Biomass as a major RE carrier versus Biomass within the concept of changing energy markets – part 2

J. Knápek

knapek@fel.cvut.cz

Czech Technical University in Prague, Faculty of Electrical Engineering

Content

1. General context – update

2. Biomass sources

3. 1st, 2nd and 3rd generation biofuels

4. New trends in biomass – selected examples

5. Agroforestry and agrivoltacs – example of the new trend

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

Ý. Biomass potentials and dynamic character of biomass potential

RES development context

RES development including biomass should be understood within the context of changing energy and other markets, EU strategic policies and global context

Combination of energy branch transformation tasks:

- Short term goals („to manage current needs“)
- Long term goals (transformation pathways taking into account rest of globalized world)

Safety, reliability and competitiveness

Risk and uncertainties on the energy market

Risks and uncertainties - changes since 2020

- Changes on energy markets started even before 2020 (winter package, Green Deal, …)
- Uncertainty in energy markets, prices and availability of energy commodities
- Continuous decline since spring 2023 (spor versus short term market)

Long term contracts– natural gas www.pxe.cz, one year, Cal 23 (2/9/2020: 14,5 EUR/MWh, 2.2.2023 52,5 EUR/MWh). 9.5.2024: 38,3 EUR/MWh

Long term contracts– www.pxe.cz, one year baseload, Cal 23 (24/3/2022: 174 EUR/MWh,el, 26/8/2022: 984 EUR/MWh, 2.2.2023 135 EUR/MWh, 31.1.2024: 81 EUR/MWh), 9.5.2024 97 EUR/MWh

Risk and uncertainties on all markets

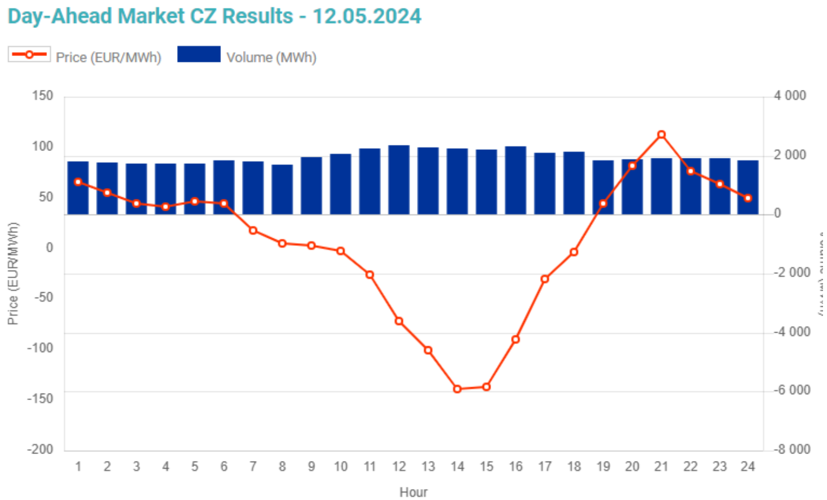
Risks and uncertainties

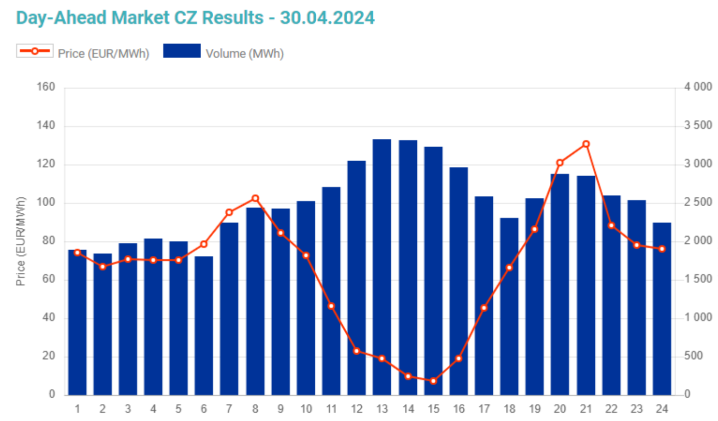
- There is an interplay of several factors:
  - Post-covid jump-starting of economies
  - Implementation of the Green Deal (see Fit for 55), impact of rapid decarbonisation, prices of emission allowances, asymmetric impacts on different economies
    - Energy prices are reflected in all branches - e.g. in agriculture (crop production) directly (prices of liquid fuels) and indirectly (prices of artificial fertilizers and overall higher prices of inputs) and in food production (directly energy prices, indirectly increased market demand for commodities

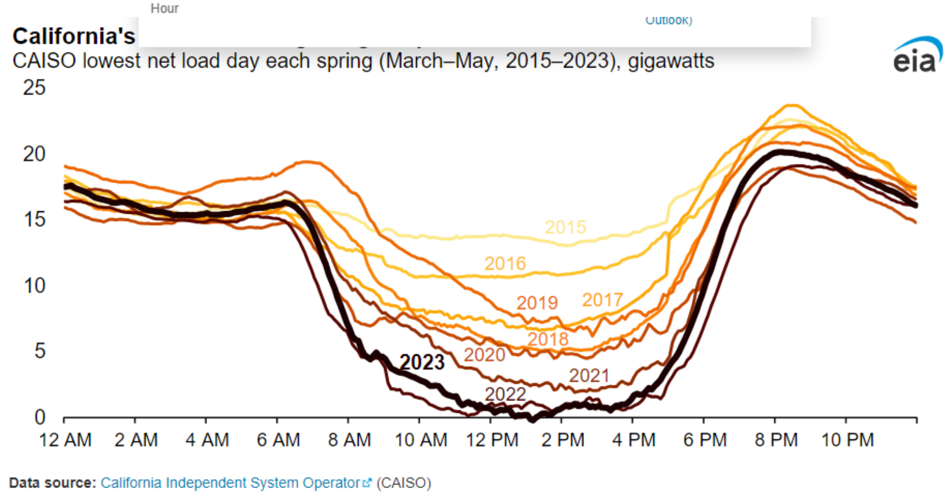
https://tradingeconomics.com/commodity/carbon

Source: www.kurzy.cz/komodity

Fluctuation of power prices



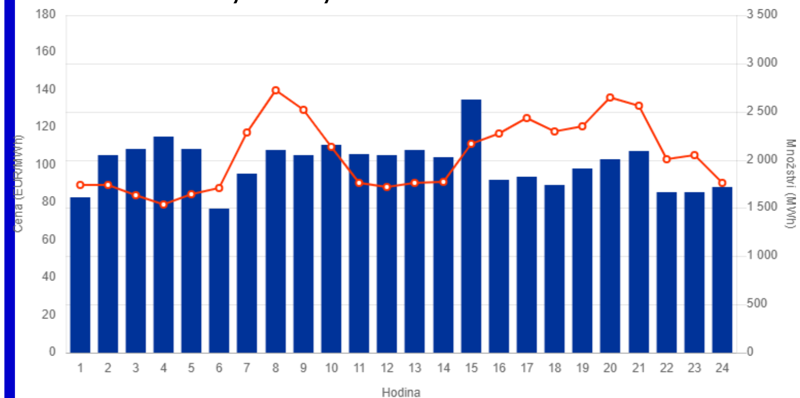




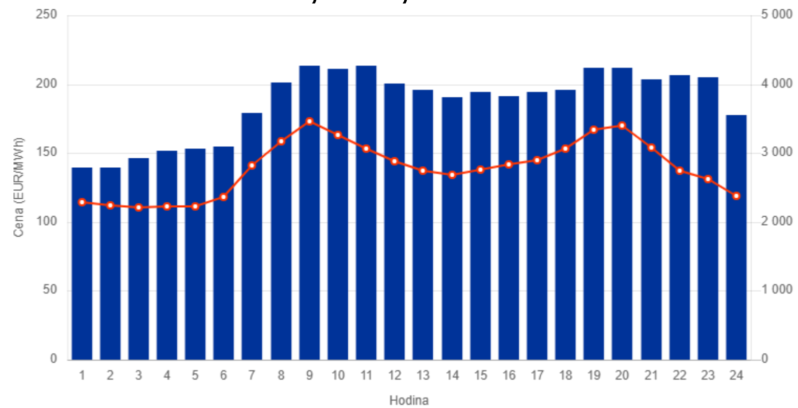
ARAMIS

Changes of power prices

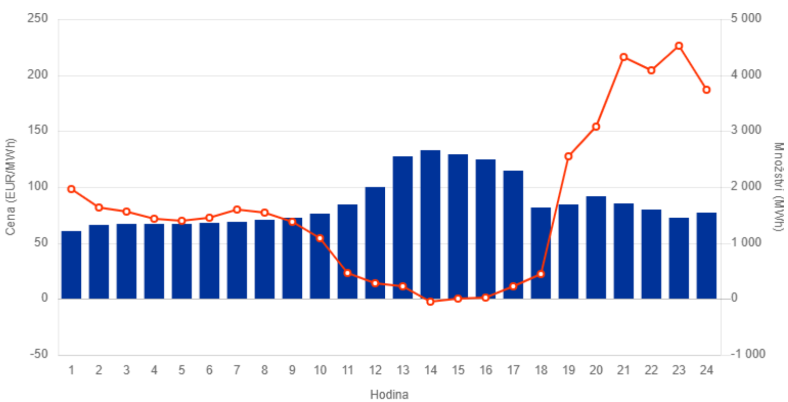
DAM, CZ, 30.3.2023



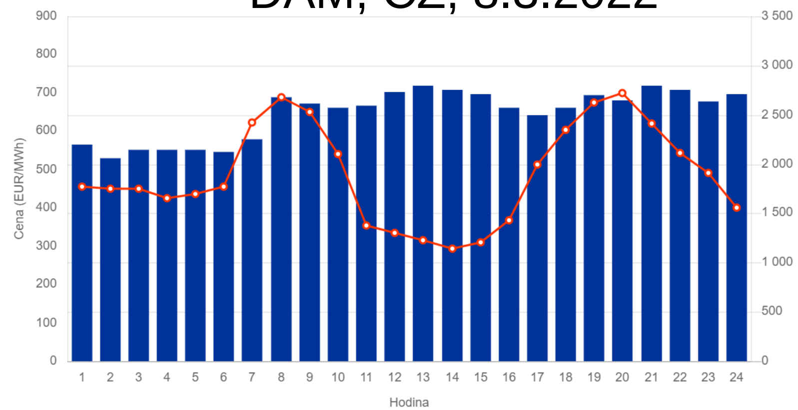
DAM, CZ, 8.3.2023



DAM, CZ, 10.4.2023



DAM, CZ, 8.3.2022



Why has the price of electricity in March 2023 fallen compared to March 2022? What factors are influencing this? Where can electricity prices fall? What will be the next development? And what happened on 10.4.2023 ?

