>
<tr>
<td>Sheep</td>
<td>3,984,100</td>
</tr>
<tr>
<td>Poultry</td>
<td>5,226,500</td>
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</tbody>
</table>

**Black Sea**

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>4,621,485</td>
</tr>
<tr>
<td>Sheep</td>
<td>2,247,590</td>
</tr>
<tr>
<td>Poultry</td>
<td>92,033,750</td>
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</tbody>
</table>
### Total Energy Value of Agricultural Residues in Turkey

<table>
<thead>
<tr>
<th>Regions</th>
<th>Field Crops (PJ)</th>
<th>Fruits (PJ)</th>
<th>Animals (PJ/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean</td>
<td>25</td>
<td>8.0</td>
<td>11</td>
</tr>
<tr>
<td>Aegean</td>
<td>24.2</td>
<td>11</td>
<td>15.3</td>
</tr>
<tr>
<td>Marmara</td>
<td>41.0</td>
<td>18</td>
<td>9.5</td>
</tr>
<tr>
<td>Central Anatolian</td>
<td>31.3</td>
<td>14</td>
<td>1.0</td>
</tr>
<tr>
<td>East Anatolian</td>
<td>8.2</td>
<td>4</td>
<td>0.9</td>
</tr>
<tr>
<td>South-eastern Anatolian</td>
<td>37.1</td>
<td>16</td>
<td>4.0</td>
</tr>
<tr>
<td>Black Sea</td>
<td>29.8</td>
<td>13</td>
<td>48</td>
</tr>
</tbody>
</table>

**TOTAL** 228.4 100 74.8 100 60.1 100

- **Maize**: 33.4%
- **Wheat**: 27.6%
- **Cotton**: 18.1%
- **Hazelnut**: 55.8%
- **Olive**: 25.9%

### Agricultural Biomass Potential of Turkey

[Click for Regional Data]

---

**Exploitation of Agricultural Residues in Turkey**

[http://www.agrowaste-tr.org](http://www.agrowaste-tr.org)
Exploitation of Agricultural Residues in Turkey

Conclusions on Exploitation of Agricultural Residues

• Although there are sufficient quantities of residues in the country, certain parameters should be taken into account before making a strategy for their energy exploitation.
  ➢ Small farming size depends on the region (increases harvesting and transportation costs).
  ➢ Environmental risks caused by the removal of the residues from the field (erosion in sloping and low fertility areas, etc.).
  ➢ Opportunity cost of the residue (e.g. cereals straw has already a market price as it is sold for animal feeding purposes and paper industry)
  ➢ Lack of commercial harvesting machinery for certain residue types (e.g. higher cutting stalks of maize and cereals, cotton residues).
Agricultural residues in Estonia - resources and possibilities

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Estonian University of Life Sciences
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Background

Half of the agricultural land has not being used in recent years (since 1990s)
Background

After recession, small increase in agriculture

More attention to technical crops (rape) presently

### Background

<table>
<thead>
<tr>
<th></th>
<th>Agriculture production thousands tons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Total</td>
<td>809.8</td>
</tr>
<tr>
<td>Cereals</td>
<td>329.3</td>
</tr>
<tr>
<td>....rye</td>
<td>28.9</td>
</tr>
<tr>
<td>....winter wheat</td>
<td>21.7</td>
</tr>
<tr>
<td>....winter barley</td>
<td>0.1</td>
</tr>
<tr>
<td>....triticale</td>
<td>4.2</td>
</tr>
<tr>
<td>....summer wheat</td>
<td>47.2</td>
</tr>
<tr>
<td>....summer barley</td>
<td>165.1</td>
</tr>
<tr>
<td>....oats</td>
<td>53.3</td>
</tr>
<tr>
<td>....mixture</td>
<td>12.6</td>
</tr>
<tr>
<td>....buckwheat</td>
<td>0.5</td>
</tr>
<tr>
<td>Legumes</td>
<td>3.9</td>
</tr>
<tr>
<td>Technical crops</td>
<td>29.1</td>
</tr>
<tr>
<td>Vegetables</td>
<td>3.8</td>
</tr>
<tr>
<td>Potato</td>
<td>30.9</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>412.8</td>
</tr>
</tbody>
</table>
Background

- Number of livestock also decreased threefold
- The only increase is in sheep number

Competition between uses

- plant growing residues: feed - biogas
- straw: building material - fertiliser - biogas - burning
- manure: fertiliser - biogas - burning
Sources evaluation:

- Agricultural residues from vegetables are large in ratio, but small in total amount
- Straw production 1 t dry matter per ha varies among crops and agro-techniques
- 10% of straw needed for animals, 25…75% of straw needed for field fertilisation

Case studies. Biogas

Jööri Biogas plant:
- opened in 2005
- raw material pig slurry and sewage sludge
- capacity 350 kW
Case studies. Biogas

Problems with Jööri Biogas plant
- lack of technical malfunction backup system
- system corrosion
- poor residue usage

Case studies. Straw boilers

Tamsalu straw boiler
- energy supply for the distant heating plant
- capacity 850 kW
- established in 2006
Case studies. Straw boilers

Problematic:

- supply system with straw
- influence on local soil
- subsidy policy

Poorly studied resources

- Influence of agricultural residues as fertilisers for energy crops?
- Pig slurry biogas digestate to SRF
Poorly studied resources

Resource of Natura 2000 semi-natural communities for biomass production?

Amount and quality of hay in mandatory set aside areas (resource 20,000 ha)
Sources of biomass, energy potential and collection of statistical data concerning availability and utilization of biomass in Slovakia

The Agricultural Technical and Testing Institute
SKTC 106
900 41 Rovinka
The laboratory of applied research, technology and consulting

Ing. František Zacharda, PhD
Dipl. Ing. Pepich Štefan
Dipl. Ing. Mariana Čeppanova
e-mail: ceppanova@sktc-106.sk
www.sktc-106.sk

Map of Slovak regions
### Characteristics of the regions of Slovakia

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of inhabitants</th>
<th>Area in km²</th>
<th>Number of inhabitants per km²</th>
<th>The number of villages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratislava</td>
<td>599 042</td>
<td>2 052</td>
<td>292</td>
<td>73</td>
</tr>
<tr>
<td>Trnava</td>
<td>550 918</td>
<td>4 147</td>
<td>133</td>
<td>251</td>
</tr>
<tr>
<td>Trenčín</td>
<td>604 917</td>
<td>4 502</td>
<td>134</td>
<td>276</td>
</tr>
<tr>
<td>Nitra</td>
<td>712 312</td>
<td>6 344</td>
<td>112</td>
<td>315</td>
</tr>
<tr>
<td>Žilina</td>
<td>692 434</td>
<td>6 801</td>
<td>102</td>
<td>315</td>
</tr>
<tr>
<td>Banská Bystrica</td>
<td>661 343</td>
<td>9 455</td>
<td>70</td>
<td>516</td>
</tr>
<tr>
<td>Prešov</td>
<td>791 335</td>
<td>8 981</td>
<td>88</td>
<td>666</td>
</tr>
<tr>
<td>Košice</td>
<td>766 650</td>
<td>6 752</td>
<td>114</td>
<td>440</td>
</tr>
<tr>
<td>Slovakia</td>
<td>5 378 951</td>
<td>49 034</td>
<td>110</td>
<td>2 898</td>
</tr>
</tbody>
</table>

### Structure of regions in Slovakia (ha)

<table>
<thead>
<tr>
<th>Region</th>
<th>Arable land</th>
<th>Agricultural land</th>
<th>Forest land</th>
<th>Water areas</th>
<th>Built-up areas</th>
<th>Other area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratislava</td>
<td>46 141</td>
<td>66 012</td>
<td>75 429</td>
<td>5 582</td>
<td>14 230</td>
<td>19 683</td>
</tr>
<tr>
<td>Trnava</td>
<td>264 323</td>
<td>294 322</td>
<td>65 205</td>
<td>14 363</td>
<td>26 546</td>
<td>28 650</td>
</tr>
<tr>
<td>Trenčín</td>
<td>100 097</td>
<td>186 891</td>
<td>220 537</td>
<td>6 296</td>
<td>22 601</td>
<td>20 164</td>
</tr>
<tr>
<td>Nitra</td>
<td>407 032</td>
<td>469 763</td>
<td>96 094</td>
<td>15 653</td>
<td>37 088</td>
<td>31 428</td>
</tr>
<tr>
<td>Žilina</td>
<td>64 437</td>
<td>248 067</td>
<td>376 191</td>
<td>12 814</td>
<td>24 591</td>
<td>31 210</td>
</tr>
<tr>
<td>Banská Bystrica</td>
<td>168 621</td>
<td>419 634</td>
<td>462 113</td>
<td>7 861</td>
<td>32 660</td>
<td>31 117</td>
</tr>
<tr>
<td>Prešov</td>
<td>154 921</td>
<td>218 055</td>
<td>440 504</td>
<td>14 131</td>
<td>30 861</td>
<td>40 459</td>
</tr>
<tr>
<td>Košice</td>
<td>205 591</td>
<td>338 469</td>
<td>266 056</td>
<td>16 231</td>
<td>33 898</td>
<td>36 715</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1 411 163</td>
<td>2 439 408</td>
<td>2 002 129</td>
<td>92 932</td>
<td>222 475</td>
<td>146 404</td>
</tr>
</tbody>
</table>
Acreage of agricultural land in Slovakia (ha)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Year 2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used agricultural land</td>
<td>2,236,036</td>
<td>1,934,659</td>
<td>1,941,380</td>
</tr>
<tr>
<td>From that: arable lands</td>
<td>1,379,379</td>
<td>1,360,893</td>
<td>1,357,201</td>
</tr>
<tr>
<td>permanent grasslands</td>
<td>794,733</td>
<td>514,478</td>
<td>524,110</td>
</tr>
</tbody>
</table>

CLASSIFICATION OF AGRICULTURAL BIOMASS
### Harvested areas for main crops (2005)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>vineyards</td>
<td>12.9</td>
</tr>
<tr>
<td>Leguminous plants</td>
<td>16.4</td>
</tr>
<tr>
<td>sunflower</td>
<td>91.1</td>
</tr>
<tr>
<td>rape</td>
<td>106.2</td>
</tr>
<tr>
<td>potatoes</td>
<td>19.1</td>
</tr>
<tr>
<td>sugar beet</td>
<td>33.2</td>
</tr>
<tr>
<td>corn</td>
<td>154.1</td>
</tr>
<tr>
<td>barley</td>
<td>204.2</td>
</tr>
<tr>
<td>wheat</td>
<td>373</td>
</tr>
<tr>
<td>cereal total</td>
<td>794.6</td>
</tr>
</tbody>
</table>

### Yields of the main crops (2005)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>vineyards</td>
<td>4.17</td>
</tr>
<tr>
<td>Leguminous plants</td>
<td>2.13</td>
</tr>
<tr>
<td>sunflower</td>
<td>2.14</td>
</tr>
<tr>
<td>rape</td>
<td>2.21</td>
</tr>
<tr>
<td>potatoes</td>
<td>15.77</td>
</tr>
<tr>
<td>sugar beet</td>
<td>52.16</td>
</tr>
<tr>
<td>corn</td>
<td>6.97</td>
</tr>
<tr>
<td>barley</td>
<td>3.82</td>
</tr>
<tr>
<td>wheat</td>
<td>4.31</td>
</tr>
<tr>
<td>cereal total</td>
<td>4.51</td>
</tr>
</tbody>
</table>
### Number of farm animals until 1.12.2005

