# Biomass II - competition between conventional and energy crops

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1. Current and expected role of biomass – EU and Czech Republic
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3. Biomass from energy crop – different points of view on its price
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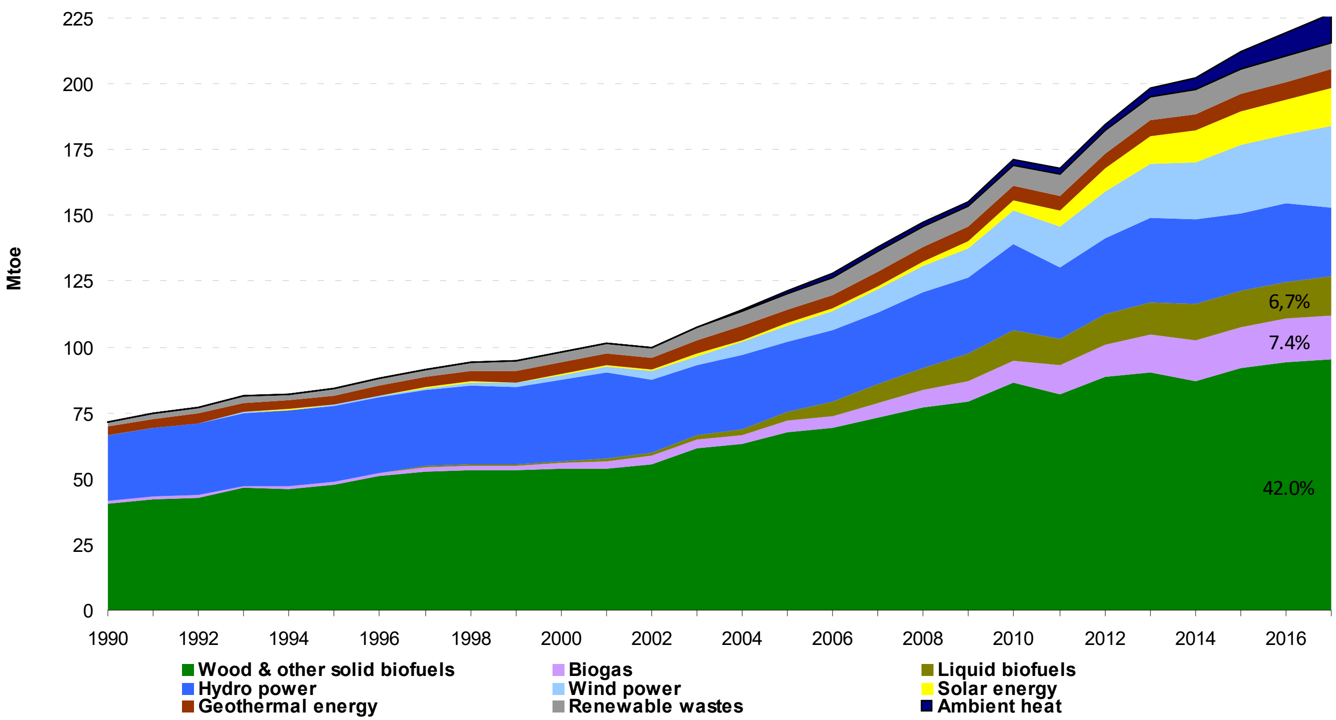
# Biomass – important and decisive RES at present

EU28 (Eurostat 2017): biomass (solid, biogas, liquid biofuels) accounts for 56,1% of **primary production of energy from RES** (of which solid biomass is app. 75%)

2030: Biomass +15-55 Mtoe ?




