Biomass within the concept of changing energy markets

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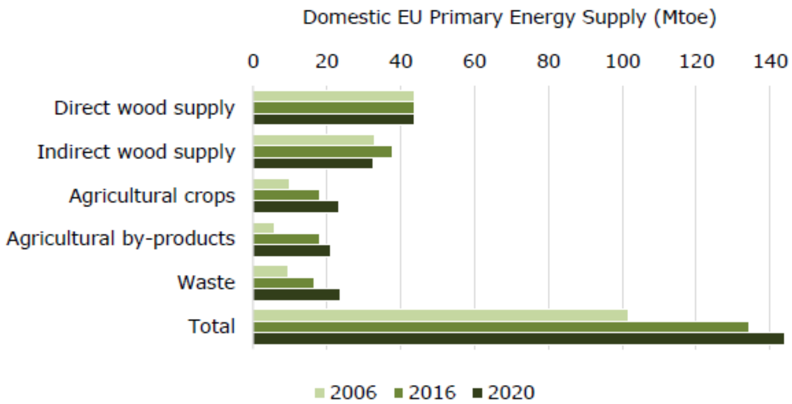
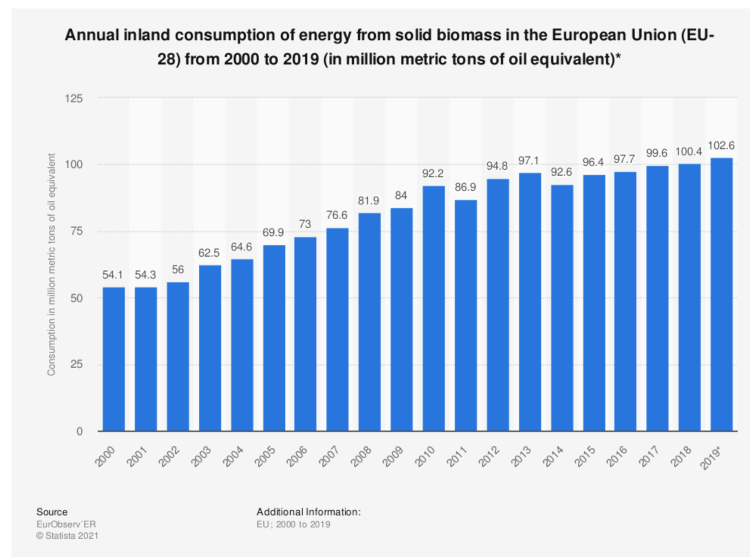
6. Economic competition between convetional and energy crop – opportunity cost point of view

General context – important role of biomass

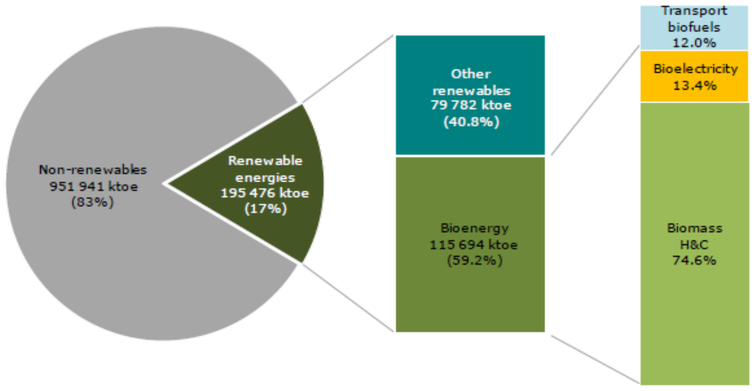


https://publications.jrc.ec.europa.eu/repository/handle/JRC109354

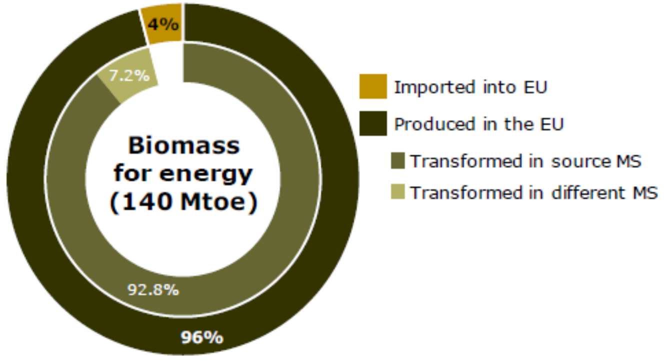
Biomass share on RES is declining but in absolute values is increasing



