Biomass in Europe

Context, trends, challenges, opportunities,

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Content

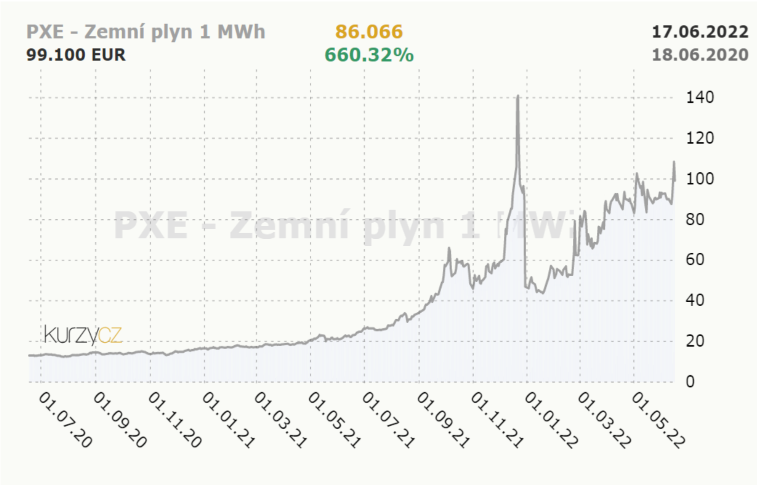
1. General context – what is currently happening on energy and other markets
2. Biomass uses, advantages and disadvantages
3. Biogas / biomethane / e-fuels
4. Case study on land needed for the biogas station and biomass production cost
5. Case study on biomethane production

2022 context

Risks and uncertainties

- Rapid increase of (all) energy prices continues,
- Price signals for 1-2 years forecast persistence of high electricity and gas prices
- The market can value risk, but not uncertainty!

Long term contracts– www.pxe.cz, elektricity one year baseload, Cal 23 (17/5/2022: 239 EUR/MWh)



2022 context

Uncertainty and nervousness in energy markets persists

- Combination of several factors:
  - Continuing war in Ukraine, difficult search for a replacement for oil and gas imports from Russia
  - Post-covid jump-starting of economies (but first signals of economic recession)
  - Green Deal (see Fit for 55), rapid decarbonisation,
  - Energy prices are reflected in all areas of the NH - e.g. in agriculture (crop production), the threat of a major impact on grain-importing developing countries in particular