Biomass: 56,1%

**127.1 Mtoe**
**5321 PJ**

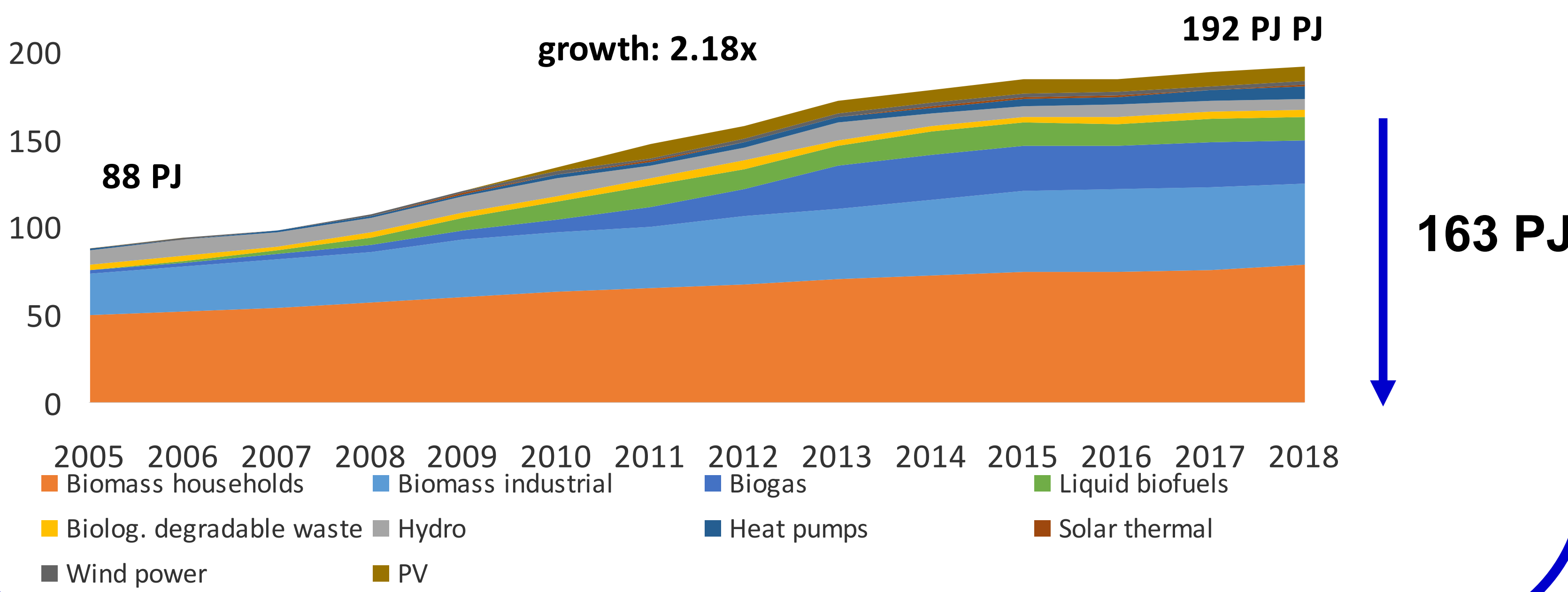
Source: Eurostat, Sustainable and optimal use of biomass for energy in the EU beyond 2020, 2017

# Biomass – important and decisive RES at present

Biomass CEE countries (Eurostat 2017): Czech Republic 86 %, Slovakia 72%, Poland 85% of RES

**2030: RES +55 PJ**
**Biomass +36 PJ**

**primary production of energy from RES, Czech Republic**




Source: RES statistics, MPO 2019, NECP, Czech Republic, MPO 2020

# Do we have realistic plans for biomass future ?

**Fundamental question – what is biomass potential and what are the factors influencing it**

- Methodologies of biomass potential determination differ significantly:
  - *the way in which agrotechnical, ecological, legislative, etc. restrictions are included in the calculation*
  - *assumptions about the future use of agricultural land, allocation of land for energy crop*
  - *learning curve effect (energy crop versus conventional crop)*
  - *impact of climate change (e.g. significant reduction of solid biomass from forestry from current bark beetle calamity in Central European countries)*
  - *many others incl.* ***economic aspect – biomass competitiveness***

# Biomass potential – definitions

***Various potential definitions, methodologies and understanding, e.g.***

**Theoretical**: only basic physical and biological constraints on biomass production are considered (soil, water availability, climate)

**Technical** (geographic, feasible): The basic environmental, agro-technical and territorial limitations are respected

**Economic**: potential that is competitive with other fuels under given conditions on the fuel market

**Realistic**: takes into account the technical constraints on the use of biomass on the part of consumers

Also another point of view: **long term** sustainable versus **short term boosting**, or biomass potential as the dynamic quantity