EU energy policy – Other news

EU ETS: (emission allowances) applies to sources above 20 MWt (defined technologies)

EU ETS II introduces a carbon price for other sectors and technologies not yet covered - from 2027

- transport (defacto carbon tax on petrol and diesel, albeit through the purchase of emission allowances by suppliers

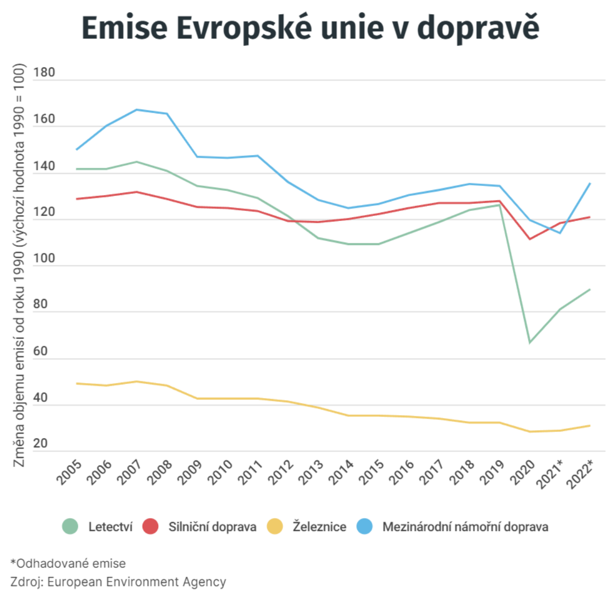
- heating of buildings (including local sources), similar principle to liquid fuels
- removing the asymmetry of the ETS impact on sources above and below 20 MWt

- ending free allocation of allowances by 2034 (especially heavy industry), aviation from 2026

- Introduction of carbon tariff (to prevent "carbon leakage" by shifting production to other countries outside the EU) This will apply to steel, cement, aluminium, fertiliser, electricity or hydrogen production.

EU energy policy – Other news

A separate new ETS II will be created for road transport fuels and buildings. This will put a price on greenhouse gas emissions from these sectors in 2027 (or 2028 if energy prices are exceptionally high). A new price stability mechanism will be established to ensure that 20 million additional allowances will be made available if the ETS II allowance price rises above €45.



EU energy policy – Other news

- Rapid development of LNG terminals.
- Natural gas spot price has reached the level of more than 3 years ago.

BUT

- Problem with payback period for LNG terminals (Taxonomy assumes natural gas only as the transient fuel/technology), but we need it right now
- Similar problem with duration of the contract for natural gas delivery

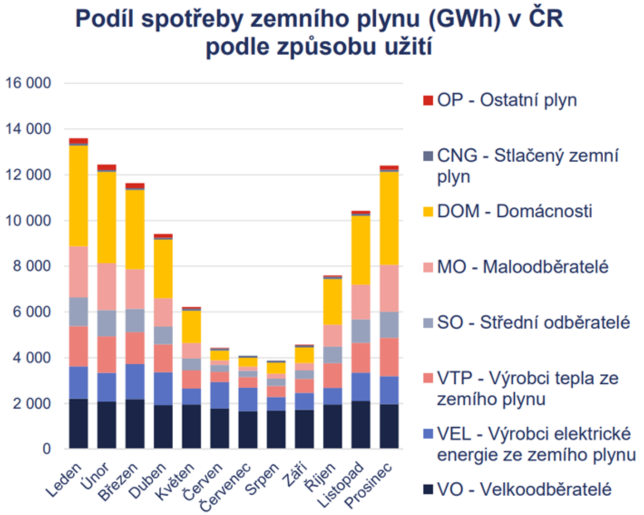
(producers require typically 15 year contracts)

- Transformation of energy systems needs time

Other context

- High seasonal profile of natural gas consumption (problem either for its assurance or substitution)

- Demostrated on the example of the Czech republic seasonal profil of natural gas consumption

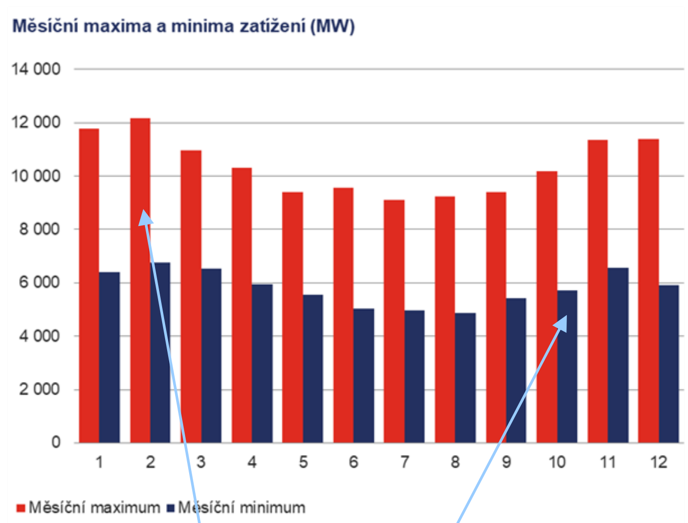


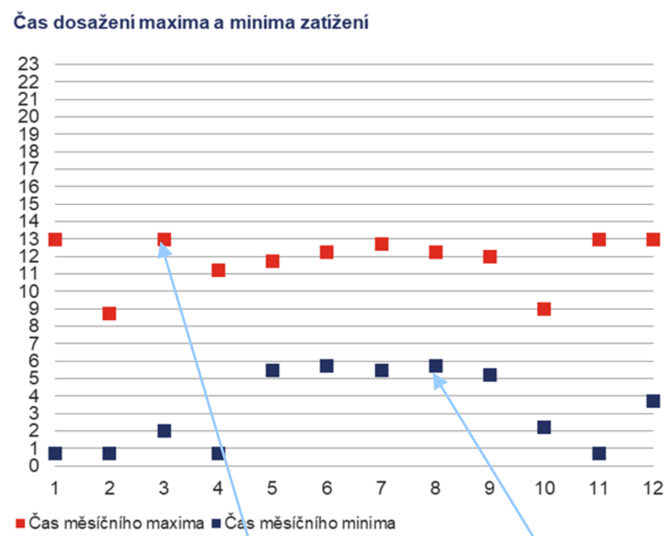
Kategorie	Spotřeba [GWh]
DOM – Domácnosti	26 899
VO – Velkoodběratelé	23 259
MO – Maloodběratelé	13 377
VEL - Výrobci elektrické energie ze zemního plynu	13 067
VTP - Výrobci tepla ze zemního plynu	12 830
SO - Střední odběratelé	8 904
OP - Ostatní plyn	1 344
CNG - Stlačený zemní plyn	1 057
CELKEM	**100 737**

DOM- households
VO-industrial consumers
MO- small consumers
VEL- power genration from gas
VTP- heat producefs from gas
SO- middle size consumers
OP- other gases
CNG- compressed natural gas

Other context

- Substitution of conventinal power generation capacities with intermitent RES – example of the Czech rep.

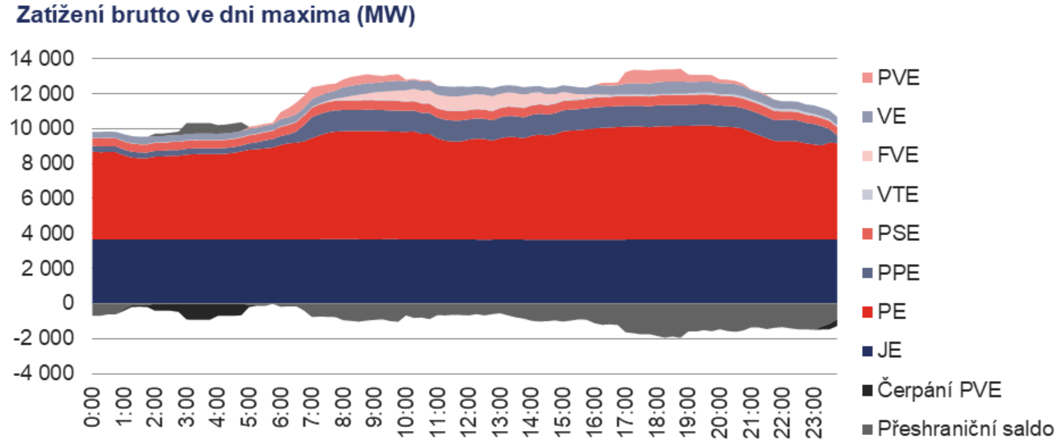




Monthly maximum, monthly minimum

Hour of monthly maximum and monthly minimum

Other context



Maximum load demand – CZ 2021

Structure of meeting load demand
JE – nuclear power plant (PP)
PE – steam PP
PPE – gas fired PP
VE – hydro PP
PVE-pump storage PP
FVE – PV PP
VTE – Wind PP

Struktura pokrytí denního maxima zatížení (15. 2. 2021 08:45)	**[MW]**	
Zatížení brutto	**12 159,0**	**100%**
Jaderné elektrárny (JE)	3 678,9	30%
Parní elektrárny (PE)	6 201,1	51%
Paroplynové elektrárny (PPE)	1 206,0	10%
Plynové a spalovací elektrárny (PSE)	554,3	5%
Vodní elektrárny (VE)	581,1	5%
Přečerpávací vodní elektrárny (PVE)	514,5	4%
Fotovoltaické elektrárny (FVE)	330,9	3%
Větrné elektrárny (VTE)	54,7	0%
Přeshraniční saldo	-962,6	-8%
Čerpání PVE	0,0	0%

ČEPS – TSO outlook for the Czch republic

PROGRESIVNÍ SCÉNÁŘ

Instalovaný výkon	Progresivní 2025	Progresivní 2030	Progresivní 2035	Progresivní 2040
Nedodávka	0 GWh	1 GWh	305 GWh	798 GWh
Saldo dovozu a vývozu	2 121 GWh	15 218 GWh	19 981 GWh	19 961 GWh
Palivové články	0 GWh	0 GWh	16 GWh	42 GWh
Bateriová akumulace	36 GWh	256 GWh	718 GWh	1 401 GWh
Vodní a přečerpávací elektrárny	2 605 GWh	3 452 GWh	3 495 GWh	3 554 GWh
Fotovoltaické elektrárny	5 658 GWh	12 469 GWh	13 782 GWh	14 518 GWh
Větrné elektrárny	1 484 GWh	2 349 GWh	5 258 GWh	7 280 GWh
Ostatní OZE	3 374 GWh	3 109 GWh	2 605 GWh	2 784 GWh
Plynové zdroje	3 273 GWh	9 298 GWh	18 195 GWh	15 437 GWh
Uhelné zdroje	24 961 GWh	9 039 GWh	0 GWh	0 GWh
Jaderné elektrárny	27 883 GWh	28 381 GWh	27 921 GWh	36 326 GWh

The Czech Republic is becoming an importer of electricity from an exporter (from where?) + the question of importing electricity at a time when production in PV and wind power plants is limited

- The open question of the operation of coal-fired power plants and the related extraction of coal for thermal power plants
- Rapid growth of electricity from RES places increased demands on flexibility services and electricity storage (will it be available in 2030?)
- What to do with surplus electricity from PV ?

DEKARBONIZAČNÍ SCÉNÁŘ

Instalovaný výkon	Dekarbonizační 2025	Dekarbonizační 2030	Dekarbonizační 2035	Dekarbonizační 2040
Nedodávka	0 GWh	83 GWh	985 GWh	2 676 GWh
Saldo dovozu a vývozu	2 377 GWh	19 989 GWh	20 008 GWh	19 990 GWh
Palivové články	0 GWh	20 GWh	383 GWh	585 GWh
Bateriová akumulace	42 GWh	283 GWh	861 GWh	1 575 GWh
Vodní a přečerpávací elektrárny	2 652 GWh	3 598 GWh	3 737 GWh	3 905 GWh
Fotovoltaické elektrárny	7 366 GWh	16 274 GWh	19 000 GWh	21 715 GWh
Větrné elektrárny	1 484 GWh	2 354 GWh	5 258 GWh	7 280 GWh
Ostatní OZE	3 374 GWh	3 431 GWh	2 605 GWh	2 783 GWh
Plynové zdroje	3 310 GWh	15 190 GWh	21 627 GWh	19 673 GWh
Uhelné zdroje	25 179 GWh	0 GWh	0 GWh	0 GWh
Jaderné elektrárny	27 883 GWh	28 370 GWh	28 071 GWh	36 265 GWh

Balance import - export

Other context

The current situation is accelerating processes already underway

- Development of RES (but care must be taken to ensure a balanced production mix with regard to the reliability of electricity supply, including in the RES segment)
- Decarbonisation of the energy sector
- Diversification of imports of primary sources
- Increased perception of the risk of asymmetric impacts on national economies (e.g. due to massive domestic support for their industries)
- Increased perception of the risk of social instability and associated energy poverty

Search for new market mechanisms (what it all involves?)