General context – important role of biomass



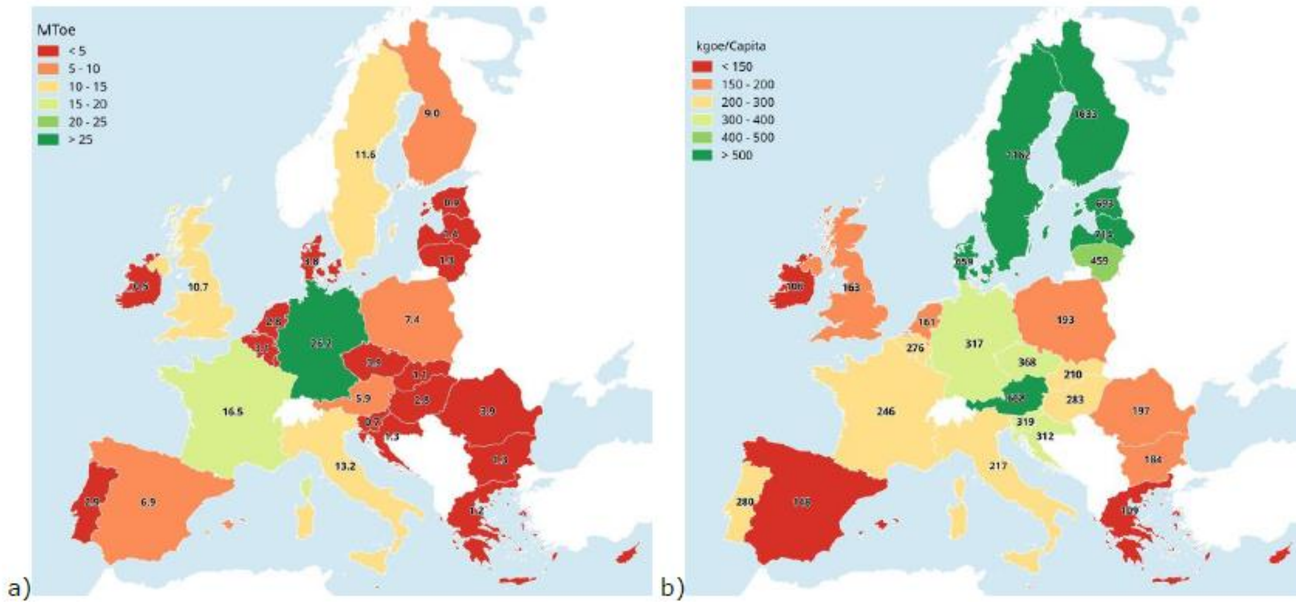
EU: 2016 – gross final energy consumption



Source: https://ec.europa.eu/jrc/en/publication/brochures-leaflets/brief-biomass-energy-european-union

General context – important role of biomass

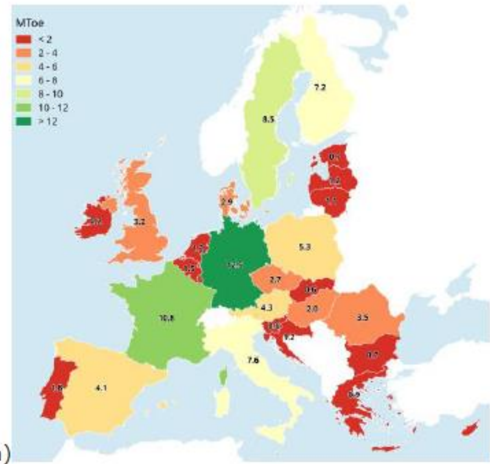
Gross inland bioenergy consumption: total and per capita



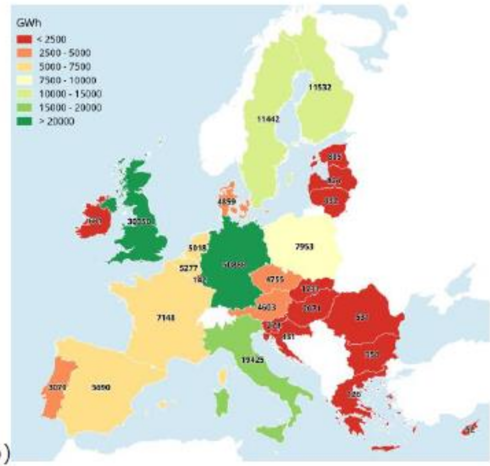
Source: https://ec.europa.eu/jrc/en/publication/brochures-leaflets/brief-biomass-energy-european-union

General context – important role of biomass

Gross final consumption of bioheat, bioelectricity and transport biofuels



a)



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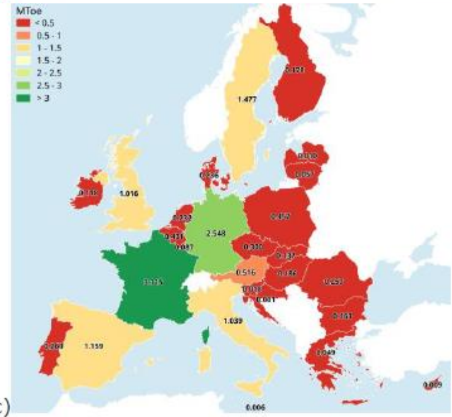


c)