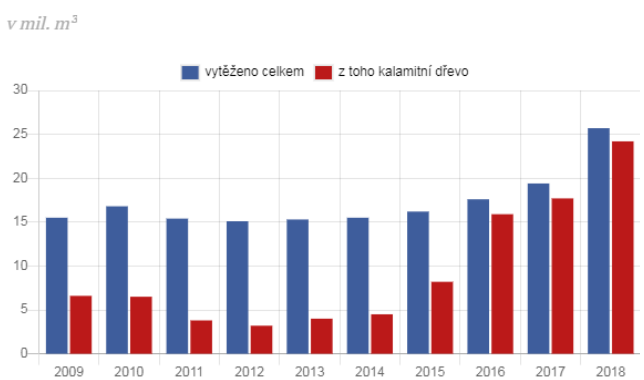
# Biomass categories

**Forest biomass** (EU 28: most important type of biomass)

- Stem wood, complementary felling
- Forest residuals

Q: *Material versus energy utilization, limitation for forest residuals utilization (soil quality, accessibility), potential distribution, natural parks, potential impact of climate change (at least in some EU countries).* ***Is it realistic to assume significant growth of forest biomass? E.g. in the Czech Republic biomass from forests can fall down to 1/10!***

# Forest tragedy – Czech Republic 2017-2020-??

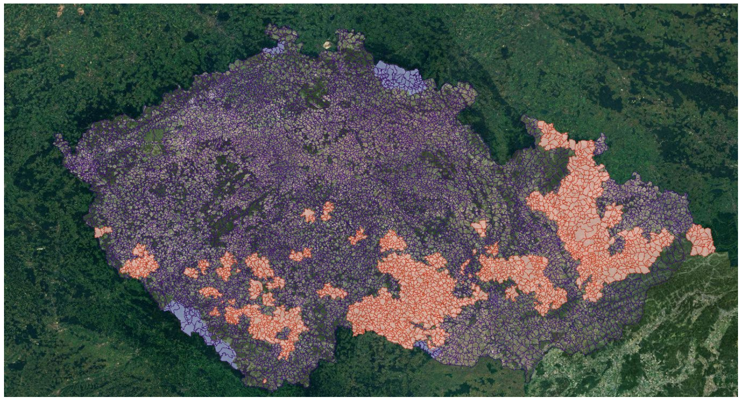



Forests: 2.7 mil. ha, coniferous 72%, spruce > 50% of total forest area

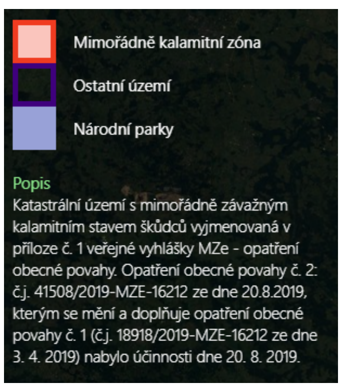
Climate change (several very dry and hot years), monoculture forests, wind calamities and massive invasion bark beetle
2019: 500 th. ha partly or fully damaged

Source: Drevmag.com, ekolist.cz

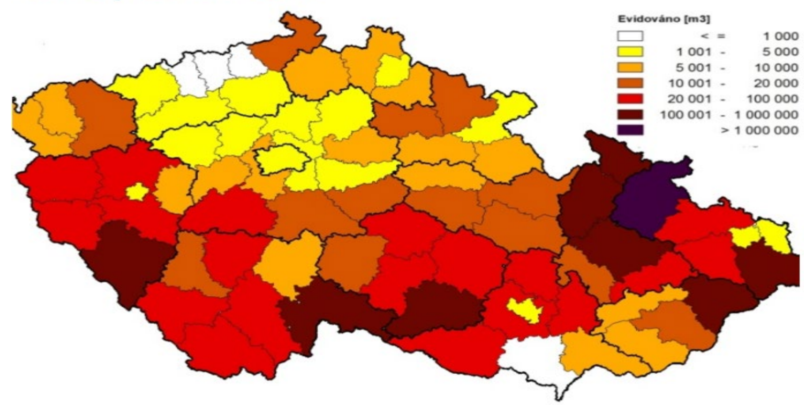
# Forest tragedy – Czech Republic 2017-2020-??