EU energy policy – New targets to 2030/2

- 2021-2022: discussion on pathways – Taxonomy
  - Classification system of investments/assets (not only for financial sector) - Regulation (EU) 2020/852: on the establishment of a framework to facilitate sustainable investment
  - Do No Significant Harm principle – 6 objectives
  - Climate change mitigation, Climate change adaptation, The sustainable use and protection of water and marine resources, The transition to a circular economy, Pollution prevention and control, The protection and restoration of biodiversity and ecosystems
  - Delegated Act: details on classification of individual technologies – great discussions on natural gas and nuclear (acceptable as the transient technologies)

EU energy policy – New targets to 2030/3

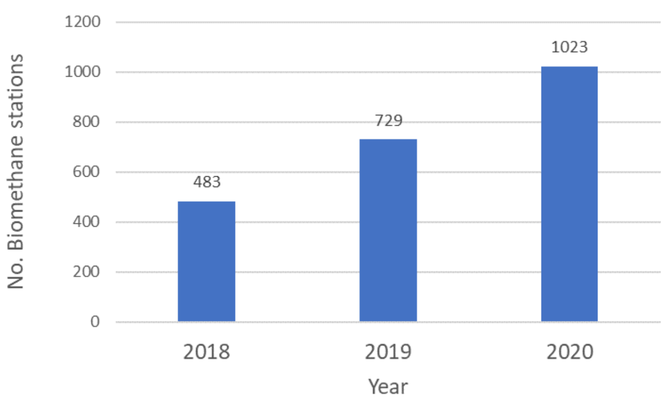
- **> 24.2.022: the world has changed …..**
- Natural gas has significant tools for decarbonization of energy branch (namely to substitute coal)
  - E.g. Germany – shut down of nuclear power plants
  - E.g Czech Republic – significant role in heating branch transformation (sources over 20 MWt: app. 70-75% natural gas, 10-15(20)% biomass, 5-10% solid alternative fuels)
- EU Commission:
  - 3/2022 RepowerEU: aimed at reduction of import dependancy (e.g. stop NG import from Russia until 2027)
  - Role of RES, incl. biomethane, etc. (biomethane from 3 bcm to 33-35 bcm)

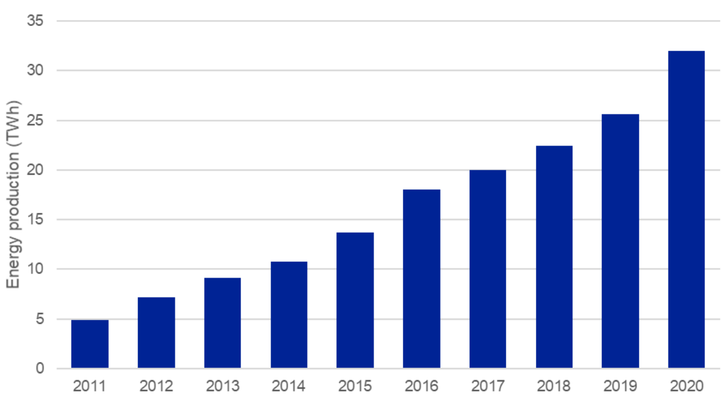
REPowerEU – biomethane targets

Biomethane is a promising biofuel for the next decade:

- Higher effectivity of land (feedstock) utilization - upgrading biogas to biomethane significantly improves the energy efficiency of the use of the input biomass

- Substitution of natural gas, can use its infrastructure



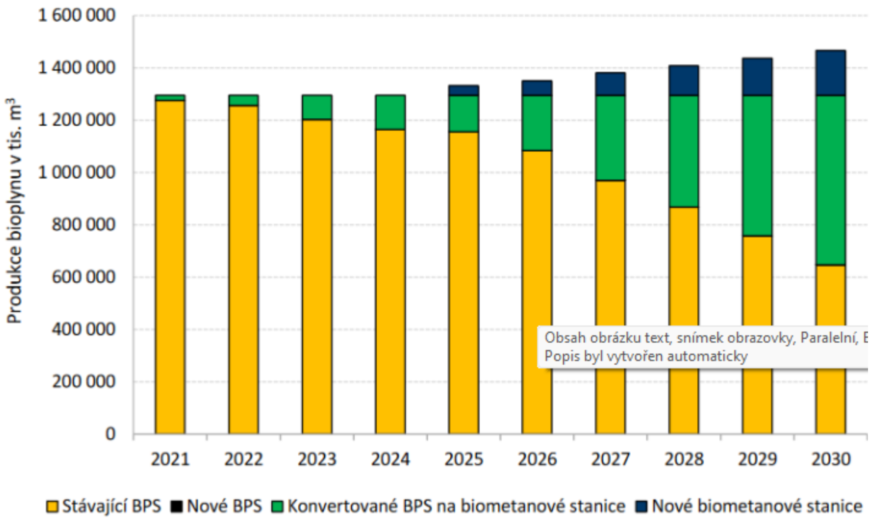


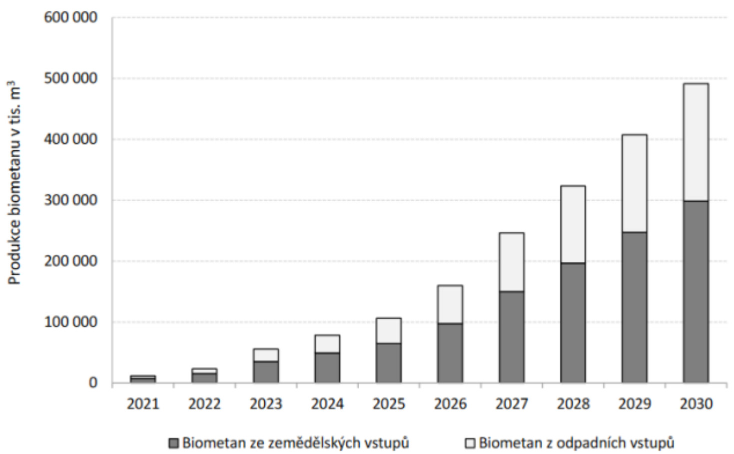
Source: EBA

Biomethane (2020): 32 TWh, app. 3.3 bln. m^3
REPowerEU – goal defined for 2030 (3/2022): 35 bln m^3 (accelerated pathway)

CZ – biomethane targets to 2030

CZ National energy climate plan – goal to 2030: 0.5 bcm of biomethane





Projection of biogas (BGS)/biomethane (BMS) production in CZ

Yellow: existing BGS, green: converted BGS into BMS, blue: new BMS

Source: CZ NECP, 2023 update

Structure of input substrates

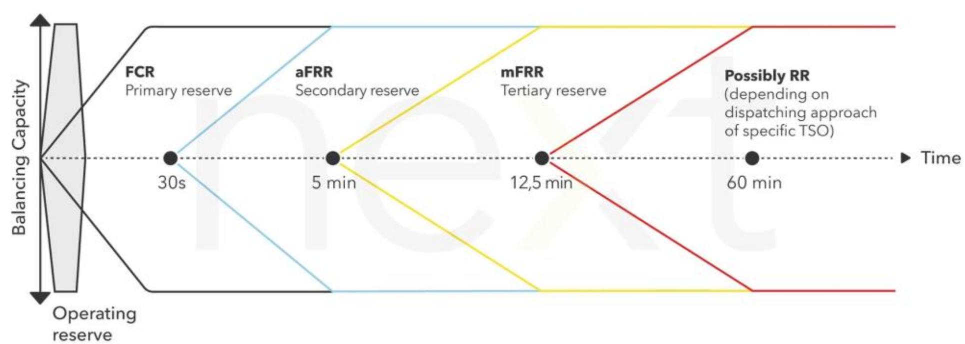
Black: from agriculture, white: waste biomass

CZ – biomethane targets to 2030 /2

CZ National energy climate plan – goal to 2030: 0.5 bcm of biomethane

- Mainly through conversion of existining BGS into BMS (cleaning technology added – typically membrane technology for separation of CO2)
- BGS in this case should solve heat source (for fermentor, technology, etc.)
- BGS has accumulation capacity – gas accumulation typically for 1-3 hours
    - Possibility to offer flexibility services
    - Conversion of BGS into BMS results in loss of flexibility services

Balancing Services According to the System Envisaged by ENTSO-E

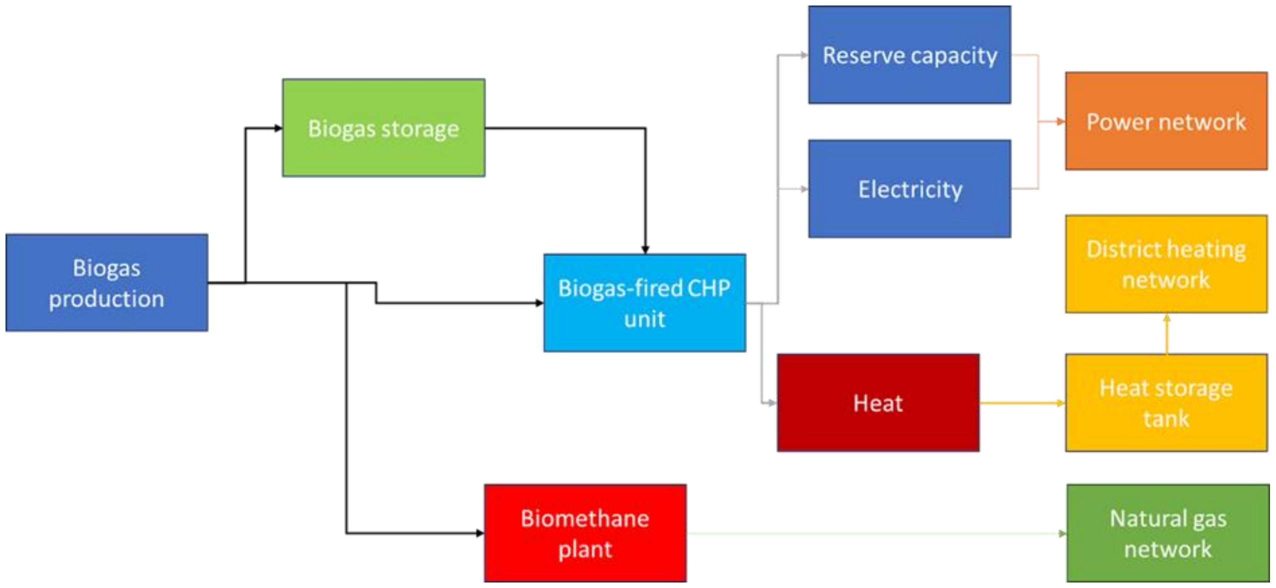


Source: Next Kraftwerke GmbH, https://www.next-kraftwerke.com/products

BUT: Quick incresase of RES in power generation mix will require additional sources of flexibility services.