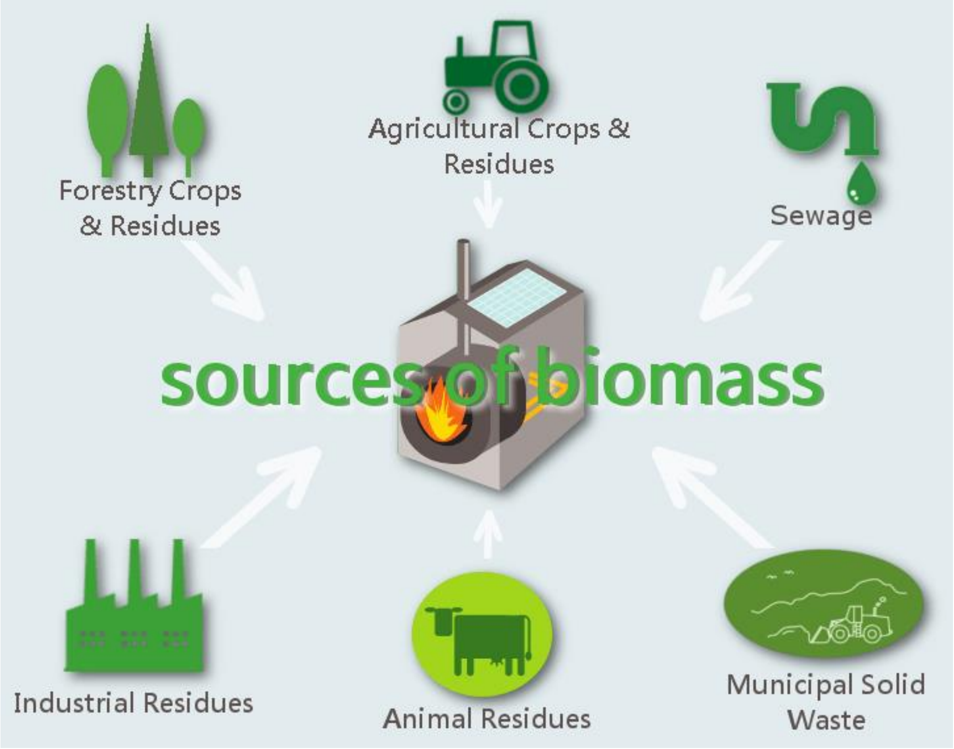
The high differences between countries are due not only to different availability, but also to different heating methods, support for the use of bioenergy, etc.

Source: https://ec.europa.eu/jrc/en/publication/brochures-leaflets/brief-biomass-energy-european-union

Biomass – biomass sources

- **biomass from agriculture** (crop residues, bagasse, animal waste, energy crops, etc.)
- **forestry** (logging residues, wood processing by-products, black liquor from the pulp and paper industry, fuelwood, etc.)
- **biological waste** (food waste, food industry waste, the organic fraction of municipal solid waste, etc.)
  - Also residuals from waste water cleaning (in CZ app. 250 th in dry matter, potential source of important elements, such as phosphorus)

Biomass – biomass sources



Source: https://www.bioenergyconsult.com/biomass-energy-sustainability/

Biomass is a very heterogeneous category containing many different types of biomass - by origin, by form, by energy content. The different types of biomass are very often not directly interchangeable. Therefore, it is not enough to look only at the potential of biomass, but also at its structure and even its geographical distribution (due to relatively high transport costs).

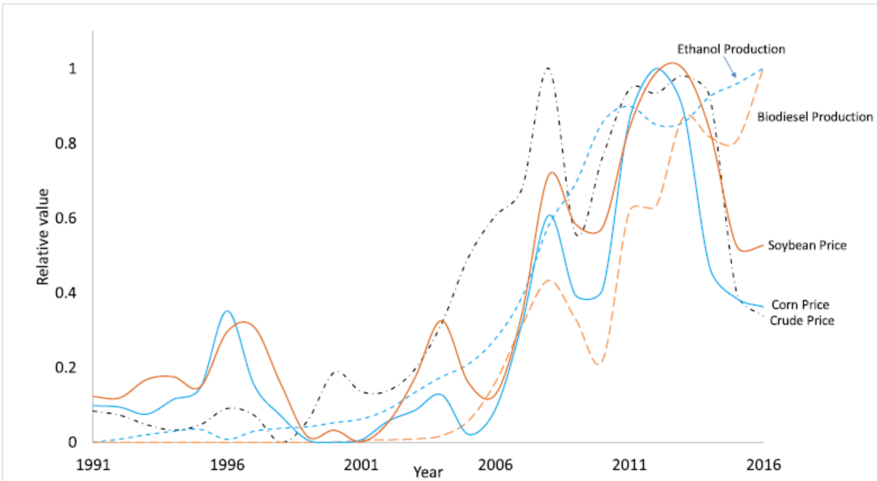
Biomass – 1st, 2nd and 3rd generation

- 1. **First-generation biofuels:** directly related to a biomass that is generally edible.
  - Competition with food production, but also material utilization
- 2. **Second-generation biofuels:** defined as fuels produced from a wide array of different feedstock, ranging from lignocellulosic feedstocks to municipal solid wastes.
  - But most of biomass types within this category needs land (e.g. energy crop), so we have competition with conventional production again
- **3. Third-generation biofuels:** related to algal biomass but could to a certain extent be linked to utilization of CO_2 as feedstock.