At the end of decade – reduction of forest biomass between 70-85% expected
Preference of forest renewal
Necessity to react on climate change




Rozsah kůrovcové kalamity představuje vysoké riziko pro rok 2019




Source: Drevmag.com, ekolist.cz

# Factors influencing biomass potential from agricultural land – dynamic quantity

**BPt=f(LAAt, SCCCt, BAPt, LCECCt, LCEECt, ICCt, IMSPt, MLAECt)**

t … time dependent

LAAt … land available area

SCCCt … structure of cultivated conventional crop

BAPt … biomass utilization for agriculture purposes (forage, bedding, soil quality improvement)

LCECCt … learning curve effect (development of expected yields of conventional crop at given site conditions)

LCEECt … learning crop effect (development of expected yields of energy crop at given site conditions)

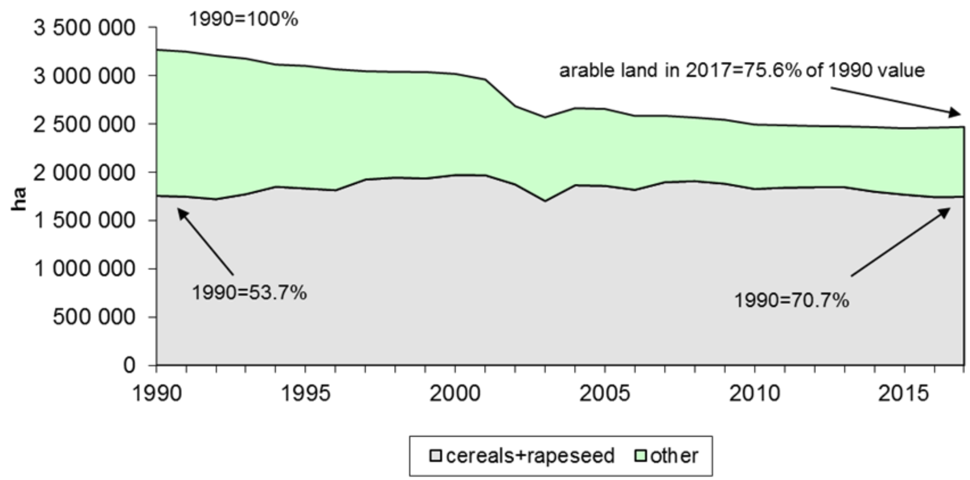
ICCt … impact of climate change on expected yields of energy and conventional crop

IMSPt … impact of measures amioed at soil and biodiversity protection on biomass yields

MLAECt … method of land allocation for energy crop (? Food preference)

# Land availability

**Changes in sowing area of conventional crops and cereals between 1990 and 2017 in the Czech Republic**




1993-2016:
-2.2%/year
Construction, urbanization, afforestation, land protection

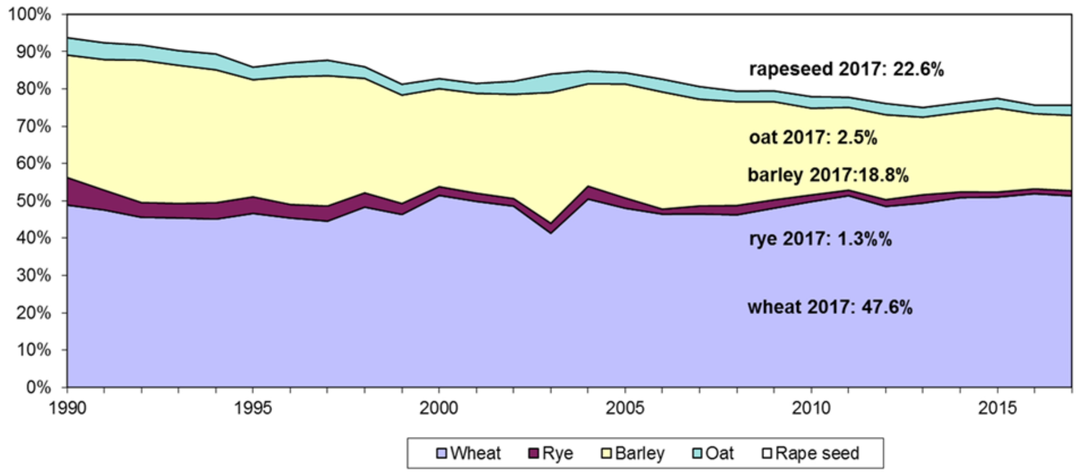
**Changes in the area of arable land in selected EU countries between 1993 and 2017**

| Country | 1993 [1000 ha] | 2016 [1000 ha] | Total change [%] | Annual average change [%] |
|---|---|---|---|---|
| Germany | 11 676 | 11 763 | 0.7 | 0.1% |
| France | 18 034 | 18 356 | 1.8 | 0.1% |
| Poland | 14 305 | 10 806 | -24.5 | -2.1% |
| EU | 120 482 | 105 453 | -12.5 | -1.0% |