ARAMIS

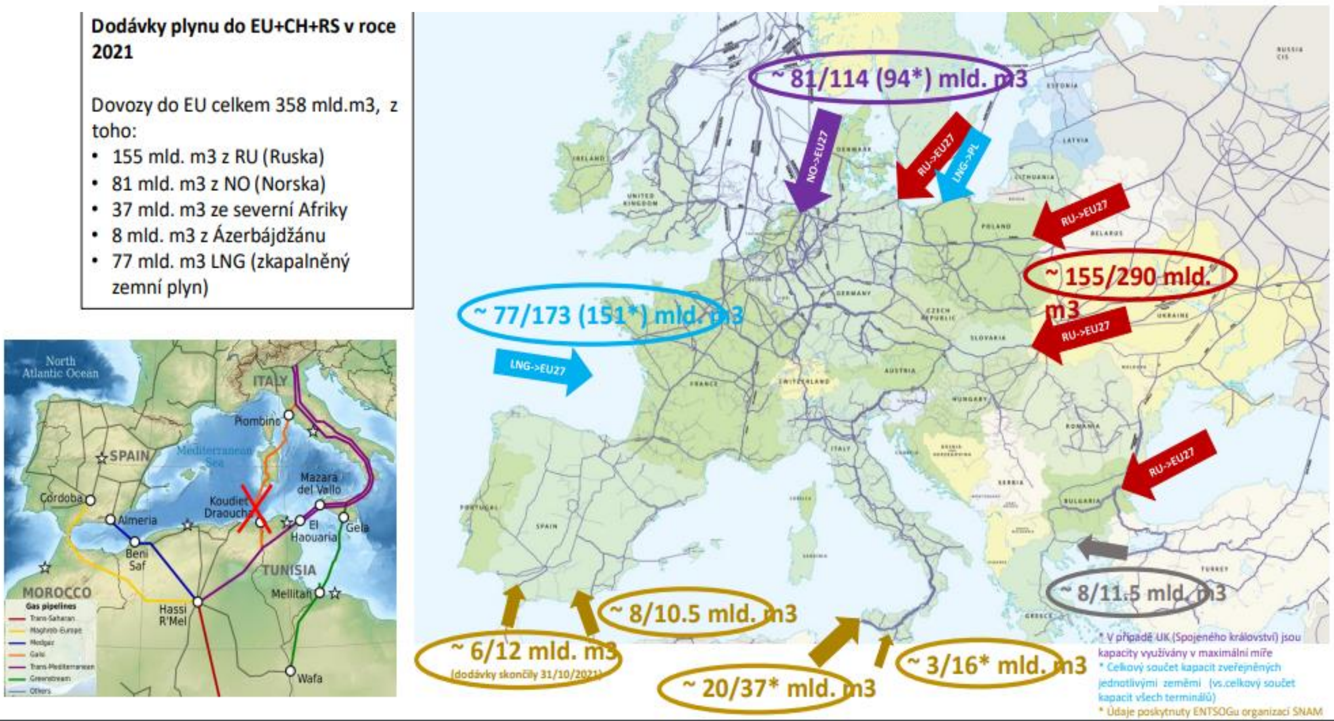
Substitution of natural gas from Russia

In 2021, Russia supplied 40% of gas consumption in the EU - 155 billion m3

- It is simply not possible to replace this amount per day, month or year
- Realistic horizon 3-5 years – LNG, but:
  - Missing infrastructure in EU – LNG terminals
  - Missing transportation capacities – LNG ships
  - Missing mining capacities
  - LNG producers require long term contracts (but last 20 years EU advocated for spot market)
  - EU searches for new deliverers, but one of the results is significant increase of LNG prices with negative impacts on developing countries (e.g. Pakistan)

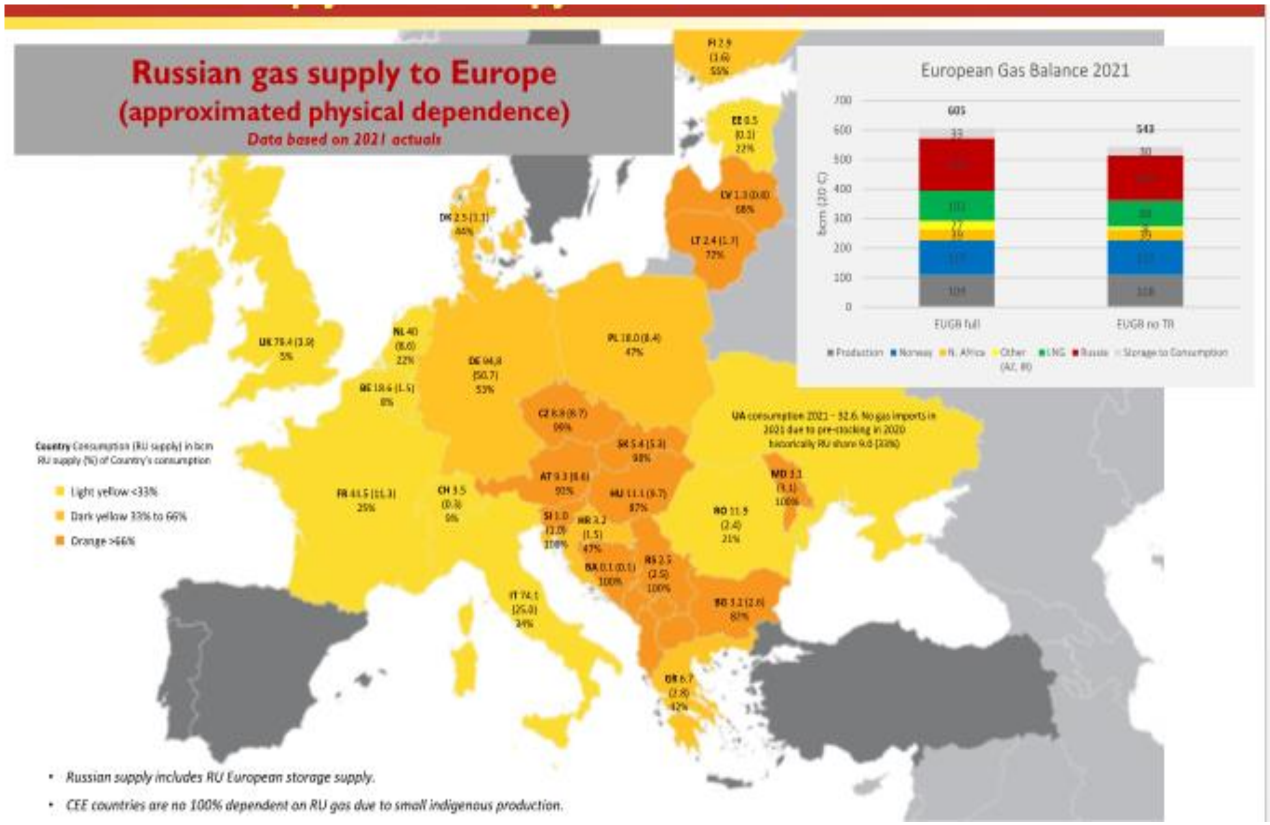
Substitution of natural gas from Russia

NG export to EU in 2021 (reality versus capacities)



