GIS-based assessment of cereal straw energy in the European Union

Robert A.H. Edwards, Marcel Šúri, Thomas A. Huld, Jean Francois Dallemand

European Commission, Joint research Centre
Institute for Environment and Sustainability, Renewable Energies, Ispra, Italy
Straw energy today in EU25+2

- abundant throughout Europe
- easy to exploit
- scalable technology

however…

- bigger installations only in DK, UK and ES
- slow transfer of know-how to other regions
- ‘pan-European’ approach missing
Straw energy potential is high

Decision making is hampered, because...

- terminology and methodologies not harmonized
- lack of comparable data
- little information below national level
- potential often not linked to the technology options
- interrelation of factors not considered and decisions are site sensitive:
  * resource/demand pattern
  * conflicts of interests
  * logistics

Straw energy assessments (PJ):
Objectives

Inventory of straw from wheat and barley in EU25+2

- actual production
- environmental constraints
- competitive use
- availability for energy

-> data disaggregation

Resolve spatially-determined issues

- how much resource, where
- what technology
- at what cost

Assist to policy- and decision-making

... from tables to maps

Suitability for large scale electricity generation

- example of Ely power station (UK, 38MW)
- economics
- suitability maps
- localization/optimization

Ongoing study – first results
Data/tools

Eurostat Newcronos (NUTS2 regions), year 2003
  • agricultural crops
  • cattle
  • land use

GIS data
  • GISCO
  • CORINE Land Cover 2000

Geographical Information System (GIS)
Straw inventory

Actual production

wheat & barley production
(1000 tonnes/region, year 2003)

straw/grain = from 0.62 to 0.94 based on grain yield

source: Eurostat NewCronos 2003

Straw production (1000 tonnes/region)
Straw inventory

Actual production  Environmental constraints  Competitive use  Availability for energy

Straw options

1. Ploughing straw back to soil
   - but rotting straw consumes soil nitrogen

(2. Burning on fields)

3. Collection from fields, but:
   * depletion of organic matter content
   * lowers water retention capacity
   * increased sensitivity to erosion
   * NW Europe: straw taking acceptable in good soils, but resisted by many farmers
   * S and SE Europe: in dry conditions not favourable, but farmers often remove it to save on N fertilizer

Soil-ecology constraints most affect areas with low density of cereals production: not yet incorporated in this study.
Straw inventory

- Cattle raising in regions (1000 heads)
- Thousand heads/region
- Use for cattle: 0-100% (use for cattle depends on straw availability, but there are also no-straw cattle sheds)
- Other use: 0-25% (mushrooms, horticulture, industry, etc.)

Most important competitive use is cattle bedding
Straw inventory

- Actual production
- Environmental constraints
- Competitive use
- Availability for energy 1/3

Straw from wheat & barley produced in 2003 (1000 tonnes/region)

Straw available for energy (1000 tonnes/region)
Straw inventory

Data disaggregation

Straw for energy in regions

\[ \text{straw for energy in regions} = \text{tonnes per hectare of arable land} \times \text{(arable land density)} \]

\[ \text{hectares of arable land per grid 5x5 km} \]

\[ \text{source: EEA, CORINE Land Cover 2000} \]

\[ \text{tonnes of ‘free straw’ per grid 5x5 km} \]

Available for energy 2/3

Actual production

Competitive use

Environmental constraints

Renewable Energies Unit
Straw inventory

Total straw production

Data disaggregation

Total straw production (1000 tonnes)

Total straw produced (tonnes/grid 5x5 km)

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<thead>
<tr>
<th>Total straw production (1000 tonnes)</th>
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<tbody>
<tr>
<td>1 - 250</td>
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<td>251 - 500</td>
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total straw per region (tonnes)

total straw (tonnes) per grid cell (5x5 km)
Straw inventory

Data disaggregation

Straw available for energy

Straw inventory

Available for energy

Actual production
Competitive use
Environmental constraints

Straw available for energy (1000 tonnes)

Straw available for energy (tonnes/grid 5x5 km)