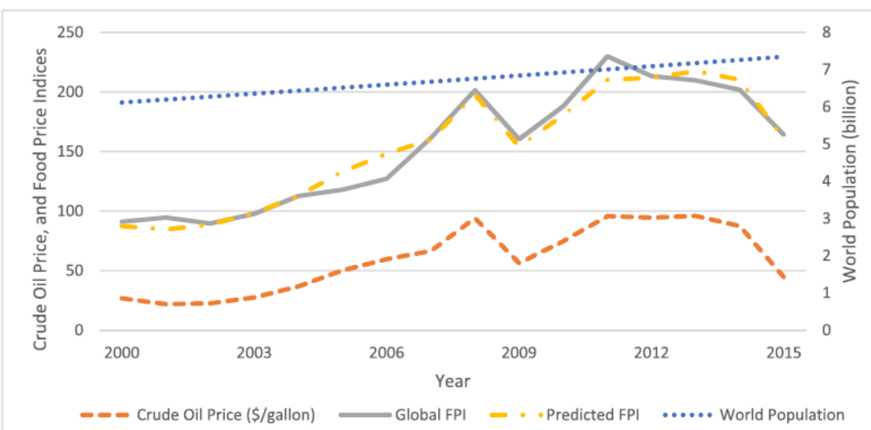
Biomass – 1st generation

- **First-generation biofuels** include bioethanol and biodiesel directly related to a biomass that is generally edible.
  - Ethanol is produced from fermation of C6 sugars (glucose), majority of production: corn aand sugar cane, others: potatoes, sugar beet, etc.
  - Biodiesel: uses biomass (oily plants and seeds), relatively complicated chemical processs requiring also methanol
  - Influence of biofueles production on market values of conventional crop
  - Preassure on economy of liquid biofuels – results also in large areas of land occupied (e.g. rapeseed in the Czech Republic occupied 17% of arable land, also leads to deforestation in some countries)

Biomass – 1st generation, economic aspects



US corn and soybean prices compared to crude oil prices, ethanol and biodiesel production

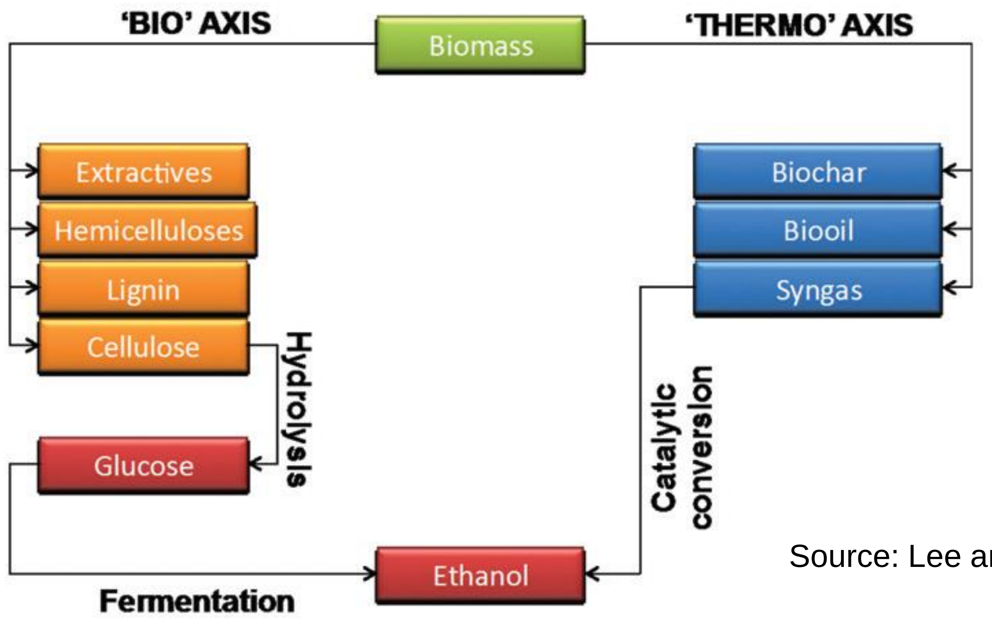


World food price index

Source: Shresta et al: Biofuel impact on food price index and land use change, Biomass and Bioenergy 124 (2019)

Biomass – 2nd generation

- Wide range of feed stocks, mostly lignocellulosis biomass, but also municipal waste, etc.
- Cheaper feedstock, but more complicated conversion, requires new technologies



"bio" and "thermo" pathways for conversion of lignocellulosic biomass into biofuels.

Source: Lee and Lavoie, doi:10.2527/af.2013-0010

Biomass – 3rd generation

- Algae: biofuels produced from algal biomass

High technical and economic challenges, e.g.
algae will produce 1 to 7 g/L/d of biomass in ideal growth conditions – large volumes are required, also keep operational temperature.
Currently mostly used for the production of biologically active substances (healt products, Biological colouring agents

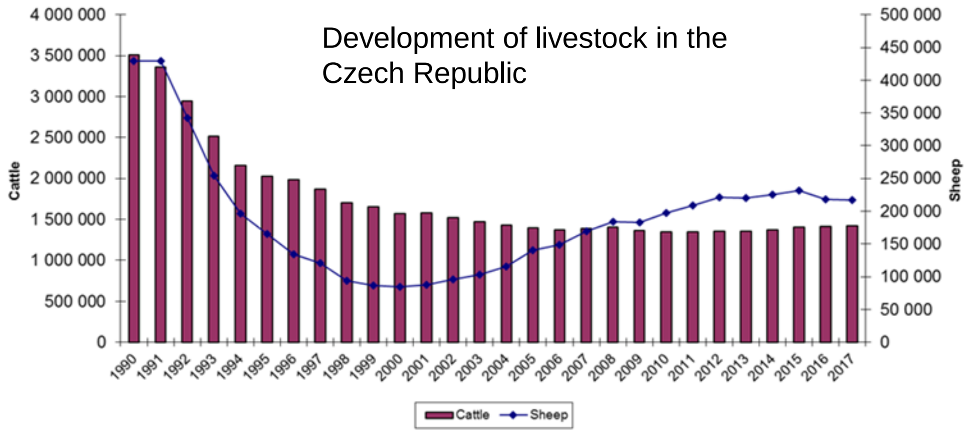
Biomass – New Trends

Biomass is often considered as an important substitute for fossil fuels, but:

- Increasing biomass potential usually requires an increase in biomass extraction from agricultural land (residual biomass from conventional crops) or from forest land (competition between food or material use and energy)

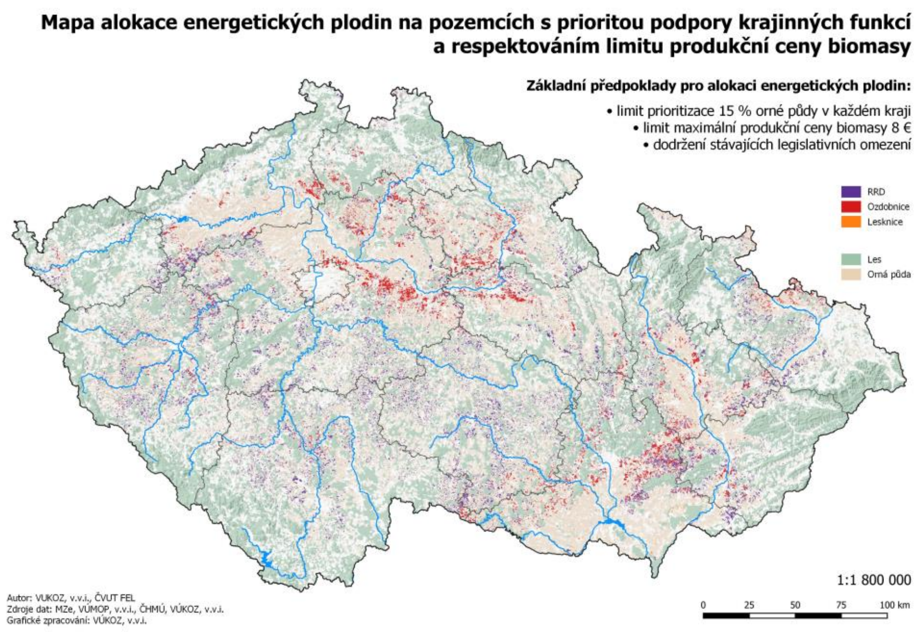
- In many countries, increasing biomass for energy use leads to deforestation (e.g. clearing land for oil palm plantations)
- In many countries (the Czech Republic is an example), the problem is the low content of the biological component in the soil (lack of natural manure due to the decline of livestock)

In many cases it is then necessary to leave a significant part of the straw for ploughing



Biomass – New Trends 2

- Plantations of perennial energy crops can serve as a suitable tool for reducing the ecological impacts of conventional agriculture



Classification system for evaluation of level of risk associated with conventional agriculture:

- Landscape connectivity - support of migration and dispersion possibilities of organisms
- Landscape heterogeneity - the size of soil blocks directly affecting habitat and species diversity
- Drought threat to land
- Threat to land from water erosion
- Threat to land from wind erosion

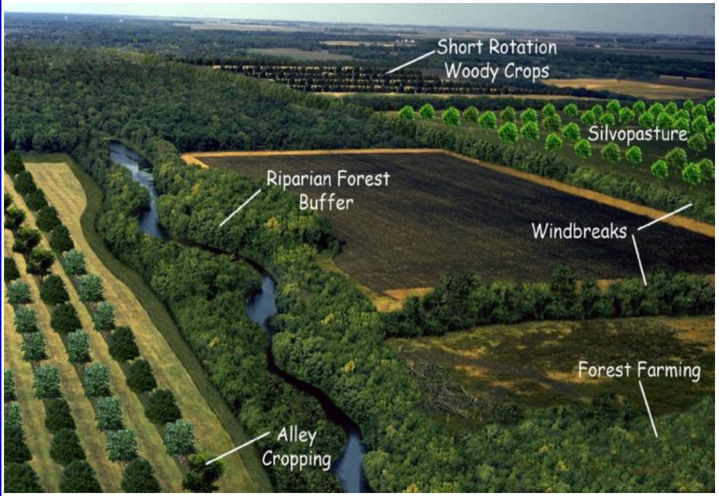
Perennial energy crops can significantly help reduce these risks

Biomass – New Trends 2

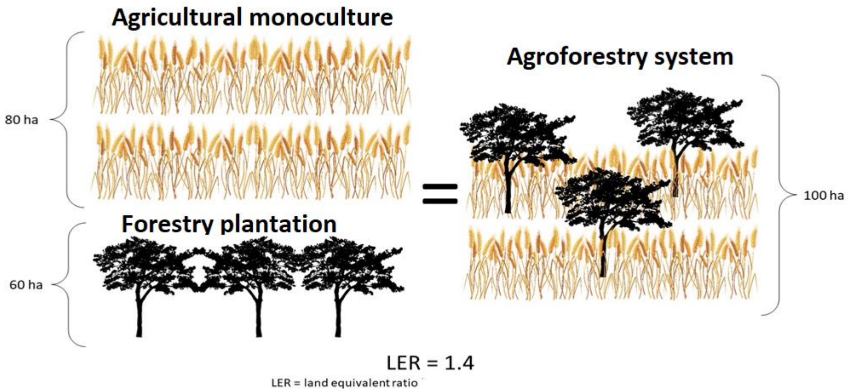
- Plantations of perennial energy crops can serve as a suitable tool for reducing the ecological impacts of conventional agriculture