Source: FAO

# Changes in structure of conventional crop

**Changes in the structure of cereals and rapeseed between 1990 and 2017 in the Czech Republic**




Source: CZSO

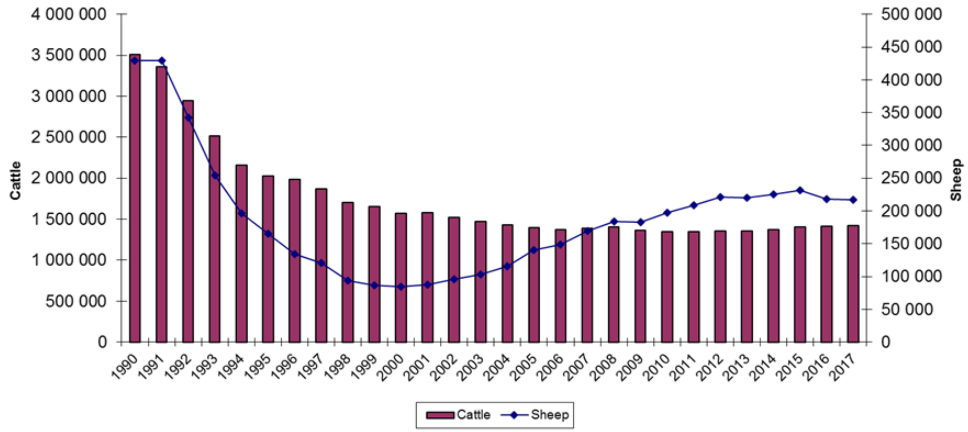
**Changes in the area of conventional crop sowing areas in EU countries between 1993 and 2016**

| Country | 1993 | 2016 | Total change | Annual average change |
|---|---|---|---|---|
| | [ha] | [ha] | [%] | [%] |
| Barley | 15 968 966 | 12 280 251 | 76.9% | -2.0% |
| Oat | 3 317 502 | 2 621 863 | 79.0% | -1.8% |
| Rye | 4 115 961 | 1 931 682 | 46.9% | -5.7% |
| Wheat | 24 854 319 | 27 035 453 | 108.8% | 0.6% |
| Rapeseed | 3 050 080 | 6 533 882 | 214.2% | 6.0% |

Source: FAO

# Changes in live stock

**Changes in the state of livestock in the Czech Republic between 1990 and 2017**




Source: CZSO

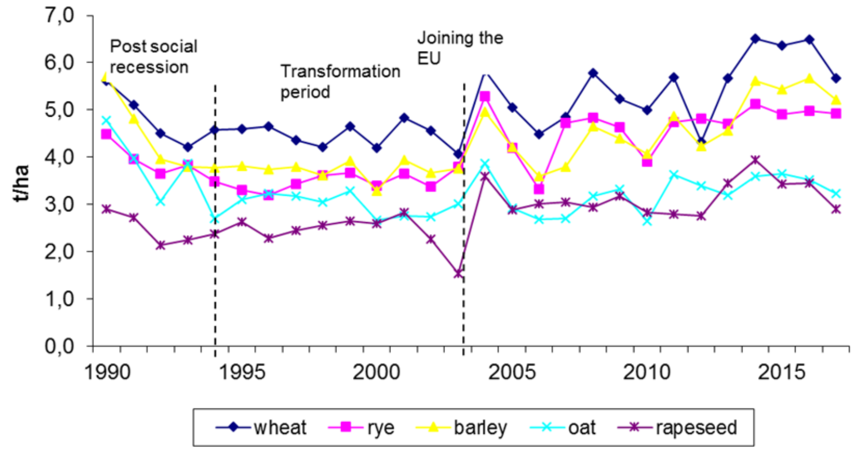
**Changes in cattle and sheep stocks between 1993 and 2016 in EU countries**

| Country | 1993 [head] | 2016 [head] | Total change [%] | Annual average change [%] |
|---|---|---|---|---|
| Cattle | 106 783 351 | 89 969 958 | 84.3% | -1.3% |
| Sheep | 136 075 366 | 98 675 585 | 72.5% | -2.4% |