<table>
<thead>
<tr>
<th>Region</th>
<th>Cattle total</th>
<th>Cows from that</th>
<th>Pigs total</th>
<th>Sow from that</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>527 889</td>
<td>229 607</td>
<td>1 108 265</td>
<td>79 529</td>
</tr>
<tr>
<td>BA</td>
<td>16 756</td>
<td>7 740</td>
<td>25 890</td>
<td>2 601</td>
</tr>
<tr>
<td>TT</td>
<td>87 240</td>
<td>34 266</td>
<td>278 275</td>
<td>22 328</td>
</tr>
<tr>
<td>TN</td>
<td>53 285</td>
<td>22 497</td>
<td>120 808</td>
<td>8 607</td>
</tr>
<tr>
<td>NR</td>
<td>83 539</td>
<td>33 234</td>
<td>317 470</td>
<td>22 432</td>
</tr>
<tr>
<td>ZA</td>
<td>72 516</td>
<td>33 132</td>
<td>36 700</td>
<td>1 591</td>
</tr>
<tr>
<td>BB</td>
<td>81 510</td>
<td>36 583</td>
<td>139 109</td>
<td>11 062</td>
</tr>
<tr>
<td>PO</td>
<td>81 139</td>
<td>39 621</td>
<td>83 724</td>
<td>4 420</td>
</tr>
<tr>
<td>KE</td>
<td>51 904</td>
<td>22 534</td>
<td>106 289</td>
<td>6 488</td>
</tr>
</tbody>
</table>

### Number of farm animals until 1.12.2005

<table>
<thead>
<tr>
<th>Region</th>
<th>Sheep total</th>
<th>Poultry total</th>
<th>Hens from that</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>320 487</td>
<td>14 084 079</td>
<td>5 591 218</td>
</tr>
<tr>
<td>BA</td>
<td>815</td>
<td>487 259</td>
<td>254 490</td>
</tr>
<tr>
<td>TT</td>
<td>1 873</td>
<td>2 101 932</td>
<td>564 058</td>
</tr>
<tr>
<td>TN</td>
<td>23 925</td>
<td>2 332 641</td>
<td>605 931</td>
</tr>
<tr>
<td>NR</td>
<td>10 064</td>
<td>3 738 784</td>
<td>1 593 775</td>
</tr>
<tr>
<td>ZA</td>
<td>74 488</td>
<td>1 242 994</td>
<td>391 892</td>
</tr>
<tr>
<td>BB</td>
<td>101 839</td>
<td>1 451 716</td>
<td>656 014</td>
</tr>
<tr>
<td>PO</td>
<td>67 710</td>
<td>1 183 055</td>
<td>554 918</td>
</tr>
<tr>
<td>KE</td>
<td>39 773</td>
<td>1 545 698</td>
<td>970 140</td>
</tr>
</tbody>
</table>

### Structure of forests according to utilization and ownership until 31.12.2005 and evolution of wood cuts

<table>
<thead>
<tr>
<th>Ownership</th>
<th>Acreage of stands (ha)</th>
<th>utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>807 753</td>
<td>1 130 786</td>
</tr>
<tr>
<td>Non-state</td>
<td>1 011 096</td>
<td>800 859</td>
</tr>
<tr>
<td>Unknown</td>
<td>112 796</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1 931 645</td>
<td>1 931 645</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wood cutting</th>
<th>Year 1990</th>
<th>2000</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Realized wood cuts in 10^3 m^3 (1) of which accidental cuts in 10^3 m^3 (2) share of accidental cuts % (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coniferous</td>
<td>2777 1858</td>
<td>3245</td>
<td>2012</td>
<td>3245 2012</td>
</tr>
<tr>
<td>Foliaceous</td>
<td>2499 766</td>
<td>30,7</td>
<td>2973</td>
<td>1010 34</td>
</tr>
<tr>
<td>Total</td>
<td>5276 2604</td>
<td>49,3</td>
<td>6218</td>
<td>3021 48</td>
</tr>
</tbody>
</table>
Average hectare production of biomass in 2004

<table>
<thead>
<tr>
<th>Waste from wood</th>
<th>Self-seeding form</th>
<th>permanent grassland</th>
<th>Vineyards</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Orchards</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunflower</td>
<td></td>
<td>3,6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td></td>
<td>5,9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rape</td>
<td></td>
<td>3,8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oat</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triticale</td>
<td></td>
<td>2,1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rye</td>
<td></td>
<td>3,7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td></td>
<td>2,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td></td>
<td>2,7</td>
<td></td>
</tr>
</tbody>
</table>

Total production of biomass in the year 2005

- Cereal straw
- Others straw
- Wood waste
- Total livestock production
Share of cereal straw (regions / total Slovak production, 2005)

Share of others types of straw (regions / total Slovak production, 2005)
Share of wood waste (regions / total Slovak production, 2005)

Share of manure from livestock production (regions / total Slovak production, 2005)
Forest biomass

- The total cutting of wood was 10,190,000 m³ in 2005
  - of which 6,927,000 m³ of coniferous wood
  - 3,263,000 m³ of foliaceous wood
- The total production of wood residues was 1,810,000 tons
- The total production of wood residues from wood-processing industry is 1,410,000 tons

Biomass for biofuels production

Supplies of crude materials for the production of esters till 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Esters (t)</th>
<th>Rape (t)</th>
<th>Required harvest area of rape (ha)</th>
<th>Total acreage of rape (ha)</th>
<th>Ratio of area to esters, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>18 376</td>
<td>55 128</td>
<td>24 944</td>
<td>106 204</td>
<td>23,48</td>
</tr>
<tr>
<td>2010</td>
<td>63 151</td>
<td>189 453</td>
<td>63 151</td>
<td>160 000</td>
<td>39,5</td>
</tr>
</tbody>
</table>

Variant 1 – Production of corn-based bioethanol

<table>
<thead>
<tr>
<th>Year</th>
<th>Bioethanol (t)</th>
<th>Corn (t)</th>
<th>Required area of corn (ha)</th>
<th>Total acreage of corn (ha)</th>
<th>Ratio of area to bioethanol, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>15 935</td>
<td>39 837</td>
<td>6 639</td>
<td>154 085</td>
<td>4,3</td>
</tr>
<tr>
<td>2010</td>
<td>47 122</td>
<td>117 805</td>
<td>16 829</td>
<td>140 000</td>
<td>12,0</td>
</tr>
</tbody>
</table>

Variant 2 – Bioethanol production on the base of high-density sown cereals

<table>
<thead>
<tr>
<th>Year</th>
<th>Bioethanol (t)</th>
<th>Cereals (t)</th>
<th>Required area of cereals (ha)</th>
<th>Total acreage of cereals (ha)</th>
<th>Ratio of area to bioethanol, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>15 935</td>
<td>52 585</td>
<td>10 517</td>
<td>372 962</td>
<td>2,8</td>
</tr>
<tr>
<td>2010</td>
<td>47 122</td>
<td>155 500</td>
<td>25 918</td>
<td>450 000</td>
<td>5,8</td>
</tr>
</tbody>
</table>
Production of Municipal Waste (MW) and Biodegradable Waste (BDW)

<table>
<thead>
<tr>
<th>Waste in t</th>
<th>Year 2004</th>
<th>Year 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal waste (MW), from that</td>
<td>1 475 123,7</td>
<td>1 558 262,9</td>
</tr>
<tr>
<td>Biodegradable waste (BDW)</td>
<td>86 547</td>
<td>95 864</td>
</tr>
</tbody>
</table>

Total energetic potential of agricultural biomass

<table>
<thead>
<tr>
<th>Sort of biomass</th>
<th>Amount/volume</th>
<th>Energetic potential in PJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agr. Biomass for incineration/combustion</td>
<td>2 031 000 t</td>
<td>28,6</td>
</tr>
<tr>
<td>Forest dendromass</td>
<td>1 810 000 t</td>
<td>16,9</td>
</tr>
<tr>
<td>Wood-processing industry</td>
<td>1 410 000 t</td>
<td>18,1</td>
</tr>
<tr>
<td>Biomass for production of bio fuels</td>
<td>200 000 t</td>
<td>7,0</td>
</tr>
<tr>
<td>Pressings and distiller-dried grains as a by-product of bio fuels</td>
<td>400 000</td>
<td>8,4</td>
</tr>
<tr>
<td>Manure from farm animals</td>
<td>13 700 000</td>
<td>9,3</td>
</tr>
<tr>
<td>Biomass planted for energy production</td>
<td>300 000 ha</td>
<td>32,0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>120,3</strong></td>
<td></td>
</tr>
</tbody>
</table>
Energetic potential of agricultural biomass categories

- Agricultural biomass for combustion: 26%
- Forest dendromass: 8%
- Wood-processing industry: 7%
- Biomass for biofuels production: 6%
- Pressings and distiller-dried grains as a by-product of biofuels: 15%
- Excrements of farm animals: 15%
- Purpose-planted biomass for energy production: 14%

Forecast of energy production in 2010

<table>
<thead>
<tr>
<th>Source</th>
<th>Year 2004, in GWh</th>
<th>Year 2010, in GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>33</td>
<td>410</td>
</tr>
<tr>
<td>Biogas</td>
<td>2</td>
<td>180</td>
</tr>
<tr>
<td>Wind-power plant</td>
<td>6</td>
<td>300</td>
</tr>
<tr>
<td>Small hydraulic power plant</td>
<td>250</td>
<td>350</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>291</strong></td>
<td><strong>1240</strong></td>
</tr>
</tbody>
</table>
Forecast of electricity production in 2010

- Wind power plants: 6 GWh (2004) and 300 GWh (2010)
- Biogas: 180 GWh (2010)
- Biomass: 33 GWh (2010)

Assumed share of several RES in power production in 2010

- Biomass: 33%
- Biogas: 24%
- Wind power plants: 15%
- Small hydraulic power plants: 28%
Risk related to the development of the use of biomass and RES in Slovakia

- lack of available capital,
- lack of scientific research,
- slow restructuring and modernization of energy technologies,
- slow change of inefficient technologies increasing production costs,
- limited financial governmental support for applied research.

Recommendations on the use of biomass in Slovakia

- issue appropriate legislative regulation to support biomass utilization most optimal solution - act supporting heat and electricity production from RES,
- develop local concept of support to biomass for energy,
- create consultation centre for biomass,
- disseminate knowledge among biomass producers,
- introduce education specialists for biomass and RES in the schools,
- support gasification and tri-generation,
- evaluate biomass in combined heat and electricity production,
- establishment and development pilot project of utilization agricultural biomass for space heating, water heating, drying agricultural biomass and electricity production.
Potentials and Limits of the use Agricultural Residues for Bioenergy in Lithuania

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Lithuanian University of Agriculture
E-mail Kestutis.Navickas@lzuu.lt
Tel. + 370 68 78 68 26
Fax. + 370 37 75 22 71

LITHUANIA

- Population - 3.4 mil
- Total area - 65000 sq km
- Agricultural land - 3.5 mil ha
- Forests - 2.0 mil ha
- Total arable land - 2.9 mil ha
- Meadows and natural pastures - 0.5 mil ha.
Lithuania’s climate conditions

Lithuanian’s climate temperate between maritime and continental. The average annual precipitation level is 630 mm, which is higher in the western and lower in the eastern part of the country. 82% of agricultural land is drained.

The average annual temperature is 6 °C (the lowest -4.8 °C in January and the highest 17.2 °C in July). The length of active growth season, with temperatures above 10 °C, is 135-150 days.

Low fertility acid soils account for 63% of the country. Fertile soils account for 26% and prevail the central part of Lithuania.

Structure of land use for agricultural activities in 2005

- Arable land: 72%
- Meadows and pastures: 11%
- Forests: 5%
- Water bodies: 2%
- Roads: 1%
- Orchard: 1%
- Buildings: 1%
- Other land: 7%
Traditionally cereals have been one of Lithuania’s most important agricultural sectors. Cereals are grown for domestic feed and food needs. Cereals cover about 60% of the total crop area and are grown on almost every farm.

After EU Accession cereal crop area increased by 10% and reached 950,000 ha in 2005. It was influenced by prospects of higher prices, direct payments and changes in the market. In 2005 81% of grain plants were sown by farmers and residents private farms. The remaining part was sown by agricultural companies.

Most popular cereals are wheat and barley. In 2005 wheat was grown on 370,000 ha, barley - 350,000 ha. Area of rye decreased due slip of prices and demand in the market.
Yields of cereals are lower than in other EU countries. In the 2005 average yield from cereals was 2.9 ton/ha. Less use of fertilizers and pesticides, small scale farms, insufficient machinery and unfavorable climate influence this difference.

There are differences of the yield on some regions, influenced by climate conditions.