- 2021: preparation of the European Forestry Strategy
- effective afforestation, protection and restoration of forests, as well as their resilience. All of this is intended to contribute to increasing the capacity of forests to absorb and store carbon dioxide
- Wood (see European Parliament resolution, 2021) is not to be used primarily as biomass to replace heat from fossil sources, but "wood should, where possible, be prioritised for longer-life uses to increase global carbon storage".
- All of the above factors will influence and limit the potential of biomass for energy in the future

Biomass – Agroforestry, example of the new trend



Main types of agroforestry systems USDA, 2010



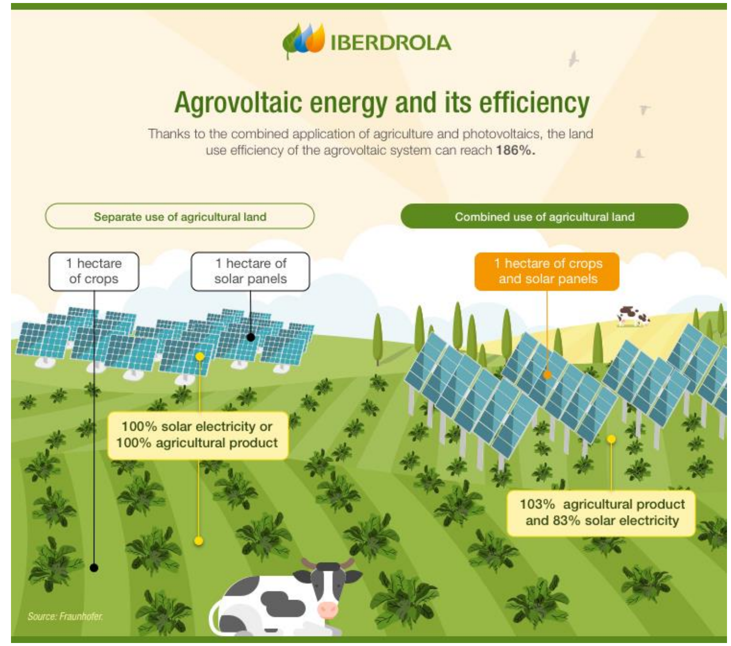
LER (*land equivivalent ratio.*) of value 1,4 means that 100 ha of AFS produces the same yields as 140 ha of trees and agricultural crops when grown separatelly. (Mead, Willey, 1990)

Agroforestry systems (ASF) means land use systems in which trees are grown in combination with agriculture on the same land (**EU regulation no. 1305/2013**)

- very innovative and flexible (for task - conditions)
- allows stable production with strong eco-services
- mitigation and adaptation measures

Biomass – Agrovoltaic, example of the new trend

www.univergysolar.com



Biomass from energy crop – different points of view on its price / cost of cultivation

Perennial energy crops – plantation lifetime:

- 10 years (e.g. Miscanthus), 20-24 years (SRC plantations)
- the decision to grow energy crops can be evaluated using investment evaluation methods - NPV of project cash flows (CF)

Biomass price - energy crop, perennials, two points of view

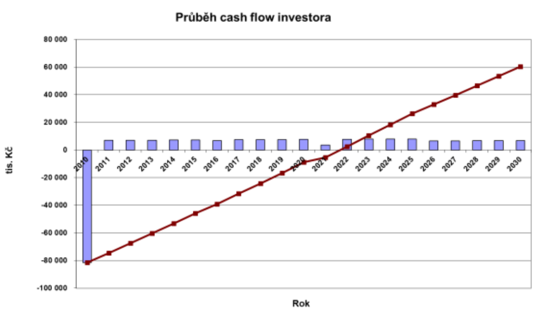
Minimum price to get required rate of return	Opportunity use of soil for conventional crops
C_{min}: $NPV_{enercrop}=0$	C_{alt}: $NPV_{enercrop}=NPV_{convcrop}$
rate of return is equal to discount rate used for NPV calculation	to get the same economic effect as from growing of conventional crop

Limit of biomass price from the consumers point of view – competition with other energies

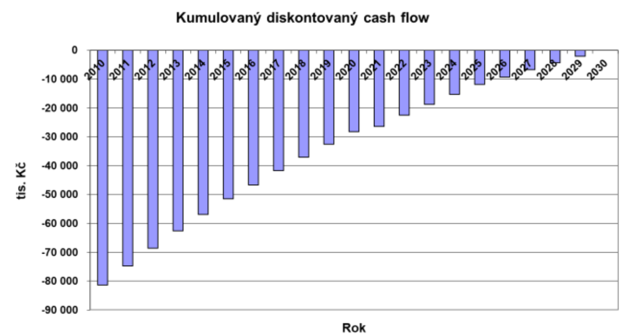
Biomass from energy crop – minimum price modelling 2

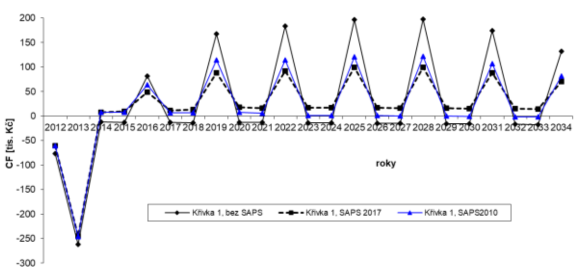
Minimum – price

- ❑ Sum of discounted CF at the end of the project equals to zero
- ❑ Example of CF and DCF profiles for