Source: FAO

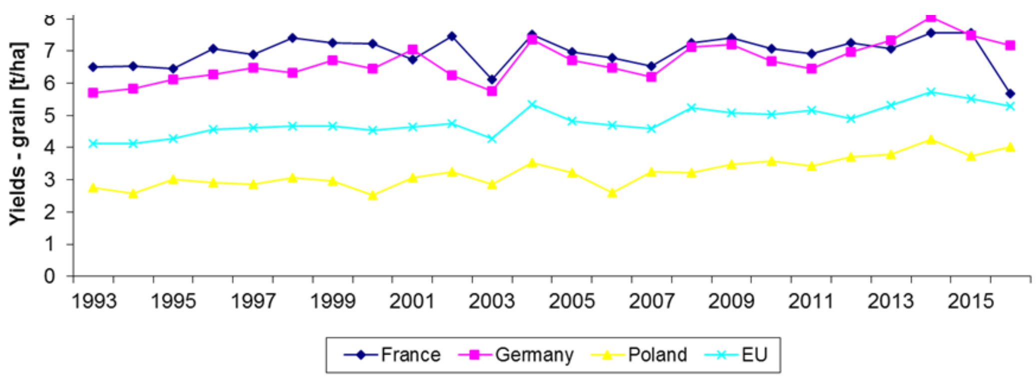
# Crop yields variability – learning curve effect

**Development of specific cereal yields between 1990 and 2017 in Czechia**




Source: CZSO

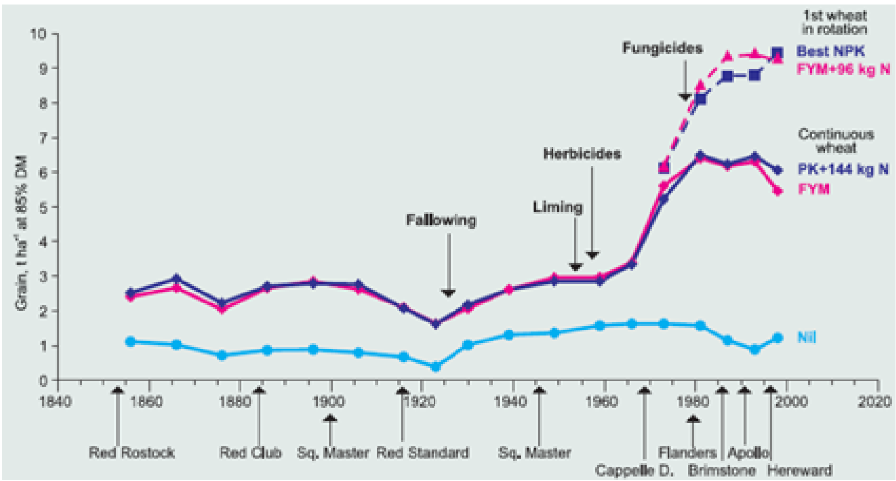
**Development of specific crop yields for the EU and selected EU states**




Source: FAO

# Crop yields variability – learning curve effect 2

**What is the learning curve effect for conventional crop – if any?**




Long-term yields of winter wheat grain. Rothamsted

Source: Johnston and Poulton, 2018

**Learning curve for energy crop - SRC plantations and perennials**

- Still limited experience, optimization of agrotechnologies (yields, cost benefit), breeding, suitable seed material, etc.
- Based on more two decades of field experiments in Czechia (VUKOZ) plus literature search: learning curve factor for energy crop is estimated 1.5-2.5%, year (in horizon up to two decades)

# Biomass from energy crop – different points of view on its price

**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**

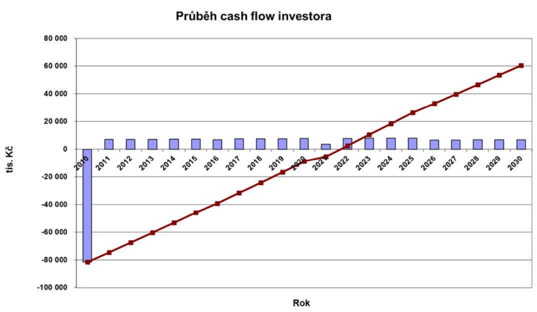
| Minimum price to get required rate of return | Opportunity use of soil for conventional crops |
| --- | --- |
| $C_{min}$: $NPV_{enercrop}=0$ | $C_{alt}$: $NPV_{enercrop}=NPV_{convcrop}$ |
| rate of return is equal to discount rate used for NPV calculation | to get the same economic effect as from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