Development of BMS should be based on systém strategy

CZ – biomethane targets to 2030 /3

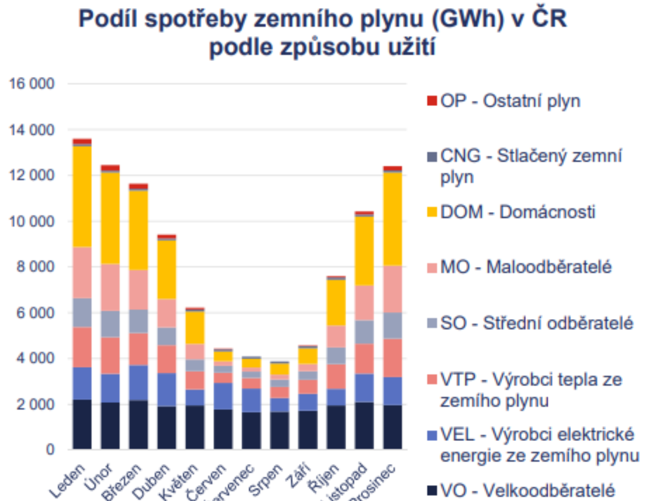


Complex solution for BMS/BGS stations

Source: own figure

Seasonal profile of NG consumption – role of gas storage

Profile of NG consumption, Czech Republic, 2021



Kategorie	Spotřeba [GWh]
DOM – Domácnosti	26 899
VO – Velkoodběratelé	23 259
MO – Maloodběratelé	13 377
VEL - Výrobci elektrické energie ze zemního plynu	13 067
VTP - Výrobci tepla ze zemního plynu	12 830
SO - Střední odběratelé	8 904
OP - Ostatní plyn	1 344
CNG - Stlačený zemní plyn	1 057
CELKEM	**100 737**

New legislation to avoid blocking of NG storage capacities – USE IT OR LOSE IT, obligation to NG storage for next season

DOM –households, VO – big consumers, MO – small business consumers, VEL – power producers from NG, VTP – neat producers from NG, SO – medium business consumers, OP – other gases

Source: Energy Regulatory Office, presentation for Czech House of commons, May 2022

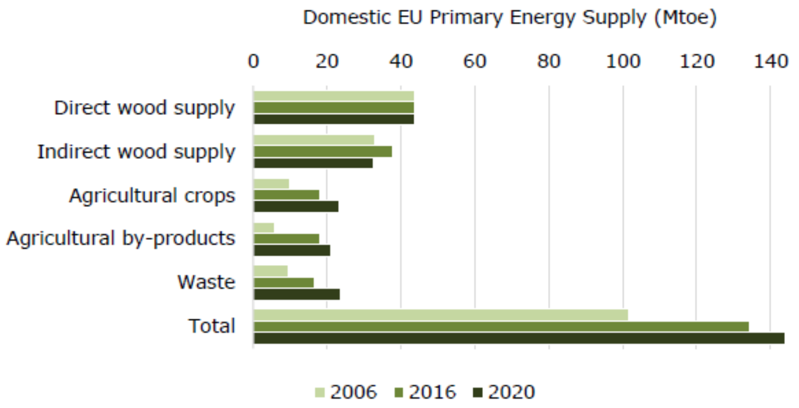
NG – intermediate solution for coal stop ?/!

- NG substitute of coal power and heat production
    - E.g. Czech Republic and district heating branch (40% of heat to households, currently 2/3 from coal)

    - Power generation based on NG is flexible, dynamic services to manage high shares of RES electricity from intermittent sources

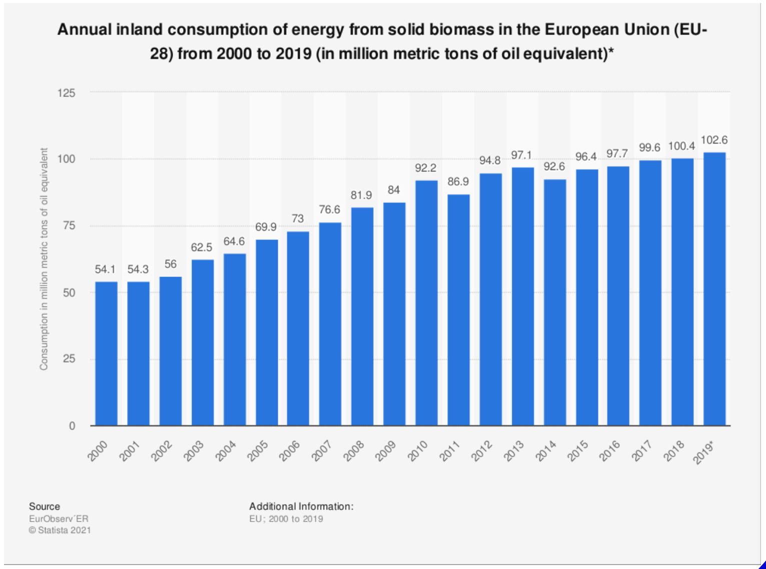
- Current situation with NG:
    - High uncertainty with heating branch transformation
    - Redefinition of energy transformation strategies, e.g. faster growth of RES, but also of coal decline
    - High shares of intermittent sources require massive investment into accumulation capacities, but also investment in dynamic services (NG was assumed)

General context – important role of biomass

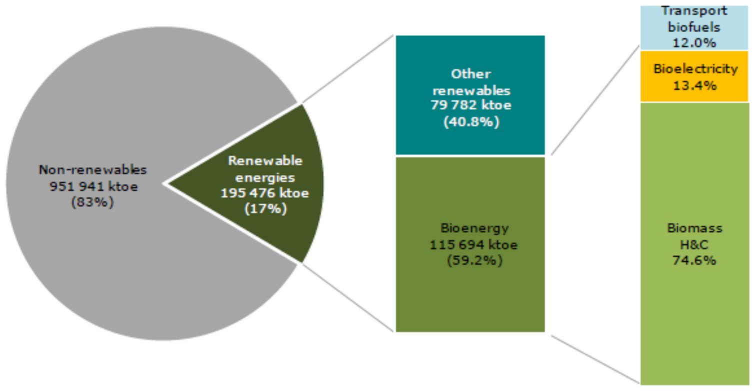


https://publications.jrc.ec.europa.eu/repository/handle/JRC109354

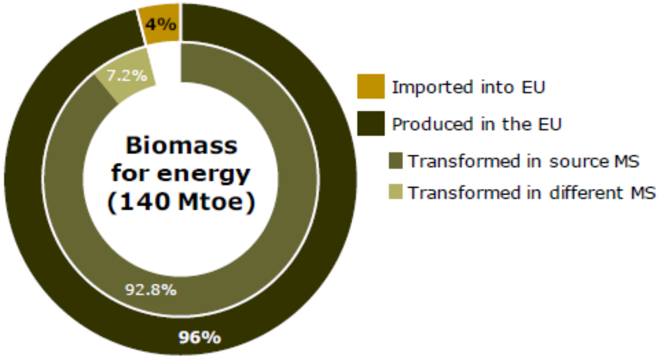
Biomass share on RES is declining but in absolute values is increasing



General context – important role of biomass



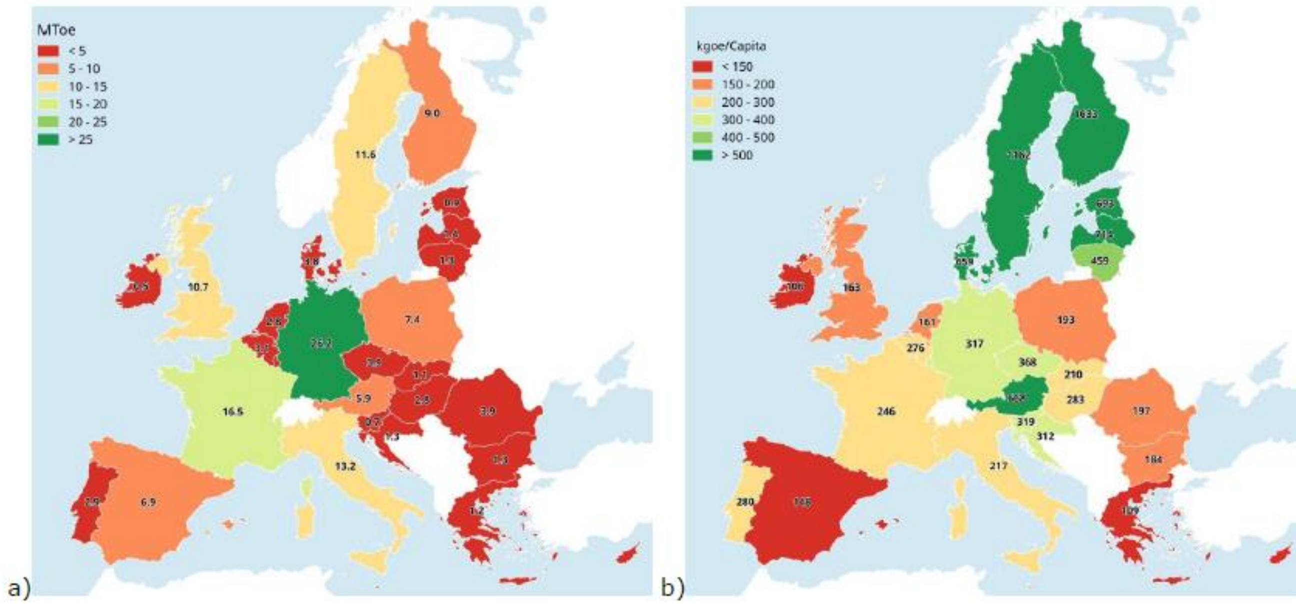
EU: 2016 – gross final energy consumption



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

General context – important role of biomass

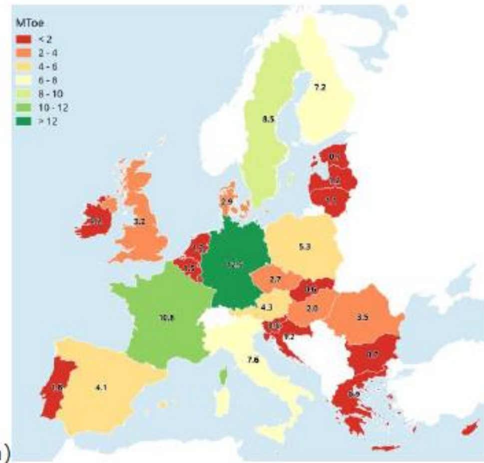
Gross inland bioenergy consumption: total and per capita



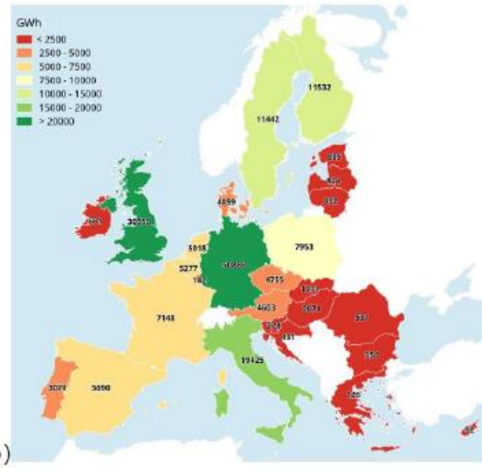
Source: https://ec.europa.eu/jrc/en/publication/brochures-leaflets/brief-biomass-energy-european-union