PV Power plant





SRC plantation CF profile

- ❑ Minimum price methodology is widely used e.g. to define FIR for electricity from renewables, for waste disposal, etc.
- ❑ To derive price of commodity from supplier point of view

Opportunity use of soil for conventional crops

C_{alt} calculation - equality of CF generated from the production of conventional crop for the duration of the energy crop plantation

$$NPV(\text{energy}) = \sum_{t=1}^{T_h} [c_{alt,1} \cdot Q_t \cdot (1+i)^{(t-1)} + S_t - \mathrm{E}_t] \cdot (1 + r_{n,d})^{-t}$$

$$NPV(conv) = \sum_{t=1}^{T_h} (R_{t,q} - C_{t,q}) \cdot (1-d) \cdot (1 + r_{n,1})^{-t}$$

$$c_{alt,1}: \quad NPV(\text{energy}) = NPV(\text{conv})$$

C_{alt} . Q + S: revenues from energy biomass plus subsidy

$r_{n,d}$,$r_{n,1}$: discount rates

T_h: energy crop plantation lifetime,

10, 24 years

rotation of conv. crop according to site conditions

R_q-C_q: market price of crop and cost of q conv. crop

Opportunity use of soil for conventional crops - 2

$$NPV(\text{energy}) = \sum_{t=1}^{T_h} [c_{alt,1} \cdot Q_t \cdot (1+i)^{(t-1)} + S_t - \mathrm{E}_t] \cdot (1+r_{n,d})^{-t}$$

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$$c_{alt,1}: \quad NPV(\text{energy}) = NPV(\text{conv})$$

Key role of risk inclusion into calculation – discount values $r_{n,d}$,$r_{n,1}$
Higher risk for perennials:

: (1) high one-off costs of plantation (approx. 1440 EUR / ha for SRC, approx. 1500 EUR / ha for Miscanthus); present value of the plantation-related costs is about 50% for SRC plantations. If, due to bad weather conditions (e.g., due to drought), the established plantation is damaged or destroyed, the farmer realizes a high loss,
(2) SRC or Miscanthus plantation do not reach the maximum yield of biomass in the first year, but only with a delay, e.g., for SRC the maximum yield is attained between 8 and 12 years, the income from the sale of biomass has a significant distance from the investment in the plantation (future income is thus more uncertaint than current expenditures for plantations establishment). **RISK INCREASE.**

Energy crop: price modelling – case example of the Czech republic 2

Methodology: biomass yields of energy and conventional crops are allocated according to soil and climate conditions on given land plot

- Soil valuation system used: 10 climate regions, 78 different soil types, app. 570 valid combinations
- Expected yield of crop for each combination of climate region and soil type (long term field experiments, expert estimates, etc.
- Arable land divided into agricultural production area - APA
  - affects production costs
  - APA determines the recommended crop rotation
  - a total of 92.3% (2,287 th. hectares) of the total arable land area included in the analysis
  - 7 year rotation cycle of conventional crop – different for each APA
  - Comparison period – based on lifetime of energy crop plantation

Year1	Year 2	Year3	Year4	Year5	Year6	Year7	Year8	…….	Year20	Year21	Year22
Crop1	Crop2	Crop3	Crop4	Crop5	Crop6	Crop7	**Crop1**	…….	Crop6	Crop7	**Crop1**

Energy crop: price modelling – case example of the Czech republic 3

Input data:

- Conventional crop price: average market prices in period 2014-2018
- Production cost of conventional crop: average cost for each APA and type of crop, year 2018 (the differences in the rated costs per hectare among the zones differ by 10% (silage maize) to 25% (winter wheat)
- Subsidy 210.6 EUR/ha
- Production cost of SRC and Miscanthus plantations: economic models based on results of experimental plantations
- Cost and revenues escalation: 2%
- Income tax rate: 19%
- Discount rates: $r_{n,d}=r_{n,1}=10\%$ (nominal)
- Land: LPIS - Land Parcel Identification System
  - Each land plot registered in LPIS is assigned to given APA and c_{alt} is calculated simulating rotation of conventional crop

Price modelling results

High profitability of conventional crops pushes the c_{alt} price up

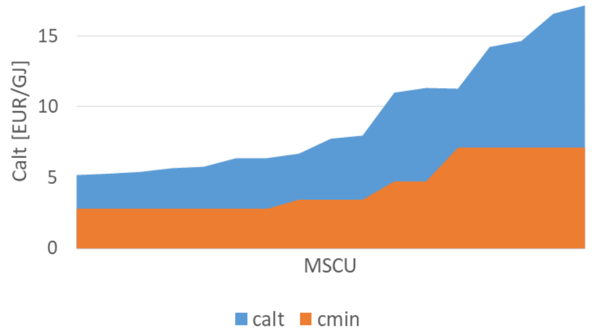
SRC plantation

Region/APA	Average		Weighted average	
	C_{min} [EUR/GJ]	C_{alt} [EUR/GJ]	C_{min} [EUR/GJ]	C_{alt} [EUR/GJ]
Maize-growing	4.4	9.3	5.2	11.4
Beet-growing	3.4	6.5	3.2	6.7
Potato-growing	3.4	6.3	3.0	5.8