Stronger competition in the EU threatens grain growers’ profitability; they need to increase cereal yields, improve grain quality, reduce costs and develop growing technologies.

The use of RES is one of the main objectives of the Lithuanian energy policy set out in the Law on Energy and the National Energy Strategy approved by Resolution of the Parliament aiming at a 12% share of renewable energy sources in the total energy consumption by 2010.

The promotion of the production and use of biofuel is foreseen in the Law on Biofuel, Biofuels for Transport and Bio-oils providing for the competence of institutions. The Law obligates to prepare measures to ensure that by 31 December 2010 the share of biofuels for transport shall amount to at least 5.75% of the total energy content of all petrol and diesel for transport purposes placed on the national market. The production of biofuel is attributed to new, environment-friendly technologies.

The Law on Electricity provides for certain priorities of electricity produced from renewable, waste or local energy sources. Electricity, produced on biomass plants, has a special price of 0.06 Euro/kWh.

The Law on Environmental Protection promotes waste recycling for energy purposes.

The Law on Pollution Tax provides that natural and legal persons implementing measures intended to reduce pollutant emissions from stationary pollution sources at least by 10%, shall be exempt from the pollution tax.

The Rules for financing the production of biofuels for transport are approved annually by the Minister for Agriculture, providing for promotion biofuel production facilitating the use of agricultural produce for non-food applications. Farmers receive the EU subsidies of 45 Euro per hectare for selling crops for energy production.

The Government approved the updated Description of the procedure including general criteria, conditions and requirements for the promotion of generation and purchasing of electric power produced using RES: it promotes electric power generation in wind, biomass and solar hydro plants of a capacity of less than 10 MW.
### Implementation of RES in Lithuania

<table>
<thead>
<tr>
<th>RE sources</th>
<th>Energy production, TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Wood</td>
<td>8.24</td>
</tr>
<tr>
<td>Straw</td>
<td>0.03</td>
</tr>
<tr>
<td>Liquid biofuel</td>
<td>0.04</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>0.00</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.02</td>
</tr>
<tr>
<td>Landfill gas</td>
<td>0.017</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.45</td>
</tr>
<tr>
<td>Solar</td>
<td>0.00</td>
</tr>
<tr>
<td>Wind</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8.80</strong></td>
</tr>
</tbody>
</table>

### Biomass energy

In 2006, Lithuania had:
- two cogeneration plants using wood waste, with a total installed capacity of 13.5 MW;
- seven biogas power plants, including five cogeneration plants (able to generate both heat and power) and two heat-only generation plants. The total installed capacity of biogas power plants is about 17.1 MW (heat generation plant - about 15.0 MW, power plant - about 2.1 MW).

At present, there are 200 boiler-houses (of over 0.3 MW capacity) using biofuel (wood, wood waste and straw). The total installed capacity of the boiler-houses is about 500 MW.

In the updated National Energy Strategy the plans are 50% of Lithuania’s central heating to be provided by biomass by 2025. Lithuania plans to double use of biomass for heat and power using wood, straw, municipal waste, as well as fast growing trees and crops.
Straw

Estimation shows that total yield of straw in Lithuania amounts to 3.5-4.0 mill tones per year. This includes rye, winter and spring wheat, triticale, barley, oats and rape straw. Traditionally straw is used for fodder, bedding, gardening and mushrooms. Part is left in the fields. It can be assumed that about 10-12% of the total amount of straw or 400-500,000 tonnes could be used as a fuel.

Straw for the fuel started to be used in Lithuania in 1996. Recently the total installed capacity of straw-fired boilers make up 5 MW. Capacities of these boilers varies from 15 to 340 kW. About 7500 tones of straw is used for fuel.

Small scale boilers are installed at individual farmhouses. Larger boilers are designated for district heating systems.

Straw yield, 1000 t.

- Barley: 870
- Wheat: 1830
- Rye: 580
- Oat: 90
- Triticale: 120
- Rape: 400
Straw use, mill. t.

- Fodder: 0.15
- Fuel: 0.008
- Bedding: 1.58
- Harvesting losses: 0.58
- Rest: 1.56
- Other use: 0.01

Regional distribution of possible use of straw for energy, 1000 t DM

Source: Lithuanian Institute of Agricultural Engineering

K. Navickas Lithuania
Estimation of straw based plants

The installation costs of straw-burning plants vary significantly from 583 to 2029 Lt/kW. Such large variation of installation costs are because different infrastructure (new boiler-house buildings, fuel storage buildings etc.) are included in the project costs. Investments are lower when boilers are placed in the existent boiler houses.

Price of straw fuel varies from 3.79 to 5.36 Lt/GJ (according to calorific value) and it depends on the way of acquisition. Three different cases in provision of straw are observed. The cheapest one is when the owner of boiler is agricultural institution or similar and has its own straw resources. The second case is when straw is purchased from farmers or agricultural companies. The third case is when owner of boiler rents field of cereals after harvesting aiming to collect straw for fuel purposes.

Average energy production cost for straw based plants is app. 18 Lt/GJ, it includes operation and maintenance cost of app. 6 Lt/GJ. Average energy price is 38 Lt/GJ (based on calorific value).

Solid biofuel (wood, straw) in district heating (%)

Source: LITBIOMA
Average costs of main fuels

<table>
<thead>
<tr>
<th>Year</th>
<th>Gas</th>
<th>Oil</th>
<th>Solid biofuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>231</td>
<td>158</td>
<td>221</td>
</tr>
<tr>
<td>1997</td>
<td>199</td>
<td>110</td>
<td>199</td>
</tr>
<tr>
<td>1998</td>
<td>175</td>
<td>78</td>
<td>178</td>
</tr>
<tr>
<td>1999</td>
<td>175</td>
<td>82</td>
<td>178</td>
</tr>
<tr>
<td>2000</td>
<td>211</td>
<td>251</td>
<td>211</td>
</tr>
<tr>
<td>2001</td>
<td>251</td>
<td>304</td>
<td>251</td>
</tr>
<tr>
<td>2002</td>
<td>304</td>
<td>362</td>
<td>304</td>
</tr>
<tr>
<td>2003</td>
<td>362</td>
<td>400</td>
<td>362</td>
</tr>
<tr>
<td>2004</td>
<td>400</td>
<td>460</td>
<td>400</td>
</tr>
<tr>
<td>2005</td>
<td>460</td>
<td>518</td>
<td>460</td>
</tr>
<tr>
<td>2006</td>
<td>518</td>
<td>625</td>
<td>518</td>
</tr>
<tr>
<td>2007</td>
<td>625</td>
<td>720</td>
<td>625</td>
</tr>
<tr>
<td>2008</td>
<td>720</td>
<td>800</td>
<td>720</td>
</tr>
</tbody>
</table>

In 2007 Lithuanian biofuel production should reach 60,000 t. Ethanol production will increase to 20,000 t, production of biodiesel will increase to 40,000 t.

The Lithuanian Ministry of Agriculture has set production targets of 190 thousand tons of biodiesel and 190 thousand tons of ethanol for 2010. Even at those levels, Lithuania believes it can produce enough raw materials domestically for biofuel production, but above 380 thousand t, it would need to import grain. The government believes that these ambitious projections are possible to meet based on the new biofuel plants under construction and the plans to increase acreage of biofuel crops.

About 10–15% of the country's agricultural crop areas could be used for the cultivation of plants intended for energy purposes. By 2010, oilseed rape (raw material for the production of biodiesel) crop areas are expected to cover about 290 000 ha, with those of cereal grains (raw material for the production of bioethanol) to cover about 250 000 ha.

Expansion area for energy cereals will make additional straw production. It can be basis for further development of new straw based energy plants.
Production of biofuel and required area of cereals

Conclusions

Cereals cover about 60% (950,000 ha) of the total crop area and are grown on almost every farm. Most popular are wheat and barley.

Total yield of straw in Lithuania amounts to 3.5-4.0 mill tones per year. Traditionally straw is used for fodder, bedding, gardening and mushrooms. Present straw use for fuel is 7500 tones per year. It can be assumed that about 10-12% of the total amount of straw or 400-500,000 tones could be used as a fuel.

The straw use as fuel increases slightly, due to the relatively expensive straw combustion equipments, big investments to infrastructure (straw collection, pressing and transportation), lack of traditions.

Growing interest of liquid biofuel production will increase area biofuel crops and straw production as well. It can influence interest of straw energy use.
CEREALS STRAW AND AGRICULTURAL RESIDUES FOR BIOENERGY IN ROMANIA

Ion Antohe
NATIONAL AGRICULTURAL RESEARCH and DEVELOPMENT INSTITUTE FUNDULEA - ROMANIA

WORKSHOP “Cereal Straw and Agricultural Residues for Bioenergy in New Member States and Candidate Countries.
NOVI-SAD – October 2-3, 2007

INDUSTRY REVOLUTION OF XXI CENTURY WILL BE MARKED AMONG OTHERS BY BIO-ECONOMY

CEREAL STRAW YIELD AND ENERGY POTENTIAL

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat crop area (million ha)</td>
<td>1,940</td>
<td>2,559</td>
<td>2,310</td>
<td>1,748</td>
<td>2,296</td>
<td>2,476</td>
<td>2,221</td>
</tr>
<tr>
<td>Total straw yield (million t dry matter)</td>
<td>2,864</td>
<td>4,449</td>
<td>2,991</td>
<td>1,582</td>
<td>4,486</td>
<td>4,392</td>
<td>3,461</td>
</tr>
<tr>
<td>Collectable straw/grain ratio</td>
<td>0,6</td>
<td>0,5</td>
<td>0,6</td>
<td>0,5</td>
<td>0,8</td>
<td>0,8</td>
<td>0,63</td>
</tr>
<tr>
<td>Energy potential: (million. toe)</td>
<td>0,9738</td>
<td>1,4831</td>
<td>0,9971</td>
<td>0,5273</td>
<td>1,4954</td>
<td>1,4641</td>
<td>1,1568</td>
</tr>
<tr>
<td>(10^3Gj)</td>
<td>40,914</td>
<td>68,965</td>
<td>46,363</td>
<td>24,520</td>
<td>71,087</td>
<td>68,081</td>
<td>52,322</td>
</tr>
<tr>
<td>Biogas = 10^3Gj</td>
<td>57,290</td>
<td>89,784</td>
<td>59,813</td>
<td>31,639</td>
<td>62,593</td>
<td>110,584</td>
<td>100,3</td>
</tr>
</tbody>
</table>

Crop area data Ministry of Agriculture - 2006
Romania's Institute of statistic
Energy equiv. E.Matei, 1995
MAIZE STOVER YIELD POTENTIAL AND ITS ENERGY POTENTIAL
ROMANIA 2000-2005

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize crop area (mil. ha)</td>
<td>3,049</td>
<td>2,974</td>
<td>2,894</td>
<td>3,199</td>
<td>3,274</td>
<td>2,628</td>
</tr>
<tr>
<td>Total stover yield (million t dry matter)</td>
<td>7,113</td>
<td>14,043</td>
<td>12,305</td>
<td>13,746</td>
<td>21,278</td>
<td>14,520</td>
</tr>
<tr>
<td>stover/grain ratio</td>
<td>1.2</td>
<td>1.2</td>
<td>1.3</td>
<td>1.1</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Energy potential: (million toe)</td>
<td>2,354</td>
<td>4,648</td>
<td>4,073</td>
<td>4,550</td>
<td>7,043</td>
<td>4,806</td>
</tr>
<tr>
<td>(10^9Gj)</td>
<td>91.192</td>
<td>180.04</td>
<td>157.756</td>
<td>176.23</td>
<td>272.790</td>
<td>207.428</td>
</tr>
<tr>
<td>Energy via Biogas 10^9Gj</td>
<td>102.211</td>
<td>201.283</td>
<td>176.372</td>
<td>274.920</td>
<td>425.558</td>
<td>290.379</td>
</tr>
</tbody>
</table>

Crop area data Ministry of Agriculture 2006
Romania’s Year of Statistic. doc. 2005
Energy potential E. Matei, 1995