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

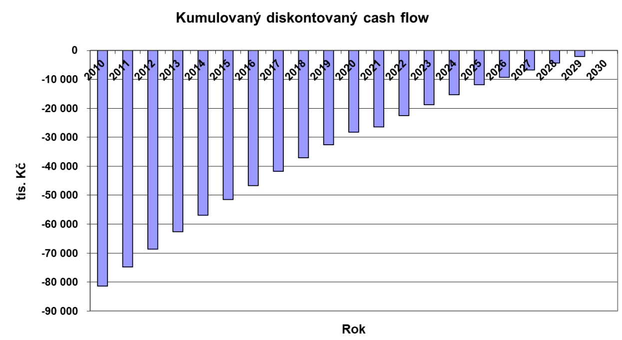
# Biomass from energy crop – minimum price modelling 2

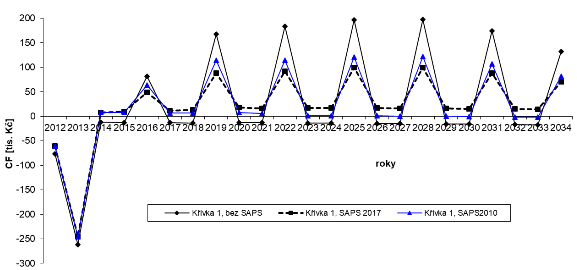
## Minimum – price

- 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

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

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

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

$C_{alt} \cdot Q + S$: 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

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

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

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

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 uncertain 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

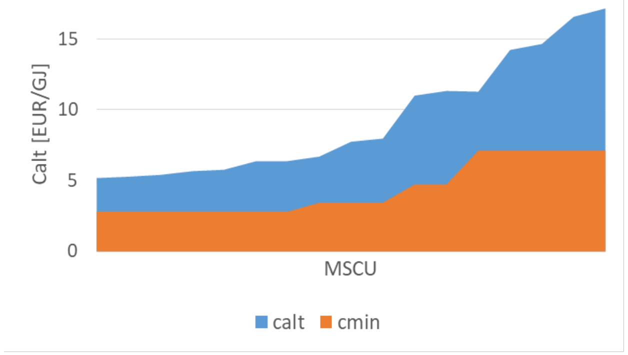
SRC plantation

| 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 |

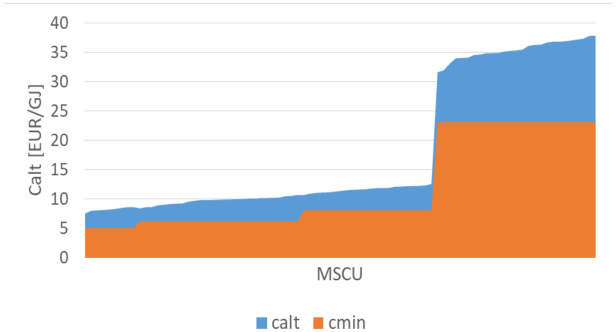
Miscathus plantation

| 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

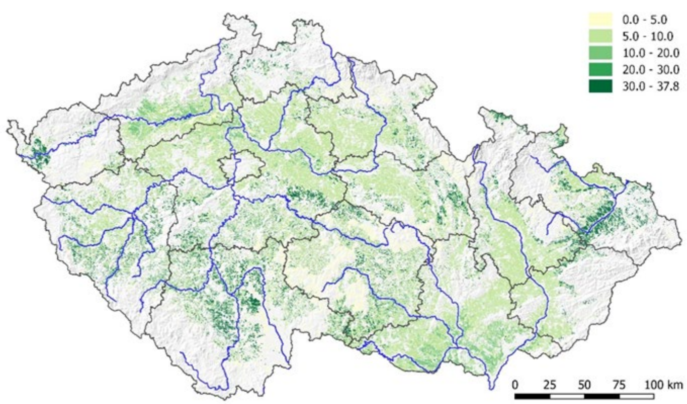



Note: prices of raw biomass without storage and transportation to final consumer

# 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
- ❑ HAVLÍČKOVÁ, K., WEGER, J., KNÁPEK, J. Modelling of biomass prices for bio-energy market in the Czech Republic, Simulation Modelling Practice and Theory, vol. 19, no. 9, pp. 1946–1956, Oct. 2011



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# Thank you for your attention !