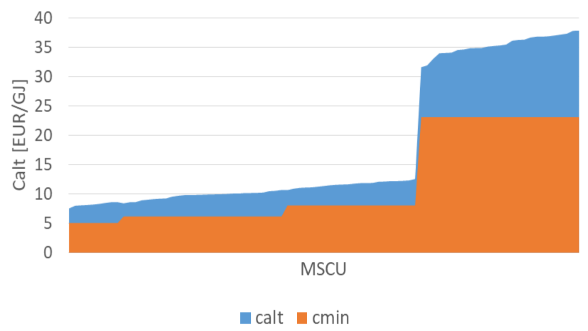
Miscathus plantation

Region/APA	Average		Weighted average	
	C_{min} [EUR/GJ]	C_{alt} [EUR/GJ]	C_{min} [EUR/GJ]	C_{alt} [EUR/GJ]
Maize-growing	7.9	10.9	7.2	10.6
Beet-growing	7.1	9.6	6.4	9.3
Potato-growing	11.9	18.2	11.2	17.3

SRC, maize growing APA



Miscanthus, potato growing APA

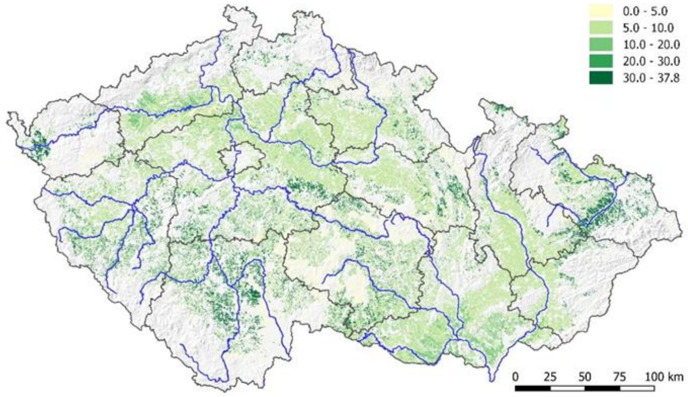


Note: prices of raw biomass without storage and transportation to final consumer

Price modelling results - 2

Factors influencing calt price:

- Suitability of given APA for energy crop – e.g. potato production area is not suitable for Miscathus – typical yields app. 2,5 t(FM)/ha,year
- High yields of conventional crop at given land plot – high profit that must be compensated by a higher c_{alt}
- Higher risk related with energy crop compared with conventional crop – higher discount rate and higher c_{min} and c_{alt} prices



c_{alt} price has high variability according to the specific conditions of the area

Example of c_{alt} price distribution for Miscanthus on the territory of the Czech Republic

Policy implication

Areas with c_{alt} lower than given maximum limit

SRC plantations

Maize-growing zone		Beet-growing zone		Potato-growing zone	
EUR/GJ	Area	EUR/GJ	Area	EUR/GJ	Area
<6	10.1%	<6	41.5%	<6	78.2%
<8	20.5%	<8	79.8%	<8	92.6%
<10	20.5%	<10	87.9%	<10	92.7%
<12	73.0%	<12	97.1%	<12	99.9%

Miscathus plantations

Maize-growing zone		Beet-growing zone		Potato-growing zone	
EUR/GJ	Area	EUR/GJ	Area	EUR/GJ	Area
<6	0.0%	<6	0.0%	<6	0.0%
<8	0,0%	<8	47.2%	<8	0.7%
<10	53.8%	<10	88.5%	<10	56.5%
<12	80.4%	<12	94.5%	<12	70.0%

Based on competition with other fuels and technologies - maximum competitive c_{alt} price limit is 6-8 EUR/GJ

Competition with conventional crop significantly reduces economic potential of energy crop

Expectations of an increase in targeted biomass may not be met!

Note: growing areas: maize: 140 th. ha, potato: 880 th. ha, beat: 972 th. ha (areas where yield of energy crop are defined, some unsuitable areas are excluded from the analysis)

Conclusion

Results of the analysis are to a large extent applicable in countries with similar conditions for growing energy and conventional crops – e.g. CE countries

Competition with conventional crop (competition for land) is pushing significantly up prices of intentionally planted biomass

Optimistic assumptions about the contribution of the energy crop may not be fulfilled

Perennial energy crops are more risky for farmers than conventional crops with a one-year production cycle - this puts further pressure to increase the price of targeted biomass

The efficiency of growing energy crops varies greatly from location to location - this requires a targeted focus on subsidies / support for the cultivation of energy crops.

Details available e.g. at:

- VÁVROVÁ, K., KNÁPEK, J., a WEGER, J. Short-term boosting of biomass energy sources – Determination of biomass potential for prevention of regional crisis situations. **Renewable and Sustainable Energy Reviews**. **2017**, 67s. 426-436. ISSN 1364-0321. DOI: https://doi.org/10.1016/j.rser.2016.09.015
- VÁVROVÁ, K., KNÁPEK, J., a WEGER, J. Modeling of biomass potential from agricultural land for energy utilization using high resolution spatial data with regard to food security scenarios. **Renewable and Sustainable Energy Reviews**. **2014**, 35s. 436-444. ISSN 1364-0321. DOI: https://doi.org/10.1016/j.rser.2014.04.008
- KNÁPEK, J., et al. Energy Biomass Competitiveness—Three Different Views on Biomass Price. **Wiley Interdisciplinary Reviews: Energy and Environment**. 2017, 6(6), ISSN 2041-8396
- KNÁPEK, J. et al. Dynamic biomass potential from agricultural land. Renewable and Sustainable Energy Reviews. 2020, 134(110319), 1-12. ISSN 1364-0321

Thank you for your attention !