<table>
<thead>
<tr>
<th>Non irrigated land</th>
<th>extensive cropping</th>
<th>intensive cropping</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Straw (wheat, barley, rye) yield - million t dry matter/yr</td>
<td>6.9</td>
<td>10.5</td>
</tr>
<tr>
<td>Energy potential (PJ/yr)</td>
<td>119</td>
<td>183.7</td>
</tr>
<tr>
<td>≈ 80 % efficiency</td>
<td>95.2</td>
<td>147.8</td>
</tr>
<tr>
<td>energy density (GJ/ha)</td>
<td>2.7</td>
<td>18.4</td>
</tr>
<tr>
<td>2) Straw (wheat, barley, rye) and agricultural residues (maize, sunflower) yield - dm t/yr</td>
<td>13.4</td>
<td>37.4</td>
</tr>
<tr>
<td>energy potential (PJ/yr)</td>
<td>266.5</td>
<td>764.2</td>
</tr>
<tr>
<td>≈ 80 % efficiency</td>
<td>212.8</td>
<td>611.4</td>
</tr>
<tr>
<td>energy density (GJ/ha)</td>
<td>6.3</td>
<td>24.2</td>
</tr>
</tbody>
</table>

Irrigated land

| Straw (wheat, barley, rye) and agricultural residues (maize, sunflower) yield (dm t/yr) | 26.1 | 72.9 |
| Energy potential PJ/yr | 520 | 1,400 |
| ≈ 80 % PJ/yr | 416 | 1,120 |
| energy density (GJ/ha) | 10.8 | 45.6 |
## BIOENERGY OBTAINABLE FROM ENERGY CROPS IN ROMANIA DURING 2007 -2010

<table>
<thead>
<tr>
<th>Crop area (million ha)</th>
<th>Straw yield (million t)</th>
<th>Energy potential (million toe)</th>
<th>10^6 Gj</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>2.428</td>
<td>1.133</td>
<td>43.894</td>
</tr>
<tr>
<td>2007</td>
<td>1.800</td>
<td>0.845</td>
<td>32.735</td>
</tr>
<tr>
<td>2010</td>
<td>1.500</td>
<td>0.720</td>
<td>27.892</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop area (million ha)</th>
<th>Stalk yield (million t)</th>
<th>Energy potential (million toe)</th>
<th>10^6 Gj</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>14.520</td>
<td>2.850</td>
<td>184.557</td>
</tr>
<tr>
<td>2007</td>
<td>2.850</td>
<td>10.050</td>
<td>191.685</td>
</tr>
<tr>
<td>2010</td>
<td>10.050</td>
<td>3.141</td>
<td>121.682</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop area (million ha)</th>
<th>Stover yield (million t)</th>
<th>Energy potential (million toe)</th>
<th>10^6 Gj</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>4.806</td>
<td>14.520</td>
<td>184.557</td>
</tr>
<tr>
<td>2007</td>
<td>4.948</td>
<td>3.141</td>
<td>121.682</td>
</tr>
<tr>
<td>2010</td>
<td>5.000</td>
<td>3.141</td>
<td>121.682</td>
</tr>
</tbody>
</table>

## SUSTAINABILITY CRITERIA FOR ENERGY CROP BIOMASS IN ROMANIA

<table>
<thead>
<tr>
<th>Resource</th>
<th>Cereals</th>
<th>Maize</th>
<th>Sunflower</th>
<th>Broocom x Sweet Sorghum-Sudanese</th>
<th>Helianthus tuberosus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.7651</td>
<td>0.8000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.7651</td>
<td>0.8000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.7651</td>
<td>0.8000</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FAILLING TO PLANNING IS .....PLANNING TO FAIL

<table>
<thead>
<tr>
<th>Resource</th>
<th>Cereals</th>
<th>Maize</th>
<th>Sunflower</th>
<th>Broocom x Sweet Sorghum-Sudanese</th>
<th>Helianthus tuberosus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 - assure food, feed, and even pharmaceuticals by refinery processing of entire crop.
1a – need insecticide treatment during vegetation
1b – usually without insecticide treatments
1c – some years or places suited to insecticide treatments at the beginning of growing durations
1i – acceptable crop sequence for farmers and ready to use technology knowledge
1ii – difficulties in stubble eradicating.
Cereals, maize, sorghum and Helianthus tuberosus – ethanol + higher potential reducing pollutant emissions than biodiesel.
SOIL FERTILITY CLASSES* OF ROMANIA AND LAND AREA DESTINED TO ENERGY PURPOSES

<table>
<thead>
<tr>
<th></th>
<th>1*</th>
<th>2*</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area (ha), of which:</td>
<td>124,363</td>
<td>2,076,873</td>
<td>3,350,379</td>
<td>236,2918</td>
<td>1,495,539</td>
<td>9,410,072</td>
</tr>
<tr>
<td>For food purposes</td>
<td>124,363</td>
<td>2,076,873</td>
<td>3,350,379</td>
<td>1,162,918</td>
<td>605,639</td>
<td>5,551,615</td>
</tr>
<tr>
<td>For non food purposes</td>
<td></td>
<td></td>
<td></td>
<td>3,058,457 of which</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for RES</td>
<td>≈1,200,000</td>
<td>800,000</td>
<td>≈ 2,000,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% from total arable land</td>
<td>9 %</td>
<td>6 %</td>
<td>15 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU regulations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 - 15 %</td>
</tr>
</tbody>
</table>

The government paid attention to food security even in the frame work of bioenergy system. About 5.5 mil. ha are reserved for food security and that include the best I-IV soil fertility classes. 1* = ≥100 kg grain/unit of suitability class. Of 9,410,072 ha, about 3,968,126 ha under desertification process and about 930,000 ha susceptible to nitrate percolation under heavy (> 100 kg N/ha) nitrate fertilisation.

ECOLOGY THE MAJOR RELIGION OF XXI CENTURY ENVIRONMENTAL IMPACTS OF THE ENERGY CROP BIOMASS PRODUCTION

<table>
<thead>
<tr>
<th></th>
<th>Soil quality</th>
<th>Water quantity and quality</th>
<th>Emissions</th>
<th>Bio-diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>erosion</td>
<td>soil compaction</td>
<td>moisture retention</td>
<td>nutrient input</td>
</tr>
<tr>
<td>Cereals wheat</td>
<td>A</td>
<td>C</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Maize</td>
<td>C</td>
<td>A</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Sunflower</td>
<td>C</td>
<td>A</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Sweet sorghum</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Helianthus tuberosus</td>
<td>A - B</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

A = slow - poor intensity  
B = medium intensity  
C = strong intensity
ENERGETICAL POTENTIAL OF RES IN ROMANIA

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Potential/yr 10^3 TOE</th>
<th>Use (intentional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>6 x10^3 Gj</td>
<td>143.3 thermal</td>
</tr>
<tr>
<td>Wind</td>
<td>23,000 Gwh</td>
<td>1,978 electric</td>
</tr>
<tr>
<td>Hydro</td>
<td>40,000 Gwh</td>
<td>516.0 electric</td>
</tr>
<tr>
<td>Biomass</td>
<td>318 x 10^6 Gj</td>
<td>7,597 thermal and transport</td>
</tr>
<tr>
<td>Geothermal</td>
<td>7 x 10^6 Gj</td>
<td>167.0 thermal</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10,504 x 10^3 Toe</strong></td>
<td></td>
</tr>
</tbody>
</table>

Evaluations of RAES; ICEMENERG; ICPE; INL; ISPH; ENERO – from Romania GD 1335/2003

Agri forestry biomass represent one of the most important sources of RSE in Romania. Energy crops biomass could make a real contribution for rising total agricultural biomass. From 5.2 Mtoe to 7.597 toe – other biomass sources (forestry and so on). Energy crops could enhance to 10 Mtoe/yr.

Biomass Used in Romania (2000)

<table>
<thead>
<tr>
<th>Biomass type</th>
<th>Energetic potential Pj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>40.03</td>
</tr>
<tr>
<td>Wood residues</td>
<td>10.3</td>
</tr>
<tr>
<td>Agricultural residues</td>
<td>35.04</td>
</tr>
<tr>
<td>Biogas</td>
<td>6.02</td>
</tr>
<tr>
<td>Others</td>
<td>≈24.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>116.0</strong> → 0.81 % from a total of 1689 Pj at national level of biomass resources</td>
</tr>
</tbody>
</table>

FOOD, FEED, ENERGY
- FORECAST FOR ROMANIAN AGRICULTURAL DEVELOPMENT 2025 - 2030 -

<table>
<thead>
<tr>
<th>BIOMASS Processing</th>
<th>OBJECTIVES</th>
<th>FOOD</th>
<th>FEED</th>
<th>ENERGY</th>
<th>ENVIRONMENT</th>
<th>RISK</th>
<th>NEW JOBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOGAS</td>
<td>5 - 6.5 million cattle</td>
<td>≈18-24 million t milk</td>
<td>-</td>
<td>=215-279 GJ</td>
<td>A</td>
<td>≈2-3.5 million</td>
<td></td>
</tr>
<tr>
<td>BIOETHANOL</td>
<td>liquid biofuel 2 x 10^6 m^3</td>
<td>1.5 – 1.8 x 10^6 million t</td>
<td>1.3 – 1.4 million toe</td>
<td>A – B</td>
<td>0.12-0.15 million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIODIESEL</td>
<td>liquid biofuel 6 -7 x 10^6 t</td>
<td>1 x 10^6 million t</td>
<td>0.50 – 0.55 million toe</td>
<td>A</td>
<td>0.1 million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PYROLYSE OIL</td>
<td>liquid biofuel =3 x 10^7</td>
<td>-</td>
<td>0.4 million toe</td>
<td>A</td>
<td>0.1 million</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bioethanol and biodiesel from energy crops could be preferred solutions

Bio gas is suitable for cattle manure processing. The cereals straw used as cattle bedding (about 9 million) is by far the best uses for obtaining, food, energy and fertiliser (humus forerunners) at the same time with a larger offer for new job (animal growing).

Pyrolysis technology is a tool for incinerating agricultural residues containing contaminant pathogens and pests

Biodiesel obtained from non traditional food oil (Rape, Camelina, etc.) could be a good solution for sustaining biodiversity, biomass chain supply and feed quantity, quality and diversity.
ONGOING PROJECTS FOR BIOFUEL PLANTS IN ROMANIA

<table>
<thead>
<tr>
<th>Ethanol plants ≥10^4 t/yr</th>
<th>Biodiesel plants ≥10^4 t/yr</th>
<th>Biogas plants</th>
<th>Fast pyrolysis plants</th>
<th>Pellet plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10</td>
<td>&gt; 7</td>
<td>&gt; 5</td>
<td>1</td>
<td>8 - 10</td>
</tr>
</tbody>
</table>

of which

- 3 plants of 10^3 t/yr
- 2 plants of 10^3 t/yr
- one plant lignocellulosic raw material which probably will start during 2009-2010
Estimated production 1000 x 10^3 t/yr

six of them being established to start operating during 2007-2008
Estimated production 600 x 10^3 t/yr

- 3 plants on sewage sludge of bioethanol plants
- one plant starting during 2008 at pilot scale and during 2009 at commercial scale

- 3 plants on straw, agricultural residues and landfill
- export of agro-forestry pellets about 50 x 10^3 t/yr

LIGNOCELLULOSE CONTENT OF CEREALS
(percentage by weight)

<table>
<thead>
<tr>
<th>Agricultural biomass</th>
<th>Cellulose* K-H</th>
<th>Lignine</th>
<th>Penthosans</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet sorghum stalks</td>
<td>28 - 32</td>
<td>15 - 17</td>
<td>19 - 23</td>
<td>2.3 - 3.7</td>
</tr>
<tr>
<td>Sweet sorghum (bagasse)</td>
<td>35</td>
<td>14</td>
<td>20.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Sorghum x Sudanense – hybrids</td>
<td>42 - 52</td>
<td>13 - 17</td>
<td>19 - 22.5</td>
<td>2.5 - 3.5</td>
</tr>
<tr>
<td>Sudanense x Sorghum</td>
<td>56.4</td>
<td>13</td>
<td>20.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Broomcorn (Sorghum var.technichum)</td>
<td>35 - 50</td>
<td>17 - 19</td>
<td>19 - 24</td>
<td>4.9</td>
</tr>
<tr>
<td>Rice straw</td>
<td>15.9</td>
<td>21.1</td>
<td>14.4</td>
<td></td>
</tr>
<tr>
<td>Wheat straw</td>
<td>45.8</td>
<td>20.0</td>
<td>24.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Agricultural residues</td>
<td>30 - 42</td>
<td>11 - 29</td>
<td>-</td>
<td>2 - 18</td>
</tr>
<tr>
<td>Jerusalem artichoke (Helianthus tuberosus (L))</td>
<td>32</td>
<td>9</td>
<td>-</td>
<td>39</td>
</tr>
</tbody>
</table>