General context – important role of biomass

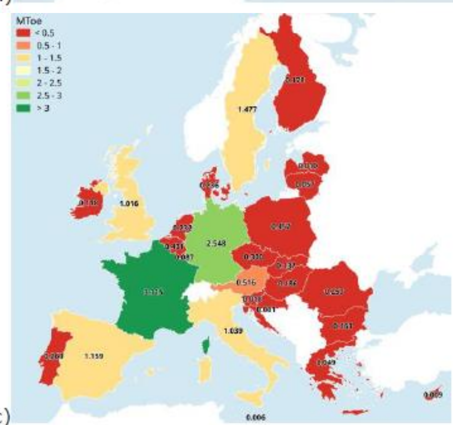
Gross final consumption of bioheat, bioelectricity and transport biofuels



a)



b)



c)

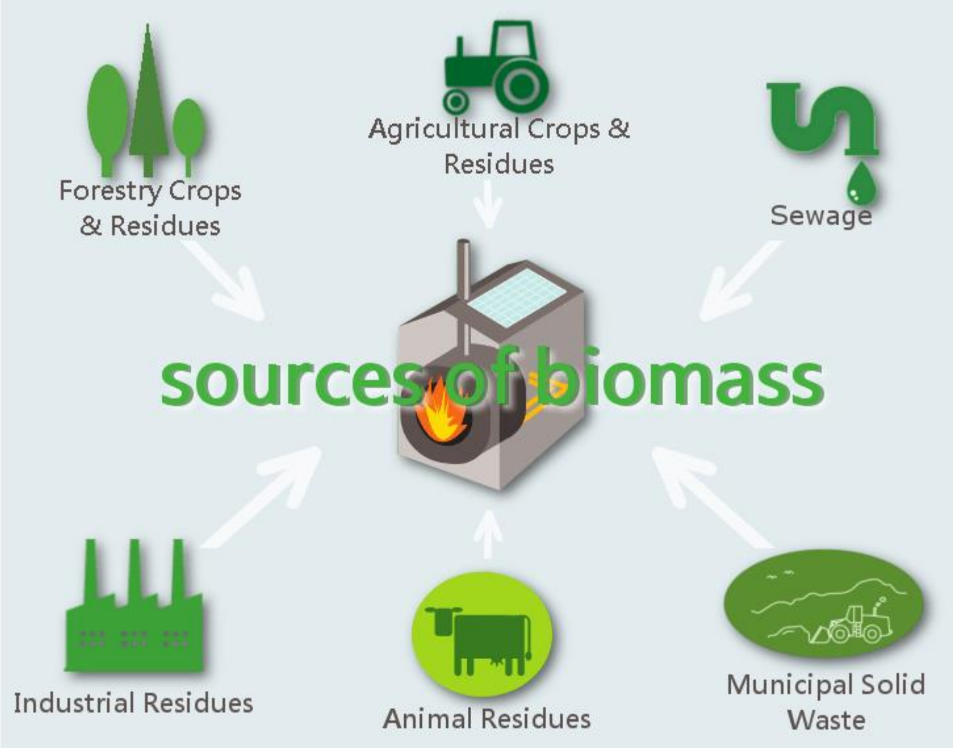
The high differences between countries are due not only to different availability, but also to different heating methods, support for the use of bioenergy, etc.

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).

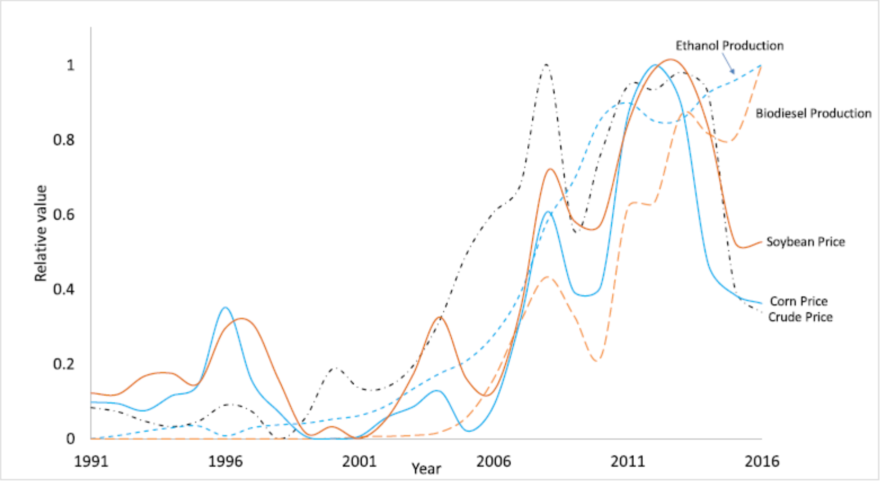
Biomass – 1st, 2nd and 3rd generation

- 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 CO2 as feedstock.

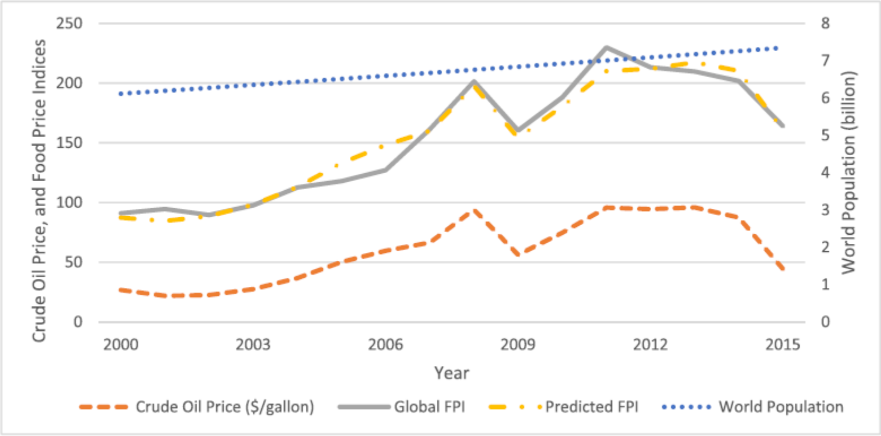
Biomass – 1st generation

- **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

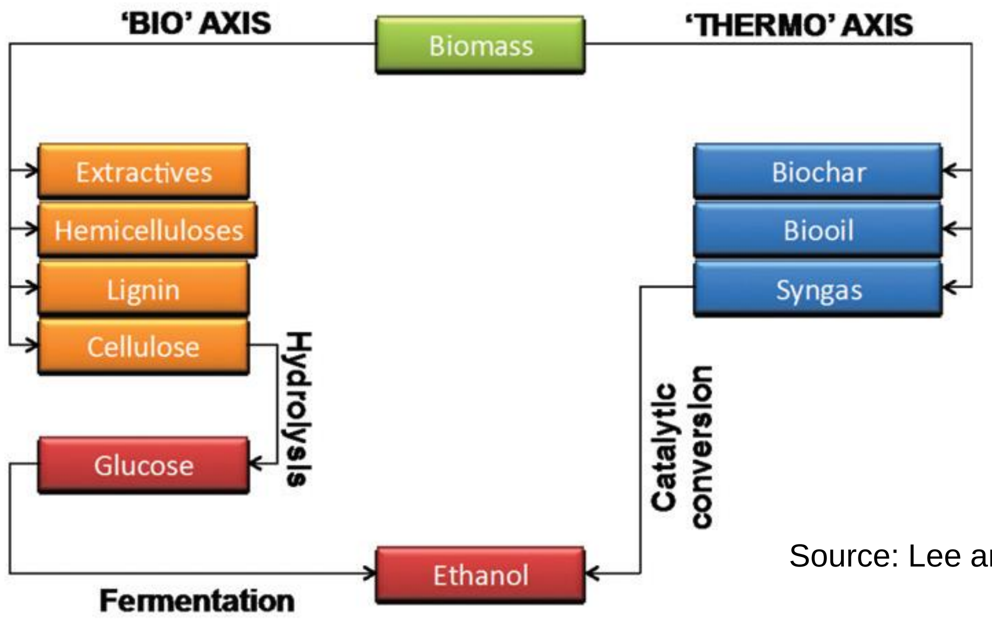


World food price index

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 („health“ products, Biological colouring agents)

High variability of biomass utilization

Various uses

- Power generation – burning of solid biomass
- Heat production – burning of solid biomass, local, small, medium and big sources
- Solid biomass can be easily transformed into solid biofuels – pellets and briquettes (can serve as coal substitute)
- Anaerobic fermentation – transformation into biogas, power generation and heat production (utilization of energy crop + waste from agriculture + food residuals)
- Biomethane production – upgrade of biogas into quality of natural gas

Advantages of biomass for energy

Major advantages:

- Non intermittent source
- Can be easily stored, transported
- Possible transformation of raw biomass to solid, liquid and gaseous biofuels
- Locally available
- Biomethane as the substitute of NG (see REPowerEU)
- Non production functions of perennials (SRC, Miscanthus, etc.)
- Stable power generation, possibility of dynamic services

Major disadvantages:

- Emissions from burning (NOx, dust particles, etc.) esp. In case of burning of unsuitable biomass in improper devices
- Low energy density (in CE conditions app. 150-250 GJ per hectare and year – try to compare with energy yield from PV on the same area)
- Competition for the land with food production
- In some cases conflict with the sustainability criteria (e.g. Oil palm plantation on burnt tropic forests, etc.)

Biomass – New Trends

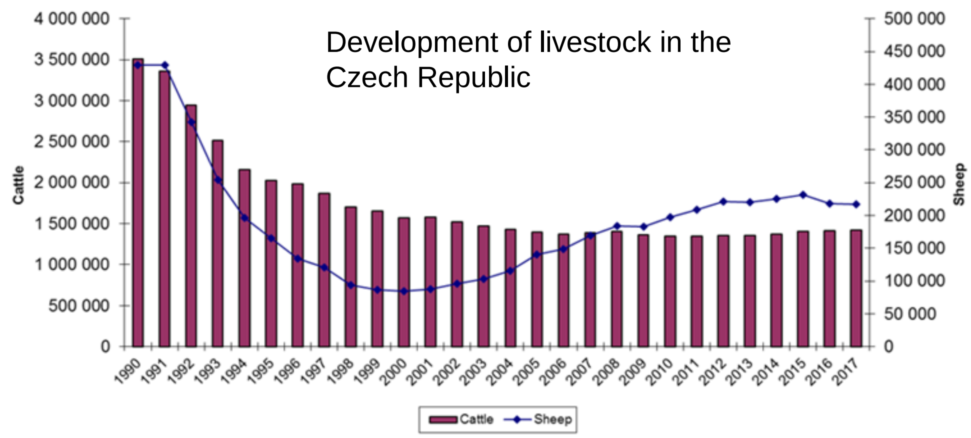
Biomass is often considered as an important substitute for fossil fuels, but:

- 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)