Total straw per region (tonnes)

Total straw (tonnes) per grid cell (5x5 km)
Suitability for large scale electricity generation

Much of our projection is based on

Ely power station (UK)

World’s biggest straw electricity power plant (in operation since 2000)

- grate boiler with steam turbine
- yearly consumption:
  - 200 000 tons straw
  + 6% natural gas energy
- straw collected within the distance up to 50 km
- 38 MWel
- plant efficiency 32%
- load factor 90%
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Generating cost of Ely-size plant

Assumptions:

- 38 MW
- Learning curve for 50th plant: costs 75% of Ely plant
- 15% capital charge = 8% interest
- Straw from 50 km radius
- Average transport distance 40 km
- Cost of straw 43.5 €/t

Total electricity cost = 0.07 €/kWh
What is the optimum size?

- straw transport costs do NOT dominate
- “optimum” size is far greater than present size
- problem is LOGISTICS:
  * 38 MW (Ely) means ~50 trucks per day (the practical limit inland)
  * larger plants are possible with ship or train transport

... SO WE INVESTIGATE SITING OF ELY-SIZED PLANTS

Assumptions:
- plant cost scales with \((MW)^{0.7}\)
- plant efficiency increments by 9% per 10x scale
- transport distance around Ely scaled from present 50 km (could be smaller in future)
Technology options

Suitability map for localization of Ely-sized (38 MW) power plants

Localization of Ely-clones:

1. Calculate map of collection radius for Ely straw consumption (+50% reserve)
Technology options

Suitability map for localization of Ely-sized (38 MW) power plants

Localization of Ely-clones:

1. Calculate map of collection radius for Ely straw consumption (+50% reserve)
2. Find most favourable site
3. Remove that straw from the map
4. Find the next-best site
5. Repeat until transport radius exceeds 50km

result

Assumption: yearly consumption of straw 200 000 tons + 50% reserve
Technical options

EU could host up to 67 “Ely clones” (38MW)
FR: 28  CZ: 1
UK: 15  IT: 1
DK: 7  SE: 1
DE: 6  SK: 1
ES: 5
PL: 2

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

Assumptions:
• yearly consumption 200 000 ton + 50% reserve
• transport distance up to 50km
Effect of resource density on electricity cost

Resource density around Ely:
- 20 km transport radius according to these assumptions

Assumptions:
- 38 MW plant (= Ely)
- average road transport distance is 15% greater than max radius
- 2/3 of straw in transport radius is collected (50% reserve)
- transport cost 0.124 €/t-km

Practical range

average tonnes straw / ha of catchment area

Ely power station  Economics/optimization  Suitability maps  Localization

Joint Research Centre
Technology options

Effect of resource density on electricity cost

Steps:

straw density -> collection radius -> transport distance -> straw cost -> electricity cost (capacity is fixed)

Our theoretical sites have electricity price 69-73 €/MWh

Assumptions:

- yearly consumption 200 000 ton + 50% reserve
- transport distance up to 50km
Other installations?

LAGGER?

- inland logistics limit to ~50 MW_{el}
- straw-to-BIOFUEL plants are more complex: need **larger** scale

SMALLER?

- Ely clones leave out 72% of available straw
- smaller CHP is economic where there is a large enough need for the heat: factories, existing district heating
- replacing local heating boilers is probably the cheapest and most practical way to save GHG with straw
- straw pellets/briquettes allow wider use
- co-firing?
Conclusions

- harmonized used of data and methodology at the level of EU25+2
- related to the bioenergy technology
- transfer of know-how to other regions

- indication of straw energy potential in regions
- and raising awareness

- site-specific studies and decisions
- are responsibility of national/regional authorities and industry

The questions to be answered

- local sustainability of straw removal: suitability map
- straw from other resources (rye, rape, maize, rice)
- competitive use – substitution of traditional use
- costs and practical problems (logistics, transportation, storage, social factors, security of supply)
- other use (CHP, heat, pellets, etc.)
- extent of trade between regions

Thank you!