K-H = Kürschner-Hoffer
CHEMICAL COMPOSITION OF STRAW AND OTHER AGRICULTURAL RESIDUES FOR GASIFICATION PURPOSE

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Humid (%)</th>
<th>Ash</th>
<th>C</th>
<th>H</th>
<th>S</th>
<th>O₂ (+N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed</td>
<td>12.24</td>
<td>5.17</td>
<td>40.05</td>
<td>5.32</td>
<td>trail</td>
<td>37.22</td>
</tr>
<tr>
<td>Rice barks</td>
<td>13.55</td>
<td>13.34</td>
<td>33.79</td>
<td>4.38</td>
<td>&quot;&quot;</td>
<td>32.94</td>
</tr>
<tr>
<td>Sunflower barks</td>
<td>12.82</td>
<td>1.89</td>
<td>37.86</td>
<td>5.26</td>
<td>&quot;&quot;</td>
<td>42.17</td>
</tr>
<tr>
<td>Cereal straw</td>
<td>6.82</td>
<td>6.52</td>
<td>43.27</td>
<td>5.35</td>
<td>&quot;&quot;</td>
<td>38.04</td>
</tr>
</tbody>
</table>

PHYSICAL CHARACTERISTICS OF AGRICULTURAL BIOMASS

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Volatile materials dm</th>
<th>Calorific value Kcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed</td>
<td>max. 65.24</td>
<td>min. 3,846</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,486</td>
</tr>
<tr>
<td>Rice barks</td>
<td>43.51</td>
<td>3,470</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,153</td>
</tr>
<tr>
<td>Sunflower barks</td>
<td>61.57</td>
<td>3,795</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,465</td>
</tr>
<tr>
<td>Cereal straw</td>
<td>71.83</td>
<td>4,070</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,740</td>
</tr>
</tbody>
</table>

LEGISLATION DRAFT FOR BIOENERGY PROMOTION IN ROMANIA

Law 199/2000 - on Efficiently use of energy in Romania
Law 443/2003 - Electrical energy producing from RES – In Romania
GD 1335/2003 - RES using strategy in Romania (Energy saving)
Law 571/2003 - on exemption of excise fee for biofuels
GD 343/2006
Law 1835 – 2004
GD 1844 – 2005 – adoption of 2003/30/CE directive
GD 44 -2006 – Biodiesel consumers and biofuels investments subsidies
GD = government decision.

ENERGY BIOMASS RATE (% OF TOTAL ENERGY CONSUMPTION) USED FOR ELECTRICITY, HEAT AND TRANSPORT

<table>
<thead>
<tr>
<th>Year</th>
<th>RES</th>
<th>Electricity</th>
<th>Heat</th>
<th>Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>2005</td>
<td>6 %</td>
<td>14 %</td>
<td>≈10 %</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>12 %</td>
<td>22 %</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>20 %</td>
<td>33 %</td>
<td></td>
</tr>
<tr>
<td>ROMANIA</td>
<td>2005</td>
<td>10.01 %</td>
<td>27 %</td>
<td>20 %</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>11%</td>
<td>29.9 %</td>
<td>5.75%</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>15 %</td>
<td>33.5 %</td>
<td>≈ 10 %</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>20%</td>
<td>≈ 50%</td>
<td>≥ 20 %</td>
</tr>
</tbody>
</table>
Balance of straw in Poland

Jan Kuś, Mariusz Matyka
Department of Systems and Economics of Crop Production

Novi Sad, 2-3 October 2007
150 years of tradition in agricultural science in Pulawy

1862 – Technical Institute of Technology Agriculture and Forestry
1917 – National Research Institute of Rural Husbandry (PINGW)
1950 – Institute of Soil Science and Plant Cultivation (IUNG)

- the oldest agricultural centre in Poland
- the second oldest agricultural centre in Europe
  (after Rothamsted)
the evaluation criteria of solutions offered by the science and advisory service

<table>
<thead>
<tr>
<th>Earlier:</th>
<th>maximization of production and profits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now:</td>
<td>the quality of products</td>
</tr>
<tr>
<td></td>
<td>economic effectiveness</td>
</tr>
<tr>
<td></td>
<td>safety for natural environment and human health</td>
</tr>
<tr>
<td></td>
<td>optimisation of use of production factors</td>
</tr>
</tbody>
</table>

Biomass – renewable energy sources
Consumption of energy carriers

<table>
<thead>
<tr>
<th>Country</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
<th>Biomass</th>
<th>Water</th>
<th>Wind</th>
<th>Geothermal</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland</td>
<td>58.79</td>
<td>23.75</td>
<td>12.8</td>
<td>4.4</td>
<td>0.01</td>
<td>0.18</td>
<td>0.31</td>
<td>0.29</td>
</tr>
<tr>
<td>UE-25</td>
<td>17.85</td>
<td>37.23</td>
<td>23.9</td>
<td>14.56</td>
<td>0.25</td>
<td>0.22</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>23.5</td>
<td>34.9</td>
<td>21.3</td>
<td>10.8</td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Targets in the area of utilization of renewable energy sources
- % in balance of primary energy:

<table>
<thead>
<tr>
<th>Specification</th>
<th>2001</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland*</td>
<td>1.0-1.5</td>
<td>7.5</td>
<td>14</td>
</tr>
<tr>
<td>UE</td>
<td>6</td>
<td>12</td>
<td>over 20</td>
</tr>
</tbody>
</table>

*Strategy for development accepted by government (5.09.2000) and approve by Sejm Republic of Poland (23.08.2001).
Possibility for utilization of straw

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrolysis</td>
<td>Gas of low calorie content</td>
</tr>
<tr>
<td>Gasification</td>
<td>Gas</td>
</tr>
<tr>
<td>Fermentation</td>
<td>Biogas</td>
</tr>
<tr>
<td>Liquefaction</td>
<td>Liquid fuel</td>
</tr>
<tr>
<td>Combustion</td>
<td>Heat energy</td>
</tr>
</tbody>
</table>

Benefits from utilization of straw for energy purposes in Poland

1. For agriculture
   - increase of the employment in the agricultural sector
   - increase the agricultural incomes,
   - reduction of the prices fluctuations of agricultural products,
   - stabilization of the agricultural production size,
   - stimulation of the local industry and development of the rural area.

2. For country
   - protection of the environment through limitation of emission NO\textsubscript{x} and closed circulation of CO\textsubscript{2}
   - increase of the energy security of Poland.
What is the reason of the surplus of straw?

- In 1985-2004, the cereals area increased in Poland from 7.8 to 8.6 million ha.
- In this period the share of cereals in the cropping pattern increased from 54 to 75%.
- In 1995-2004, cattle population decreased by 31%, sheep by 60% and horses by 50%.
- There were farms without livestock, 878,000 in 2002, (45% of total).
Sources of straw

- Cereals
- Maize
- Rape
- Pulses

Sown area in Poland in 2005 year

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Sown Area (thousands ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>wheat</td>
<td>2218</td>
</tr>
<tr>
<td>rye</td>
<td>1415</td>
</tr>
<tr>
<td>barley</td>
<td>1113</td>
</tr>
<tr>
<td>oats</td>
<td>539</td>
</tr>
<tr>
<td>triticale</td>
<td>195</td>
</tr>
<tr>
<td>maize</td>
<td>39</td>
</tr>
<tr>
<td>other cereals</td>
<td>388</td>
</tr>
<tr>
<td>Pulses</td>
<td>880</td>
</tr>
<tr>
<td>Potatoes</td>
<td>837</td>
</tr>
<tr>
<td>Industrial crops</td>
<td>440</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>15</td>
</tr>
<tr>
<td>Other crops</td>
<td>119</td>
</tr>
</tbody>
</table>
Ratio of grain : straw for cereals in Poland

Winter Wheat – 0.91
Spring Wheat – 0.94
Winter Triticale – 1.13
Winter Rye – 1.44
Winter Barley – 0.87
Spring Barley – 0.86
Oats – 1.08

Ways of straw utilization

- Fodder
- Litter
- Incorporation to soil
- Surplus for energy use
Quality of straw
Dependence of energy value upon the humidity of straw

<table>
<thead>
<tr>
<th>Humidity %</th>
<th>Fuel value (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

- --- --- Rapeseed straw
- --- --- Wheat straw
- --- --- Barley straw

Source: Gradziuk, 2006

Production of straw (average, 2002-2005)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Harvest (thousands tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter cereals</td>
<td>14,369</td>
</tr>
<tr>
<td>Spring cereals</td>
<td>8,821</td>
</tr>
<tr>
<td>Rape</td>
<td>1,206</td>
</tr>
<tr>
<td>Maize</td>
<td>2,033</td>
</tr>
<tr>
<td>Pulse crops</td>
<td>223</td>
</tr>
<tr>
<td>Total</td>
<td>26,652</td>
</tr>
</tbody>
</table>
Utilization of straw in Poland

<table>
<thead>
<tr>
<th>Utilization</th>
<th>thousand tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter</td>
<td>12,080</td>
</tr>
<tr>
<td>Fodder</td>
<td>4,059</td>
</tr>
<tr>
<td>Incorporation to soil</td>
<td>3,038</td>
</tr>
<tr>
<td>Total</td>
<td>19,177</td>
</tr>
</tbody>
</table>

How was calculated quantity of straw for incorporation

<table>
<thead>
<tr>
<th>Specification</th>
<th>Poland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of degradation of soil organic matter (t•ha(^{-1})•year(^{-1}))</td>
<td>-0.53</td>
</tr>
<tr>
<td>Dose of manure</td>
<td>7.3</td>
</tr>
<tr>
<td>Dry mass of manure (t•ha(^{-1})•year(^{-1}))</td>
<td>1.82</td>
</tr>
<tr>
<td>Reproduction of soil organic matter (t•ha(^{-1}))</td>
<td>0.64</td>
</tr>
<tr>
<td>Balance (t•ha(^{-1}))</td>
<td>0.10</td>
</tr>
<tr>
<td>Straw for incorporation (t•ha(^{-1}))</td>
<td>0.27</td>
</tr>
<tr>
<td>Sown area (thousands ha)</td>
<td>11,033</td>
</tr>
<tr>
<td>Total straw for incorporation (thousands t)</td>
<td>3,039</td>
</tr>
</tbody>
</table>
### Balance of straw in Poland

<table>
<thead>
<tr>
<th>Region</th>
<th>Harvest of straw</th>
<th>Utilization of straw:</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>litter</td>
<td>fodder</td>
<td>incorporation on soil</td>
</tr>
<tr>
<td>Poland</td>
<td>26,652</td>
<td>12,080</td>
<td>4,059</td>
</tr>
<tr>
<td>Dolnośląskie</td>
<td>2,382</td>
<td>323</td>
<td>99</td>
</tr>
<tr>
<td>Kujawsko-pomorskie</td>
<td>2,280</td>
<td>1,047</td>
<td>294</td>
</tr>
<tr>
<td>Lubelskie</td>
<td>2,429</td>
<td>916</td>
<td>325</td>
</tr>
<tr>
<td>Lubuskie</td>
<td>674</td>
<td>181</td>
<td>52</td>
</tr>
<tr>
<td>Łódzkie</td>
<td>1,664</td>
<td>961</td>
<td>324</td>
</tr>
<tr>
<td>Małopolskie</td>
<td>770</td>
<td>564</td>
<td>223</td>
</tr>
<tr>
<td>Mazowieckie</td>
<td>2,739</td>
<td>1,808</td>
<td>695</td>
</tr>
<tr>
<td>Opolskie</td>
<td>1,613</td>
<td>346</td>
<td>91</td>
</tr>
<tr>
<td>Podkarpackie</td>
<td>806</td>
<td>392</td>
<td>152</td>
</tr>
<tr>
<td>Podlaskie</td>
<td>1,268</td>
<td>1,160</td>
<td>507</td>
</tr>
<tr>
<td>Pomorskie</td>
<td>1,402</td>
<td>519</td>
<td>141</td>
</tr>
<tr>
<td>Śląskie</td>
<td>773</td>
<td>332</td>
<td>109</td>
</tr>
<tr>
<td>Świętokrzyskie</td>
<td>713</td>
<td>399</td>
<td>154</td>
</tr>
<tr>
<td>Warmińsko-mazurskie</td>
<td>1,463</td>
<td>750</td>
<td>291</td>
</tr>
<tr>
<td>Wielkopolskie</td>
<td>3,909</td>
<td>2,061</td>
<td>519</td>
</tr>
<tr>
<td>Zachodniopomorskie</td>
<td>1,767</td>
<td>321</td>
<td>83</td>
</tr>
</tbody>
</table>