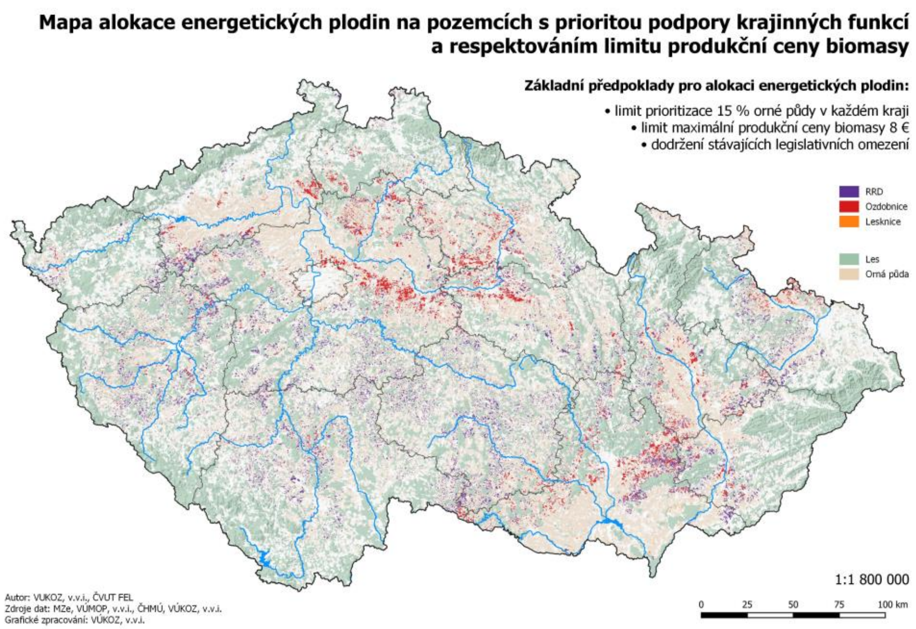
- In many countries (the Czech Republic is an example), the problem is the low content of the biological component in the soil (lack of natural manure due to the decline of livestock)

  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 – New Trends 3

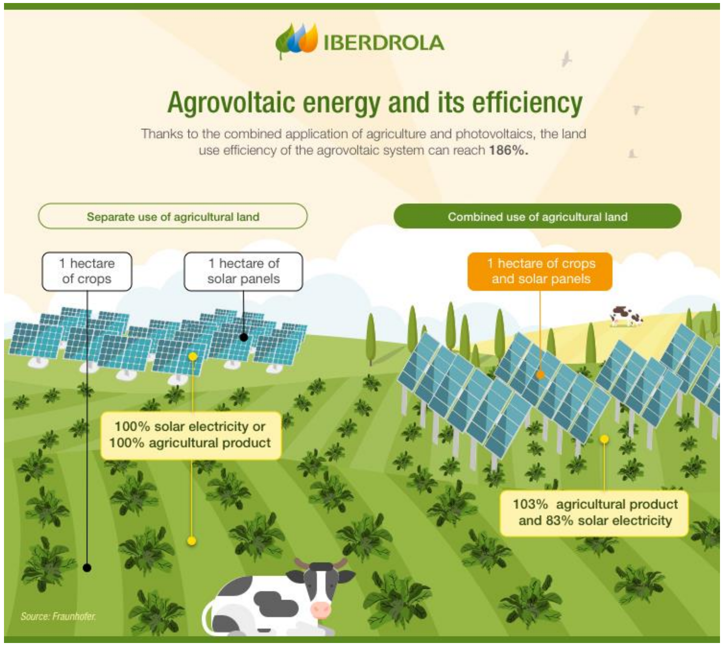
Biobelts with fruit trees on erosion-prone slopes (left; Šardice, Moravian Tuscany) and alternating belts of erosion-resistant and anti-erosion crops (right: maize - barley, Němčičky

Biomass – New Trends 4

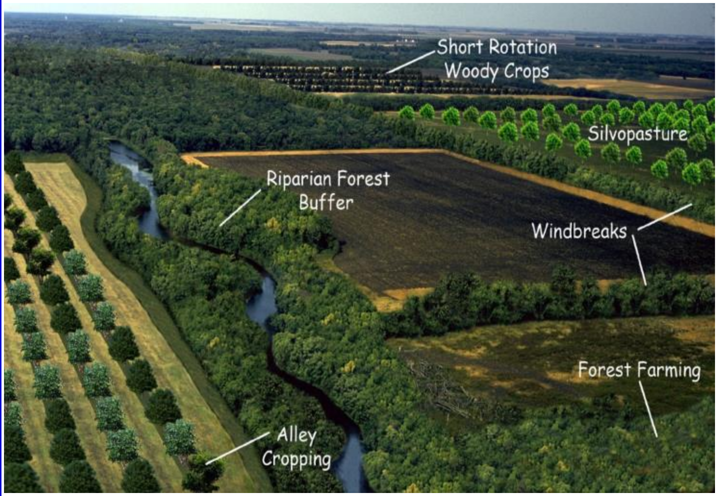
Plantations of energy crops perform important productive and non-productive functions in the landscape (on the left - harvesting of the RRD plantation for Plzeňská teplárenská a.s., on the right - plantation of ornamental plants in the summer season performing the function of permanent greenery even after harvesting monocultures of annual crops in Vysočina)

Biomass – Agrovoltaic, example of the new trend

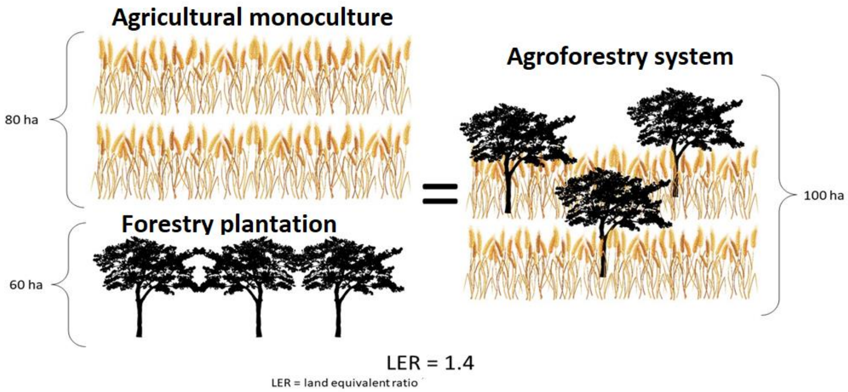
www.univergysolar.com



Biomass – Agroforestry, example of the new trend



Main types of agroforestry systems USDA, 2010

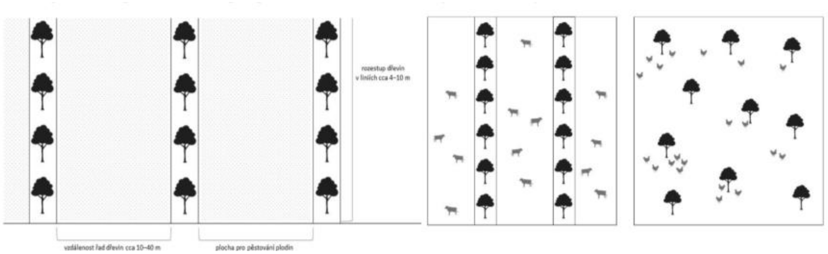


LER (*land equivivalent ratio.*) of value 1,4 means that 100 ha of AFS produces the same yields as 140 ha of trees and agricultural crops when grown separatelly. (Mead, Willey, 1990)

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**)

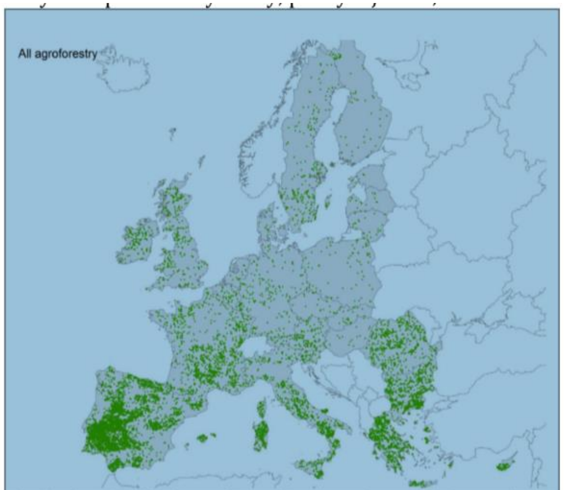
- very innovative and flexible (for task - conditions)
- allows stable production with strong eco-services
- mitigation and adaptation measures

Biomass – Agroforestry, example of the new trend



Obrázek 3.4 Ukázky silvopastevního agrolesnictví – stromy na pastvinách

Biomass – Agroforestry, example of the new trend

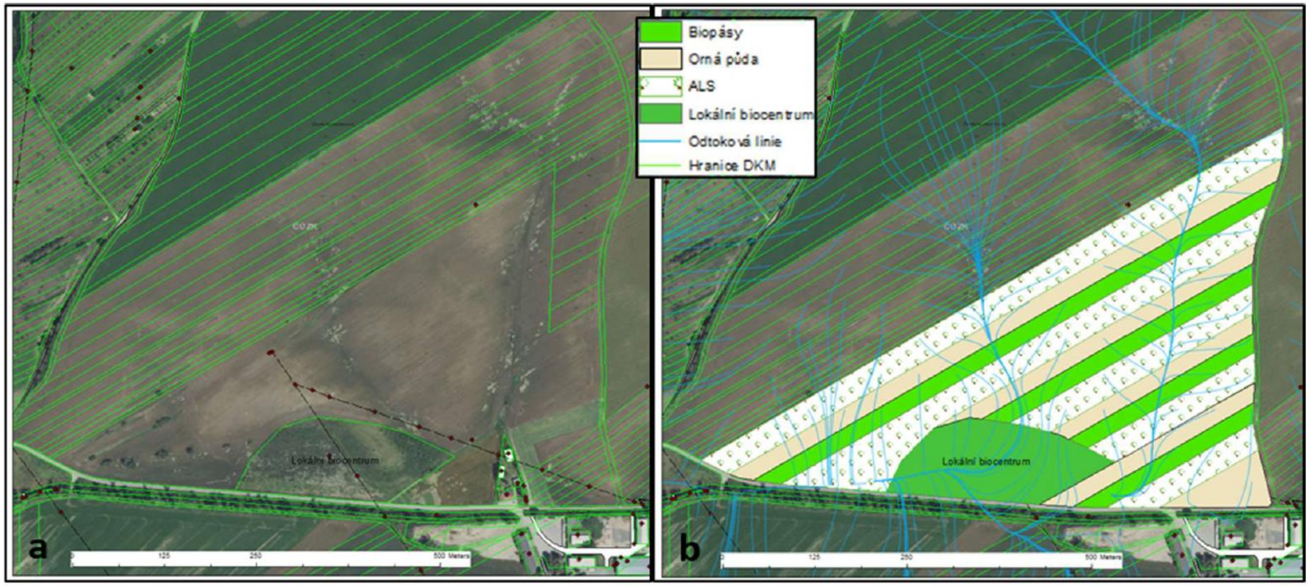


Obrázek 3.5 Odhadované rozšíření agrolesnických systémů v Evropě (den Herder a kol. 2017)

Obr. 3.8 Výsadba dřevitých (nezakořeněných) řízků RRD do výmladkových pásů se provádí ručně mechanizovaně sazečem do kvalitně připravené a odplevelené půdy.