### Regional differentiation in surplus of straw

- Dolnośląskie: 618
- Kujawsko-pomorskie: 939
- Lubelskie: 742
- Lubuskie: 422
- Łódzkie: 236
- Małopolskie: 920
- Mazowieckie: 379
- Opolskie: 160
- Podkarpackie: 32
- Podlaskie: 259
- Pomorskie: 0
- Śląskie: 0
- Świętokrzyskie: 0
- Warmińsko-mazurskie: 0
- Wielkopolskie: 0
- Zachodniopomorskie: 0

**INSTITUTE OF SOIL SCIENCE AND PLANT CULTIVATION – NATIONAL RESEARCH INSTITUTE**
What about the future?

Straw production for energy utilization in future will grow, because:

- Cereals area will be in the same level, and it can even grow to 9 millions ha.
- Area of rape will grow from 0.5 to 1 million ha, because of biofuel production and implementation of EU Biofuels Directive (2003/30).
- Utilisation for fodder and litter will probably drop, because economic factors promote growth of individual production capacity at decrease of livestock.

Recapitulation

1. In regions with crumbled agrarian structure, despite a straw surplus, harvest and transport of straw for energy purposes will be unprofitable.
2. The yields of cereals and straw undergo seasonal fluctuation and therefore regarding for utilization of productive force. Surplus of straw for energy purposes should be estimated at 4-5 million ton.
3. Large amounts of straws can be assigned for energy utilization in regions with large farms. (low level of livestock, high share of cereals and rape in sown area).
4. Precise estimation of straw surplus for country or regions is difficult. Higher precision is possible for smallest administrative units, like administrative district or commune.
"Cereals straw and agricultural residues for bioenergy
Situation in Bosnia and Herzegovina"

HYDRO-ENGINEERING INSTITUTE
SARAJEVO
Semra Fejzibegović, B.Sc in Mech. Eng.

Agricultural land in B&H

- In accordance with the National Spatial Plan of B&H for period of 1981-2000 (it is still in use until the new Plan is prepared) it has been confirmed that:
  - Agricultural land in B&H is about half (50.3%) of the total land area of B&H, which amounts to 2,573,000 ha.
  - only 31.35% of agricultural land of sustainability class I to IV.
Relevant documents for data gathering

- Strategy of mid term development of agricultural sector in FB&H (2006-2010)
- Strategy of mid term development of agriculture and rural regions in Republic Srpska (2006-2015)

Federation of B&H

- Total area – 26,110.5 km² i.e., 2.6 mil ha
- 1,140,000 ha of total agricultural land, of which 63% is cultivated, i.e. 719,000 ha (0.25 ha/inhabitant)
- 411,000 ha tillage (57.2% of cultivated land)
- 42,000 ha orchards (5.8%)
- 4,000 ha vineyards (0.6 %)
- 262,000 ha natural meadow (36.4%).
Republic of Srpska Entity in B&H

- 1,241,000 ha of agricultural land, of which
- 908,000 ha of cultivated land, of which
- 590,000 ha are tillage and gardens.

Land characteristics in B&H

- 60 % of cultivated land is at least 500 m above sea level
- Five sixth of the territory with slope above 12%, which limits mechanical cultivation
Land characteristics in B&H

- 70% of land surface in B&H with erosion risk
- and about 200,000 ha with flood risk.

Site conditions

- Climate and precipitation pattern are not favourable for agriculture
- Water shortage in summer period is main limiting factor for agriculture development in Mediterranean part of the country, where agriculture is impossible without irrigation.
Agricultural practice

- Currently, the irrigated area is 4,630 ha, and potential area that should be irrigated is 74,000 ha
- The existing irrigation systems are damaged due to the war and neglect.
- Most of the land in North part of B&H which is used as cultivated land should be drained.

Cereal straw resources

- In FB&H for 2006 there are:
- 33,493 ha of harvested cereals (wheat, rye, barley, oat)
- Ratio of mass of seed/ha and mass of straw is approx. 1:1
- 0.359 t/ha of stubble ploughed in
Production of agricultural waste (FB&H, 2006)

- Cereals straw amounts to approximately 12,000 t/year
- Silage and hay is approximately 70,000 t/year

Agricultural practice

- Organic production- 116 ha of land (0.016% in relation to total cultivated land)
- 259.9 ha of land for integrated fruit production (0.62% in relation to total land under the orchards)
- There are no institutions and economic instruments for agricultural waste management
Cattle raising in B&H

- Good natural conditions for development, especially in North-West Region of B&H where it has been estimated that current number of livestock is only 35% of the pre war number
- According to the Statistical Yearbook, largest livestock in Tuzla Canton (the largest production of manure)

Current research

- Feasibility Study - Animal waste - Integrated problem solving of farm and slaughterhouse waste in North West region of B&H - EU CARDS Program for B&H - May 2005
- North-West Region covers 13 municipalities from FB&H and 21 municipalities from RS
Production of manure in north west region

- Questionnaire sent to 300 farms
- The total quantity of manure produced in Federation of B&H for 2006 has been calculated on the basis of daily and annual manure for each type of livestock
- The produced manure is approximately 4,550,000 t/year
- The most part of this amount (80%) has been spread over the cultivated land

### Production of manure

<table>
<thead>
<tr>
<th>Type of livestock</th>
<th>Number of head</th>
<th>Fresh manure per head (t/year)</th>
<th>Total production of manure (t/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cattle</td>
<td>233,289</td>
<td>15.33</td>
<td>3,576,320</td>
</tr>
<tr>
<td>Total sheep</td>
<td>541,606</td>
<td>0.661</td>
<td>358,002</td>
</tr>
<tr>
<td>Total pigs</td>
<td>94,196</td>
<td>2.92</td>
<td>275,052</td>
</tr>
<tr>
<td>Total horses</td>
<td>9,690</td>
<td>8</td>
<td>77,520</td>
</tr>
<tr>
<td>Total goats</td>
<td>44,849</td>
<td>0.679</td>
<td>30,452</td>
</tr>
<tr>
<td>Total poultry</td>
<td>6,786,100</td>
<td>0.034</td>
<td>230,727</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>4,548,073</td>
</tr>
</tbody>
</table>
Production of waste from cattle breeding

- Approx. 4,550,000 t/year of manure
- Approx. 4,700 t/year of waste animal tissue

Waste management

- Fertilizing of the agricultural land is a common use in B&H
- Currently, there are no systems for biogas production from agricultural waste
- No incineration plants
According to Solid Waste Management Strategy in B&H (August 2000):

- Due to high costs of building and operation of incineration plants for hazardous waste, it has been considered that no incineration plant would be cost effective in next 10 years.
- If the volume of waste is going to increase and economic situation is going to improve, such solution can be feasible.

Agricultural Cooperative “Vrtoče” Bosanski Petrovac

- System for gasification and incineration of biomass waste from poultry slaughterhouse with capacity of incineration of about 500 kg/day of such material.
- Operation hours of this plant is 10 to 12 hours/day.
- Power: 300 kW.
- Basic fuel:
  - Animal waste from poultry slaughterhouse
- Support fuel:
  - Wood waste,
  - Agricultural waste,
Environmental aspects

- Emissions in accordance with EU standards and existing bylaws in RS and FB&H.
- Residence time of flue gases in secondary chamber is 2-4 sec, at temperature up to 1300°C are sufficient for elimination of possible halogenated organic substances.
- NOx reduction is possible with use of staged incineration concept.

CONCLUSION

- Land suitable for agriculture is scarce.
- The situation is worsened by minefields that prevent substantial areas of the land from being used for agriculture.
- Most of the land is not suitable for agriculture without irrigation.
Cereals straw and agricultural residues for energy production in Latvia

Imants Plume,
Dainis Viesturs,
Latvia University of Agriculture,
Latvia

E-mail: imants@sc.llu.lv

Latvia

- Habitants 2,3 mil.
- Area 64 600 km²
- Forests 45%
- Highest point above sea level – 326 m
- Precipitation ~ 550...650 mm/year
- Evaporation ~ 400...450 mm/year
- Primary energy consumption – 199 PJ/year
- Share of renewable energy in primary energy consumption 34,5%
Renewable energy structure in Latvia (2004)

- **Wood, straw - 82.9%**
- **Hydropower - 16.4%**
- **Biogas - 0.42%**
- **Wind – 0.28%**


- Share of wood biomass in primary energy consumption – 28.8%
- Share of wood biomass for district heating – 24.2%
- Share of wood biomass for local and household heating – 56.2%
- Utilized forest biomass (for different purposes) – 10.75 mil. m³ (78 PJ)
- Exported wood biomass – 1.4 mil. t (25.2 PJ)
- Yearly growth of forest biomass -16.5 mil. m³ (120 PJ)
- Potential for increase of wood biomass harvest for energy production – 5.8 mil. m³/year (41.8 PJ)
Biofuel production for transport in Latvia

- Share of biodiesel and bioethanol in total fuel consumption for transport was 0.33% in year 2005 (target of 5.75% for Latvia in 2010).

- Biodiesel produced from 62,000 tons of rapeseed (51% of all rapeseed production) in 3 plants and bio-oil produced in 1 plant in 2006.

- Bioethanol produced from grain (wheat, rye, triticale) – 9,000 tons in 2006 (full capacity of 2 plants for bioethanol production was 19,500 t in 2006).

Plants for electric energy production from renewable sources (2005)

- Hydropower plants produces 97.7% of all renewable electricity

- Cogeneration using wood – 4 plants (2.5 MW)

- Cogeneration using biogas – 3 plants (7.5 MW)

- The task for Latvia in electricity production from renewable sources is 49.3% of total electric energy consumption in 2010.
**Agricultural land in Latvia (2006)**

- Area, thous. Ha
  - Cereals: 512
  - Rape: 85
  - Legumes: 13
  - Sugar-beet: 13
  - Fodder: 3
  - Potato: 45
  - Vegetable: 13
  - Other crop: 45
  - Green manure: 2
  - Fallow: 346
  - Unused (former agric.land): 256

**Straw and grass production in 2002-2005**

<table>
<thead>
<tr>
<th>Cereals and rape</th>
<th>Area, thousand ha (aver. 2002)</th>
<th>Grain yield (aver. 2002-06), t/ha</th>
<th>Grain: straw ratio</th>
<th>Straw, grass, thousand t</th>
<th>Straw, grass, available for energy, thousand t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>215</td>
<td>3,1</td>
<td>~ 1:0,9</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>136</td>
<td>2,1</td>
<td>~ 1:1</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td>43</td>
<td>2,3</td>
<td>~ 1:1,2</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>53</td>
<td>1,7</td>
<td>~ 1:1,1</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Rape</td>
<td>51</td>
<td>1,7</td>
<td>~ 1:1,3</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Sum, straw</td>
<td>545</td>
<td></td>
<td></td>
<td>1216</td>
<td>174 (14 %)</td>
</tr>
<tr>
<td>Fallow grass</td>
<td>341</td>
<td>1,9</td>
<td></td>
<td>649</td>
<td>325 (50% area)</td>
</tr>
</tbody>
</table>
### Energy potential from agricultural biomass residues in Latvia (2006)

<table>
<thead>
<tr>
<th>Name of residues</th>
<th>Biomass</th>
<th>Energy from burning</th>
<th>Biogas available</th>
<th>Biogas energy</th>
<th>Energy from technically most feasible utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Th. t</td>
<td>PJ</td>
<td>Mil. m³</td>
<td>PJ</td>
<td>PJ</td>
</tr>
<tr>
<td>Straw</td>
<td>174 (18% moisture)</td>
<td>2,5</td>
<td></td>
<td>2,5</td>
<td></td>
</tr>
<tr>
<td>Energy crop (maize, 2% of agr. land)</td>
<td>160 (DM)</td>
<td>2,1 (pellets)</td>
<td>22,4 (from maize juice)</td>
<td>0,5</td>
<td>2,6 (2,1+0,5)</td>
</tr>
<tr>
<td>Grass, fallow land</td>
<td>325 (DM)</td>
<td>4,5 (pellets)</td>
<td>48 (from grass juice)</td>
<td>1,1</td>
<td>5,6 (4,5+1,1)</td>
</tr>
<tr>
<td>Livestock wastes</td>
<td>6100 (natural)</td>
<td></td>
<td></td>
<td>290</td>
<td>6,5</td>
</tr>
<tr>
<td>Degradable household wastes</td>
<td>400 (natural)</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Wastewater sludge</td>
<td>180 (natural)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Plant for straw burning in Saulaine, Latvia

![Plant for straw burning in Saulaine, Latvia](image)
Plant for heat production from straw in Saulaine, Latvia

- Power of plant for burning of - 1,36 MW
- Efficiency of straw boiler 87%
- Efficiency of boiler together with distribution net – 70%
- Heat energy produced – 20 TJ/year
- Utilised biomass - wheat straw, 1300 tons/year
- Area for straw production ≈ 500 ha
- Average transport distance ≈ 6 km
- Density of square bales – 0,11...0,12 t/m³
- Weight of bale ≈ 500 kg
- Straw price (transport costs included) – 23,8 €/t
- Investments 425 000 €/MW
- Time of service of – 20 years

Running expenses, per year:
- Salary (for 4 persons) – 47 000 €/MW
- Refund of investments - 2150 €/MW
- Purchase of straw - 23800 €/MW
- Rate of interest 6% - 5750 €/MW
- Electricity and materials – 1550 €/MW
- Overhead expenses-7000 €/MW
- Total cost for 1 GJ energy production by straw boiler: 4,4 €/GJ

Calculation of amount of cereals and rape straw for energy in Latvia (2002-06)

- Cereals and rape straw available for energy calculates:
  \[ S_e = Y_g - S_m A_s - L - M \ [t] \]
  where,
  - \(S_e\) – straw available for energy, t;
  - \(Y_g\) – straw yield, t;
  - \(A_s\) - area of cereals and rape, ha;
  - \(S_m\)– straw not removed from field to keep organic matter content at the same level for Latvia conditions, t, \(S_m=1,6\) t/ha;
  - \(L\) – straw for litter, t,
  - \(I\) – straw for chemical industry, t

Amount of cereals and rape straw can be utilised for energy production (calculation was provided for 5-year period - 2002-2006):

\[ S_e = 1216 - 545 \times 1,6 - 160 - 10 = 174 \ [thousand\ t] \]
Constraints and recommendations for straw burning for energy

- Straw have a significant content of Cl (Cl=0.17...0.6%), which may cause formation of dioxines at combustion temperatures around 600°C at normal residence time in the furnace.

- Straw contains significant content of N (N=0.5...1.2%), that can be a source of nitrogen oxides emissions at temperatures above 750°C.

- Straw contains significant content of potassium, that facilitates ash melting at temperatures above 800°C.

Recommendations

- Optimal combustion temperatures of straw are within the range of 700-750 °C.

- Continuous material feed is preferable, which decreases the residence time of straw at temperature 600°C, which prevent dioxins formation.

Conclusions

- Potential of unharvested wood biomass energy in Latvia is 5.8 million m³/year (41.8 PJ/year).

- Potential of cereals and rape straw for energy production is 14% of total straw available, or 174 thousands t/year (2.5 PJ).

- Potential of energy crop (maize) from 2% of agricultural land (5.7 t dry matter/ha) for energy production is (2.6 PJ), that can be obtained by maize juice anaerobic treatment (0.5 PJ) and from pellets (2.1 PJ) produced from residues.

- Potential of fallow grass (1.9 t DM/ha) by grass juice anaerobic treatment (1.1 PJ) and from pellets (4.5 PJ).

- Feasible biogas production potential is 30% of theoretical biogas energy obtainable from animal wastes, degradable household wastes and wastewater sludge, or 2 PJ.

- Straw burning plant in Saulaine (Latvia) produces heat energy at a price of 4.34 €/GJ.

- It is recommended to feed boilers with straw in continuous flow and to keep process temperature in range 700-750 °C to minimise excessive dioxins or nitrite oxides formation as well as to prevent ash melting.
Bioverda Activities For Energy Plants

2/3 October 2007, Novi Sad

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Group Overview

- **Total 05 Revenue**: ~ €468m
- **Market Capitalisation**: ~ €1.3bn

- Roads
- Waste
- Energy
- Telecoms

C. R. G. 33.3%
Roads - Ireland
Toll Concessions

M1 North-Link
WEST-LINK
EAST-LINK

greenstar
setting the standards
Dublin Bay Project is Ireland’s largest Anaerobic Digestion Plant - 4MW of power… and expanding
Growth Platform
Going Forward

Security of Energy Supply

Climate Change

Resource Depletion

Renewable Energy and Sustainable Waste Management

greenstar
setting the standard

Bioverda
SUSTAINABLE ENERGY

Airtricity
May Progress

IRL
UK
Other

IRL
UK
US
Continental Europe

IRL
UK
US
Continental Europe

Who is Bioverda?

- Bioverda is the Bioenergy business subsidiary of NTR plc
- Bioverda is focused on two key areas:
  - Biofuels (Biodiesel, Bioethanol)
  - Bioenergy (Landfill Gas, Anaerobic Digestion & Biomass)
- Geographic asset focus in Europe and North America
- Pipeline being developed across all areas with significant potential for investment

Goal is to be top 5 player – “Be a Bioenergy Major”
Bioverda Locations

Landfill Gas to Energy

25MW generated from 7 landfill sites - Producing 135,000 MWh p.a.
German Biodiesel Plants

Financed in 2006

- Integrated seed crushing & biodiesel esterification plant in Neubrandenburg;
- Output of 45,000 t/p.a. biodiesel with 100kt expansion potential
- Integrated seed crushing & biodiesel esterification plant in Ebeleben;
- Initial output of 95,000 t/p.a. biodiesel

The Challenge & The Solution (Total investment approx. EUR 70 million)

- Market entry for foreign Sponsor & market risk due to changing Govt support
- Close & efficient collaboration with KfW IPEX-Bank & State Government

GOE Castleblake, Ireland

Planned 250kT AD plant (Animal by-products / biomass)
50kT Biodiesel Plant from Tallow
Virgin Bioverda JV – EGP, Tennessee

- 330 kt corn based Ethanol plant
- Based on ICM / Fagen technology
A Fully Constructed 330 kt Plant

Why Bioverda?

- Part of NTR plc, a leading renewable energy developer (€3bn)
- Strategic objective to be top player in target markets
- Global trading focus for inputs and off-takes
- Good people focused on building a world class business
Why Central-Eastern Europe

- Huge potential of biomass source
- „Untapped market“
- Attractive regulatory framework in most countries (adopting EU directives)
- Energy consumption of these countries grow fast
- Attractive green tariffs
- Fallow lands available for energy crops
- Growing yield

Practical difficulties of a bioenergy project from an investor’s point of view

General

- No/less experience in bioenergy project development

- Choosing the right Technology
  - Efficient and proven technology
Practical difficulties of a bioenergy project from an investor’s point of view

Economics

- Small land size of farmers
  - In some countries farmers have small lands which makes the security of feedstock more difficult
- Raw material price
  - Hedging
  - Crossholding
  - Indexation
  - Price formula
  - Renting land from farmers

Selling heat
- it makes the project more efficient (economically and environmentally) and also it can be the margin in case raw material price is going up sharply in the future.

Central heating systems

Period of guaranteed power purchase
Practical difficulties of a bioenergy project from an investor’s point of view

Sustainable raw material source

- In some central and eastern European Countries straw is burnt on the field as it is the cheapest way to get rid of it (also good for the soil)
- Choosing the right energy crops (based on climate and quality of soil)

Logistics

- economical radius (30-50 km) might be more if transportation is cheaper
- Storage
- Financial situations of farmers
  - Do farmers have the equipment to collect and bail the straw or to transport it?
    - Investor might have to pay for these equipment in order to bail and transport the straw
    - Available Funds for farmers to improve their equipment?
Workshop Motivation

"Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries"
Workshop

"Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries"

Place: Novi Sad, Serbia

Date: 2 - 3 October 2007.

Background

This Workshop is organised by the Institute for Environment and Sustainability (IES) of the Joint Research Centre (JRC) of the European Commission (http://www.jrc.ec.europa.eu) and the University of Novi Sad, Faculty of Technical Sciences, Department for Biosystems Engineering, and the Academy of Sciences and Arts of Vojvodina, Serbia. The Workshop is organised within the JRC-IES Action: Quality and Performance of Biofuels (http://re.jrc.ec.europa.eu/biof) of the Renewable Energies Unit.

It follows a previous joint seminar on Sustainable "Sustainable Bioenergy cropping systems for the Mediterranean" held in Madrid, Spain, on 9-10 February 2006 and a JRC Expert Consultation on the "Cereals Straw Resources for Bioenergy in the European Union" Pamplona, on 18-19 October 2006. It also follows the Workshop "Data Gathering for the New Member States and Candidate Countries on Renewable Energies", held in Cavtat-Dubrovnik, Croatia, on 15-16 November 2006 (http://re.jrc.ec.europa.eu/biof/html/Documents_Publications.htm).

The present Workshop addresses the use of agricultural residues (cereal straw, green tops, manure) and especially of cereals straw for bioenergy production in New Member States, Candidate Countries and Western Balkan Countries.

Motivation

The European Union has a target of 12 % of total energy consumption to be produced from renewable energy sources by 2010. In addition, in 2010, renewables should contribute by 21 % of gross inland electricity consumption. Biofuels and other renewable fuels for transport should also reach the target of 5.75 % of all petrol and diesel consumption for transport (on the basis of energy content) by 31 December 2010.

In order to reach the mentioned targets, the European Commission has issued a Communication on a Biomass Action Plan and its corresponding Impact Assessment. The European Commission released a communication comprising an EU strategy for biofuels based on the Biomass Action Plan, aiming at biofuels promotion, preparation for large-scale use of biofuels by improving their cost-competitiveness, support of the research into second-generation biofuels and exploration of the opportunities for the production of biofuel feedstocks and biofuels.

The European Council (Brussels, 8/9 March 2007) endorsed a binding target of a 20 % share of renewable energies in overall EU energy consumption by 2020 (differentiated national overall targets ) and a 10 % binding minimum target to be achieved by all Member States for the share of biofuels in overall EU transport consumption by 2020.

In addition to the existing European legislation on electricity from renewables and use of biofuels, a Directive on heating and cooling from renewables is in preparation. Consequently, the use of biomass in transport fuel, heat and electricity production will have to increase substantially in order to meet these targets.
Main Issues

Resources of cereal straw and agricultural residues

The question to answer is what are the cereal straw and agricultural resources at national/regional/local level that could be used for bioenergy production. This will provide information on best locations for a bioenergy plant site, but also on plant size.

Of importance is how much agricultural residues are generated in a certain region, the amount which is available and their physical and chemical characteristics. The amount of agricultural residues is directly related to crop production, which in turn depends on crop yield and cultivated area. The data of importance is agricultural practice (tillage/no tillage, straw shortness, organic farming, irrigation), cultivated area, yield and total production.