Obr. 3.-11 Polní pokusy s pěstováním pšenice a brambor v ALS-1 Michovky a odběr vzorků pšenice pro analýzy z kontrolního pole

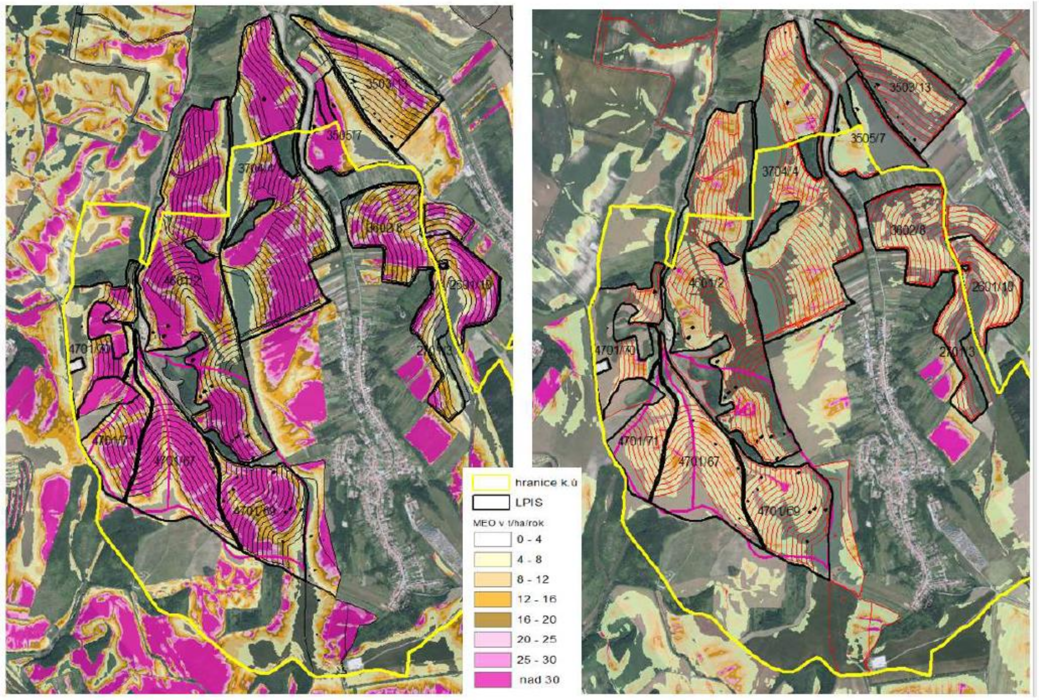
Biomass – Agroforestry, example of the new trend



Obr. 4.-2 Příklad uspořádání pásů ALS v kombinaci s dalšími kulturami a) současný stav – orná půda bez návrhu opatření, b) ALS v kombinaci s biopásy a ornou půdou (víceletá pícnina) se zobrazením odtokových linií

Example of an ALS strip arrangement in combination with other crops (a) Current situation - arable land without (b) ALS in combination with biobelts and arable land (perennial forage) showing runoff lines

Biomass – Agroforestry, example of the new trend



Obr. 4.-3 Příklad vyhodnocení protierozní účinnosti ALS-PSP na modelovém území v k. ú. Bošovice

Example of the evaluation of the anti-erosion effectiveness of ALS-PSP on a model area in the municipality of. Bošovice

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

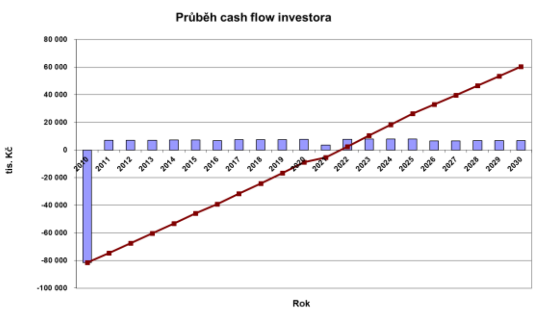
Minimum price to get required rate of return	Opportunity use of soil for conventional crops
C_{min}: $NPV_{enercrop}=0$	C_{alt}: $NPV_{enercrop}=NPV_{convcrop}$
rate of return is equal to discount rate used for NPV calculation	to get the same economic effect as from growing of conventional crop

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

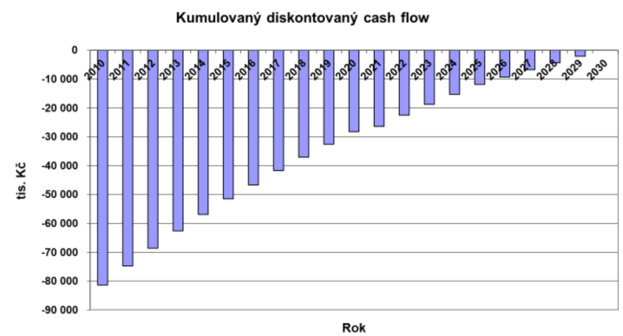
Biomass from energy crop – minimum price modelling 2

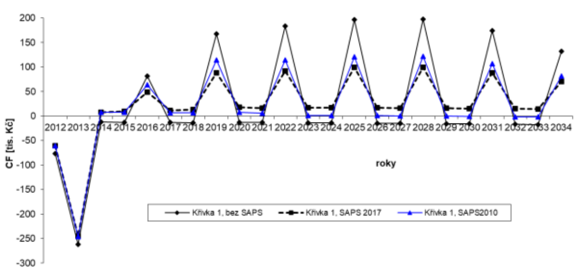
Minimum – price

- 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

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

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

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

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

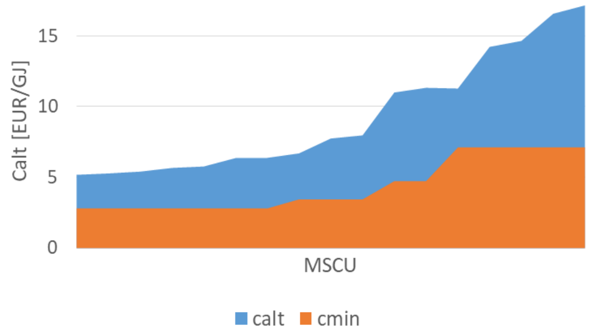
Price modelling results

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

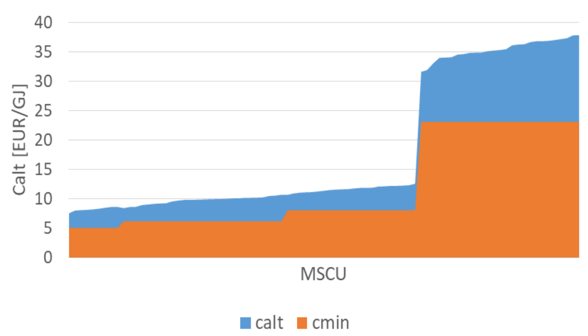
SRC, maize growing APA



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

Miscanthus, potato growing APA

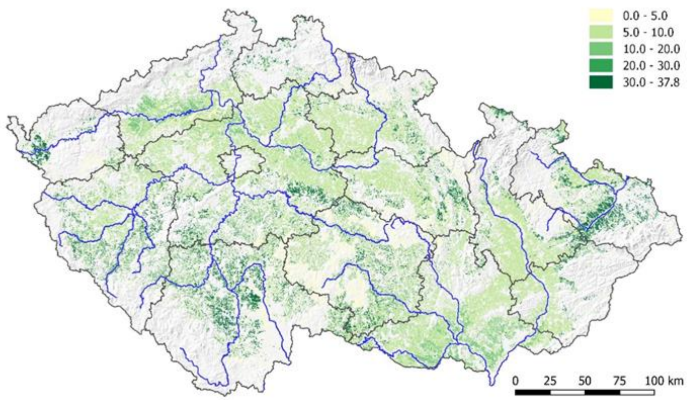


Note: prices of raw biomass without storage and transportation to final consumer

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%

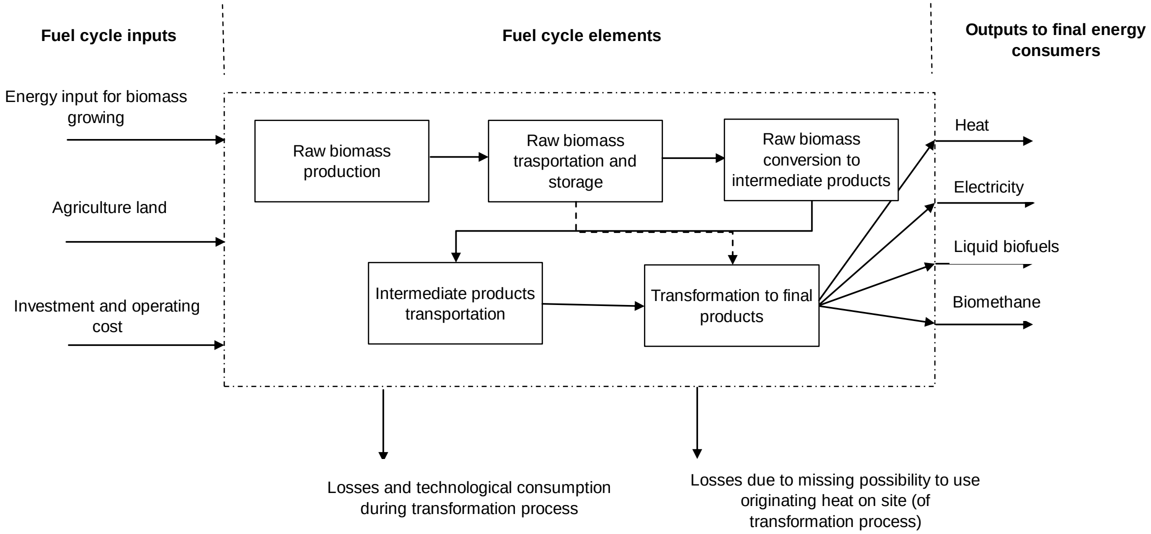
Based on competition with other fuels and technologies - maximum competitive c_{alt} price limit is 6-8 EUR/GJ

Competition with conventional crop significantly reduces economic potential of energy crop

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

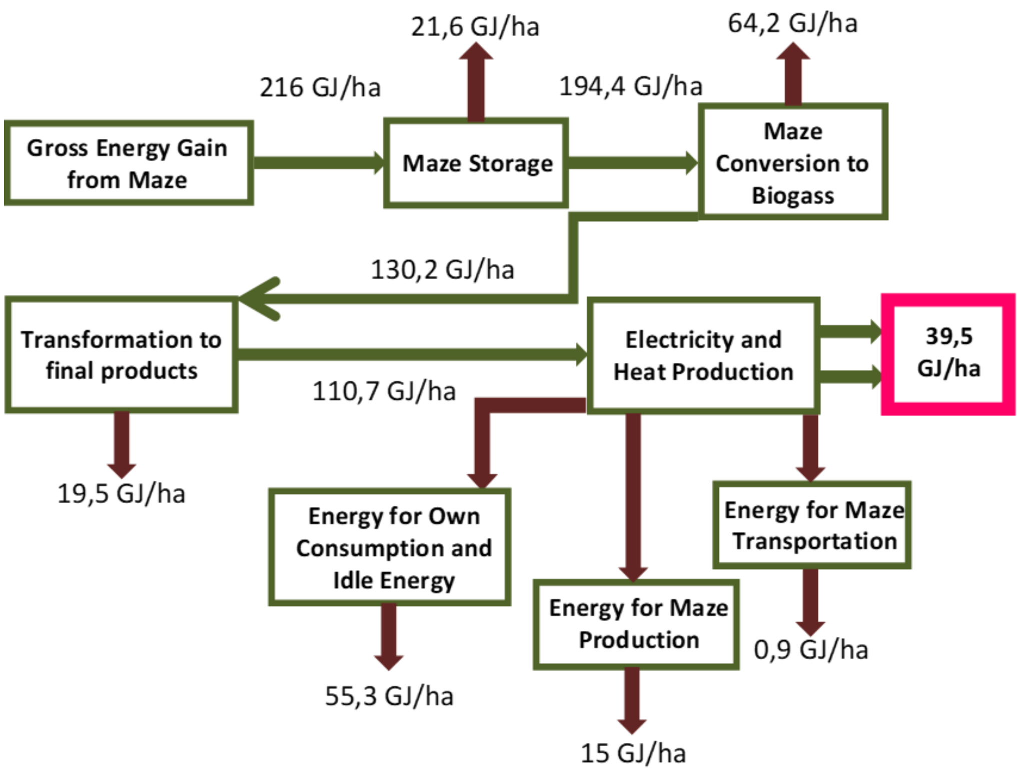
Note: growing areas: maize: 140 th. ha, potato: 880 th. ha, beat: 972 th. ha (areas where yield of energy crop are defined, some unsuitable areas are excluded from the analysis)