The agricultural residues removal rate and the quantity that must be left on land depends on climate conditions (wind patterns, rainfall patterns), and local site suitability (soil type, soil fertility, land slope, risk of soil erosion), farming practices (culture crop rotation, tillage practices).

An important issue is related to the competitive uses of cereal straw and agricultural residues: animal breeding, mushrooms cultivation, horticulture, etc.

Environmental & agricultural constraints

The environmental benefits of using biomass resources is the most important driving force encouraging the use of biomass for energy production. One of the basic rules of sustainability requires that biomass use should be consistent with environmental quality requirements and produces green environmentally friendly bioenergy.

The existing agricultural resources, soil characteristics, sites conditions and different agricultural farming practices should to be taken into consideration when talking about straw removal for further use for bioenergy. Agricultural residues left on land provide the ecosystem with nutrients, reduce the risk of soil erosion and regulate water retention.

Therefore, the effect of biomass removal from the field on the organic matter content of the soils (soil carbon content and nutrients availability), CO₂ emissions, depletion of organic matter content, water retention capacity of soils, as well as increased sensitivity to erosion should be considered. Biomass removal should also not affect soil fertility and land productivity.

Implementation issues

Biomass could play an important role for sustainable energy production. Biomass is a local/regional resource, which could contribute to the rural regional development and security of energy supply. It could also contribute to the improvement of competitiveness and local/regional employment whilst creating environmental benefits in terms of greenhouse gas emissions reduction. Implementation of bioenergy technologies depends on the concepts for bioenergy technologies, availability and efficiency of conversion technologies, economic issues, environmental norms or regulations to be fulfilled, requirements of conversion plants, etc.

The biomass resources (quantity, harvesting period, multi-annual yield variation, collection distance), logistics (energy demand in the area, storage, security of supply), technological (available technologies), economical (costs of resources and cost of energy), social issues (perception and attitude of farmers) as well as policy support measures should be considered for the use of cereal straw and agricultural residues for bioenergy.

An objective of the workshop is to contribute to forming a cost-supply curve for straw and other agricultural residues in EU.

Goals

This Workshop aims at bringing together researchers and professionals in the energy field regarding the cereals straw and agricultural residues utilisation for bioenergy production in New Member States (NMS), Candidate Countries (CC) and Western Balkan Countries (WBC).
The Workshop addresses the cereal straw and agricultural residues availability, potential for bioenergy, implementation, present use and current experience in EU, demonstration projects, economics of bioenergy, etc. The Workshop aims specifically at technical discussions, in order to develop expertise, exchange information and knowledge and improve data collection on:

- resources of cereal straw and agricultural residues;
- environmental & agronomic constraints;
- implementation issues.

JRC has produced an estimate of straw resources (from wheat and barley) available for use in large-scale plants. It starts with statistical and GIS data for EU25+2 to assess the energy potential of straw. First the straw produced was calculated on from GIS cereals production taking into account variations in yield. Next, the major competitive uses were subtracted. This was done on the basis of correlations between straw, cattle population and human population. Costs were assigned based on collection and transport costs in Western Europe.

Clearly many of the assumptions and rules used in this preliminary assessment will differ for local conditions in NMS and candidate countries. From JRC point of view, the main Workshop objective is to see how these estimates should be adjusted for conditions in New Member States and Candidate Countries, as well as to generally improve them.

**Critical Issues to be addressed**

**Basic Resources**

- What is the ratio of straw: grain for wheat and barley. Can the ratio be correlated with yield? What other crops could contribute?

**Environmental limits**

- Can we make some rules for how frequently one may take straw instead of incorporating it?
  - formula based on soil, climate, technologies;
  - effect on subsequent yields and fertiliser requirements;
  - other effects of incorporating straw;
- What percentage reserve of supply in catchments' area to account for:
  - seasonal variations;
  - bargaining with farmers;
  - inaccessible fields.

**Competitive uses**

- What are the main competitive uses (percentage);
- Correlation with:
  - cattle population;
  - cattle housing;
  - horses;
  - horticulture / mushrooms.
- Existing uses for energy

**Costs**

- Costs for collection, transport, storage;
- Extra costs due to terrain etc.;
- Different conversion plants: cost vs. size; technical improvements;
• Optimized plant size;
• Logistical limits on plant size.

Expected outcome
The Workshop aims at collecting more information on the state of knowledge on the availability and possible use of cereal straw and agricultural residues, status, problems and barriers for implementation, and perspectives for development. The Workshop aims to carry out interactive technical discussions to share experience and draw conclusions that could be valuable for developing new projects using cereal straw and agricultural residues in New Member States, Candidate Countries and Western Candidate Countries.

The outcome of the Workshop will be summarized in proceedings, focussing on the three topics above and based on the contribution of the meeting participants.

Experts
This Workshop aims to include 20 participants from New Member States, Candidate Countries and Western Balkan Countries as well as from several European Union Member States or regions with valuable experience in the use of cereal straw and agricultural residues for bioenergy including 2nd generation biofuels. Experts will originate mainly from agricultural and environmental institutes, renewable energy institutes, research centres and energy companies. National experts are invited to prepare for the Workshop a presentation covering the critical issues to be addressed:

• cereals farming practices and soil characteristics;
• cereal straw and agricultural residues resources and competitive uses;
• present situation related to the use of cereal straw and agricultural residues for bioenergy;
• environmental issues related to cereal straw and agricultural residues utilisation;
• practical problems of bioenergy plants operation using cereal straw and other agricultural residues, in terms of resources, logistics, technology and economics;
• socio issues (perception and attitude of farmers);
• development or planning for bioenergy plants on cereal straw and agricultural residues;
• new developments in bioenergy policies and public support mechanisms.

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Workshop Agenda

"Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries"
Tuesday 2nd October 2007

13.00 – 14.00 Welcome Lunch

14.00 Welcome address: Mr. Tomislav Papic, Provincial Deputy Secretary for Energy and Mineral Resources.
Welcome address: Prof. Dr. Milos Tesic, Secretary General of the Academy of Sciences and Arts of Vojvodina.

Session 1. Resources of cereal straw and agricultural residues

Chair: Milos Tesic, Secretary General of the Academy of Sciences and Arts of Vojvodina.
Rapporteur: H. Huseyin Ozturk, University of Cukurova, Faculty of Agriculture, Adana, Turkey.

14.00 – 14.30 "Current activities, recent developments and trends for bioenergy and biofuels in EU", Nicolae Scarlat, European Commission, Joint Research Centre, Institute for Environment and Sustainability.

14.30 – 15.00 "Cereal/soybean straw and other crop residues utilization as fin Serbia – status and prospects", Milan Martinov, Milos Tesic, Faculty of Technical Sciences, Novi Sad, Serbia.

15.00 – 15.30 "Biomass as a renewable source of energy in the Czech Republic", Sergej Ustak, Crop Research Institute, Praha, Czech Republic.

15.30 – 16.00 "Potential use of cereal straw and agricultural residues for bioenergy in Slovenia", Franc Bavec, Martina Bavec, University of Maribor, Faculty of Agriculture, Slovenia.

16.00 – 16.30 Coffee break

Session 2. Resources and competitive uses

Chair: David S. Powlson, Rothamsted Research, Harpenden, UK.
Rapporteur: Semra Fejzibegovic, Hydro-Engineering Institute Sarajevo, Bosnia and Herzegovina.

16.30 – 17.00 "Production of straw and other agricultural residues in Republic of Macedonia and possibilities for use as biofuel", Ordan Cukaliev, Faculty of Agriculture and Food, Skopje, Macedonia.

17.00 – 17.30 "Utilization of cereal straw and agricultural residues for bioenergy in Turkey", H. Huseyin Ozturk, University of Cukurova, Faculty of Agriculture, Adana, Turkey.

17.30 – 18.00 "Agricultural residues in Estonia - resources and possibilities", Katrin Heinsoo, Estonian University of Life Sciences, Estonia.

18.00 – 18.30 "Sources of biomass, energy potential and collection of statistical data concerning availability and utilization of biomass in Slovakia", Frantisek Zacharda, Stefan Pepich, Mariana Ceppanova, Technical and Testing Agricultural Institute, Slovakia.

20.00 Dinner
Wednesday 3rd October 2007

Session 3. Environmental & agricultural constraints
Chair: Milan Martinov, Faculty of Technical Sciences, Novi Sad, Serbia.
Rapporteur: Nicolae Scarlat, Institute for Environment and Sustainability (IES), Joint Research Centre (JRC), European Commission.

9.00 – 9.30 "Using straw for energy - implications for soils and agriculture", David S. Powlson, Rothamsted Research, Harpenden, UK.
9.30 – 10.00 "Potentials and limits of the use agricultural residues for bioenergy in Lithuania”, Kestutis Navickas, Lithuanian University of Agriculture, Kaunas, Lithuania.
10:00 – 10.30 "Cereal straw and agricultural residues usable for bioenergy producing – in Romania”, I. Antohe, National Agricultural Research and Development Institute, Fundulea – Romania.
10.30 – 11:00 "Straw availability end use for energy purpose in Poland", Jan Kus, Mariusz Matyka, Institute of Soil Science and Plant Cultivation - National Research Institute, Poland.
10.30 – 11:00 Coffee break

Session 4. Implementation issues
Chair: Kestutis Navickas, Lithuanian University of Agriculture, Kaunas, Lithuania
Rapporteur: Robert Halasz, Bioverda, Berlin, Germany.

11.00 – 11.30 "Cereals straw and agricultural residues for bioenergy. Situation in Bosnia and Herzegovina”, Semra Fejzibegovic, Hydro-Engineering Institute Sarajevo, Bosnia and Herzegovina.
11:30 – 12.00 "Cereals straw and agricultural residues for bioenergy production in Latvia”, Imants Plume, Dainis Viesturs, Institute of Agricultural Energetics, Latvia University of Agriculture, Latvia.
12.00 – 12.30 "Bioverda activities for bioenergy plants", Robert Halasz, Bioverda, Berlin, Germany.
12:30 – 13.00 Final discussions
13.00 -14.00 Lunch
14.00 – 19.00 Technical visit Kula Plat for drying of seed maize, using maize cobs as fuel. Company “Terming” producing 10 kW to 500 kW straw boilers. Cereal straw plant in use.
List of Participants

Workshop
"Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries"
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List of Acronyms

CC - Candidate Countries
CHP – Combined Heat and Power
CONCAWE - The oil companies European Association for environment, health and safety in refining and distribution
DH – District Heating
EC – European Commission
EE – Energy Efficiency
EEA – European Environment Agency
EUCAR - European Council for Automotive R&D
GIS – Geographic Information System
GHG - GreenHouse Gases
GMO - Genetically Modified Organisms
IEA – International Energy Agency
IES - Institute for Environment and Sustainability
JRC – Joint Research Centre
LCA – Life Cycle Analysis
NMS – New Member States
PCC – Potential Candidate Countries
R&D – Research & Development
RES – Renewable Energy Sources
RES-E – Renewable Energy Sources – Electricity
RES-H – Renewable Energy Sources – Heat
SOM – Soil Organic Matter
TGC – Tradable Green Certificates
TPES – Total Primary Energy Sources
WTW – Well to Wheel Study of Joint Research Centre/EUCAR/CONCAWE
Abstract
This document contains the Proceedings of the Workshop "Cereals straw and agricultural residues for bioenergy in New Member States and Candidate Countries" held in Novi Sad, Serbia on 2-3 October 2007. This Workshop was jointly organised by the Joint Research Centre, Institute for Environment and Sustainability and University of Novi Sad, Faculty of Technical Sciences, and Academy of Sciences and Arts of Vojvodina, Serbia. The workshop addressed the availability and possible use of agricultural crop residues and especially of cereals straw for bioenergy production, status, problems and barriers for implementation, and perspectives for development in New Member States (NMS), Candidate Countries (CC) and Potential Candidate Countries (PCC). A better understanding of the situation on cereal straw and crop residues production and competitive use in NMS, CC and PCC was needed to assess their availability and potential for the use for energy production. The main topics addressed to 1) resources of cereal straw and agricultural residues, 2) environmental & agronomic constraints and 3) implementation issues.
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