Biomass fuel cycle - effectiveness



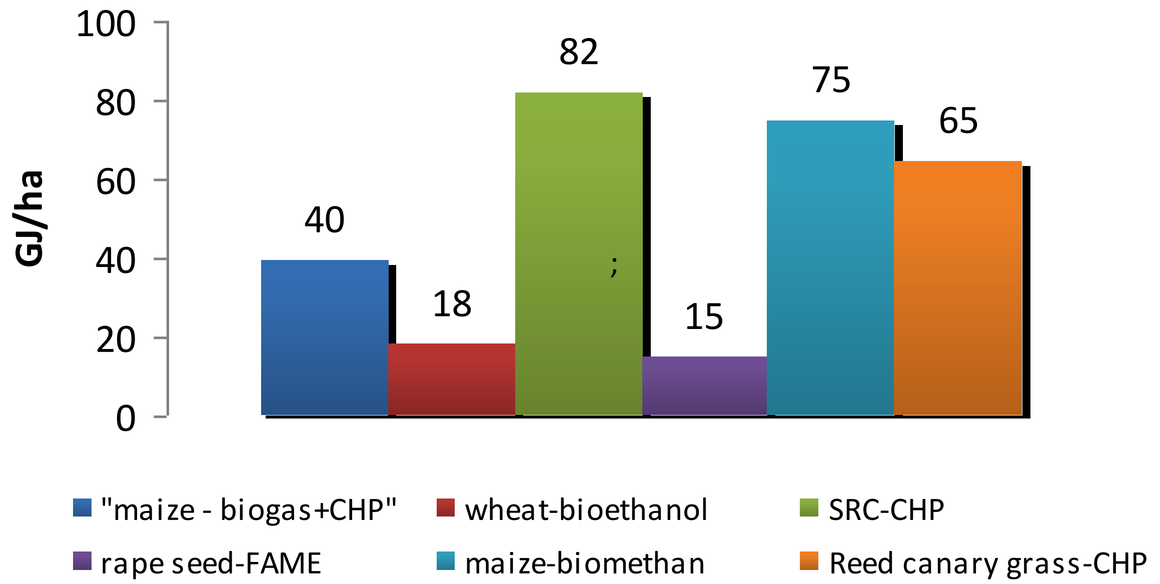
Biomass fuel cycle - effectiveness

Effectiveness of RES utilization – example of energy balance for biogas station



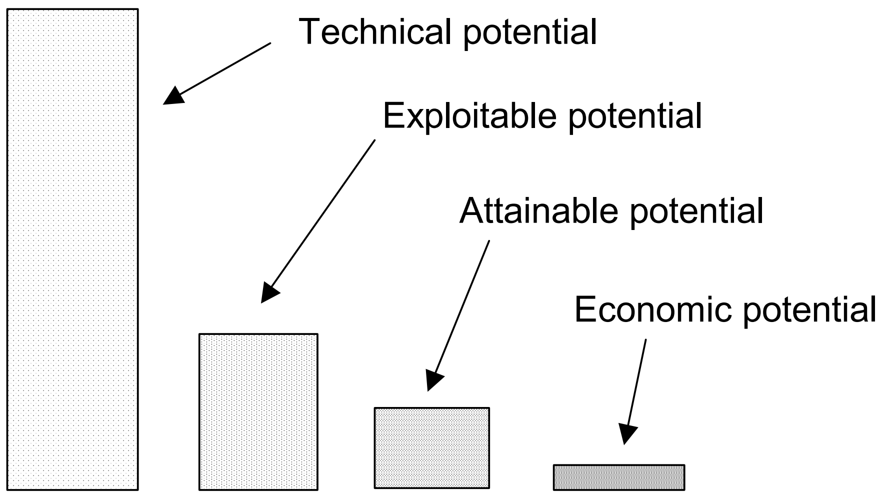
Biomass fuel cycle - effectiveness

Effectiveness of RES utilization – comparison of net yields for different biomass cycles



Biomass potential

Various definitions depending on the context – what constraints and assumption are included and what is the detail of the analysis



Biomass potential – dynamic quantity

Biomass potential:

- **Residual biomass from agriculture** – depends on agrotechnologies (e.g. reduction of fertilizers will results in higher residual biomass share given into soil
- **Residual biomass from forestry** – preference of material utilization plus higher requirement for leaving biomass on site)
- **Residual biomass from wood processing industry**
- **Residual biomass from food production and biodegradable part of municipal and industrial waste**
- **Intentionally grown energy crop**

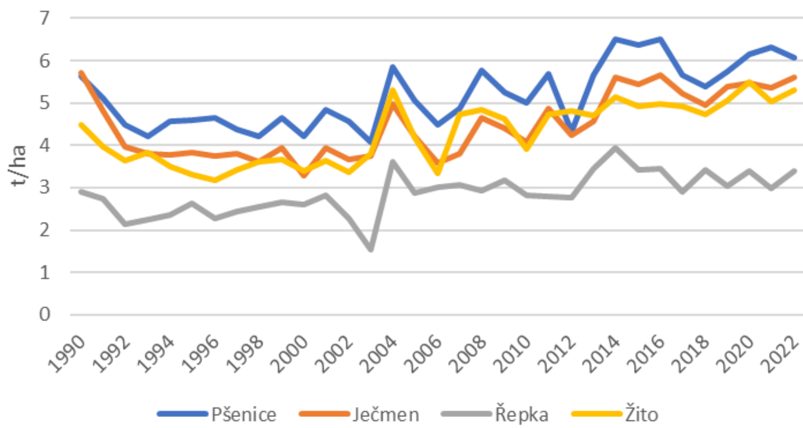
Biomass potential – dynamic quantity

E.g. biomass potential from agriculture land:

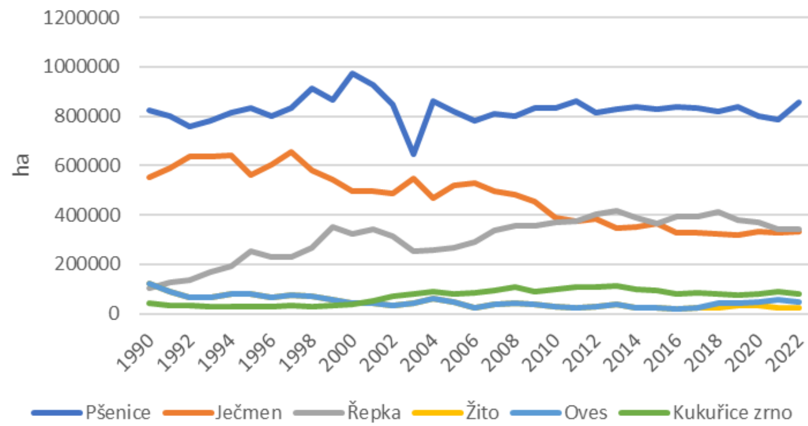
- Development of agricultural land areas
- Land area allocation strategy for EP (arable + TTP), division into perennial (for combustion) and other (for BPS and biomethane plants)
- Method of land allocation for EP (preference for food production, preference for non-productive functions of EP, ...)
- Evolution of the conventional crop structure (influences the amount of residual biomass)
- Development of the use of residual biomass of conventional crops in agriculture (changes in number of farm animals, etc.)
- Learning curve effect for conventional and energy crops
- Impact of climate change on yields of conventional and energy crops over time
- Changes in approaches to land management (soil conservation, biodiversity, reduction of chemical use and fertilizer use, etc.)

Biomass potential – dynamic quantity

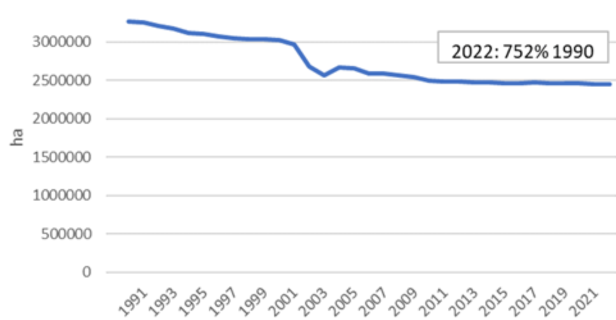
Crop yields, Czech Republic



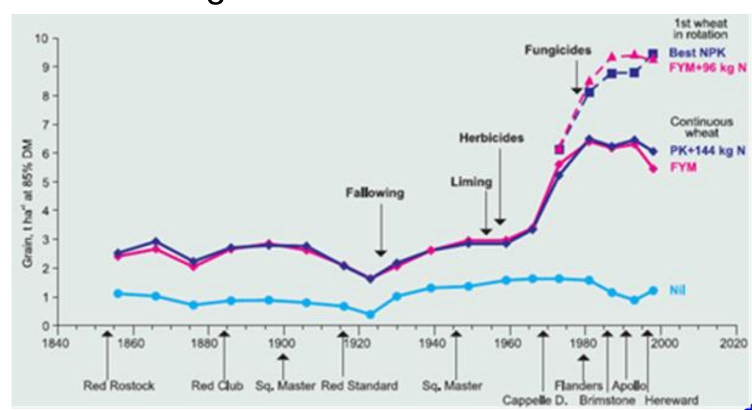
Crop sowing areas, Czech Republic



Total sowing areas, Czech Republic



Learning curve effect

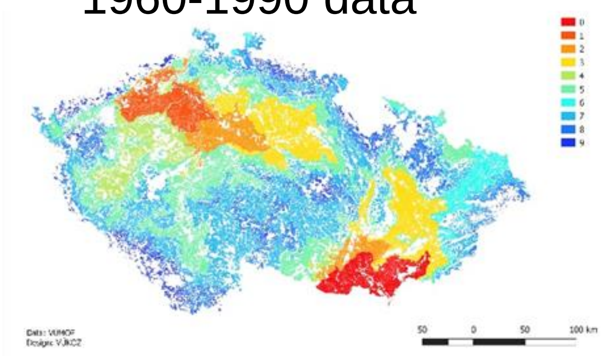


Pšenice=wheat, Ječmen=barely, Řepka=rapeseed, Žito=rye, Oves=oat, kukuřice zrno=maize corn

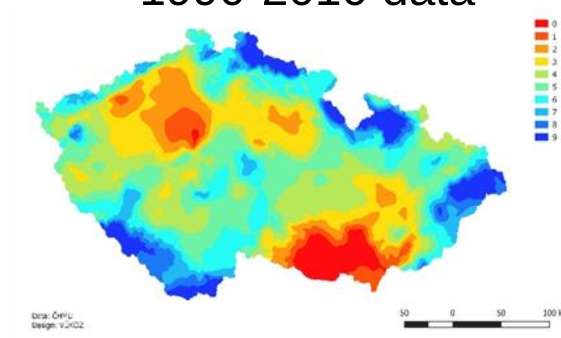
New climate regions definitions

- Until now, data from the period 1960-1990 have been used to define climate regions within the soil valuation system (BPEJ).
- Current data on parameters defining climate regions for the period 1990-2010 were used to model the impact of climate change. Climate change is already clearly visible in these data.

1960-1990 data



1990-2010 data



0 to 9 code of climate region, 0 is extremely dry, very warm, 9 is extremely damp and very cold

Change of climate region on 75% of agriculture land area, 36% move to (very) warm and (significantly) dry climate regions

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 !