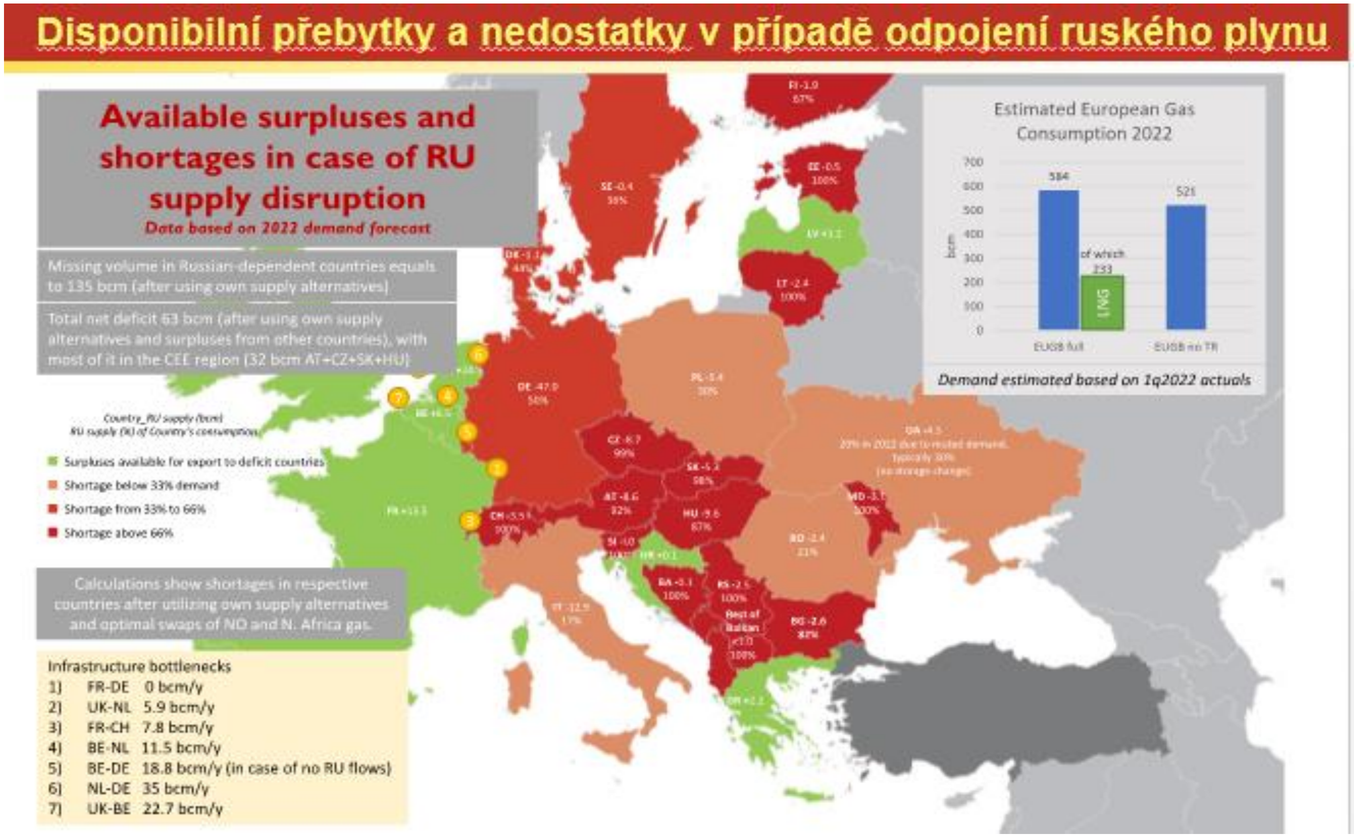
Source: Czech Gass Association, presentation for Czech House of commons, May 2022

Substitution of natural gas from Russia



Source: Czech Heat Association (TSCR), presentation for Czech House of commons, May 2022

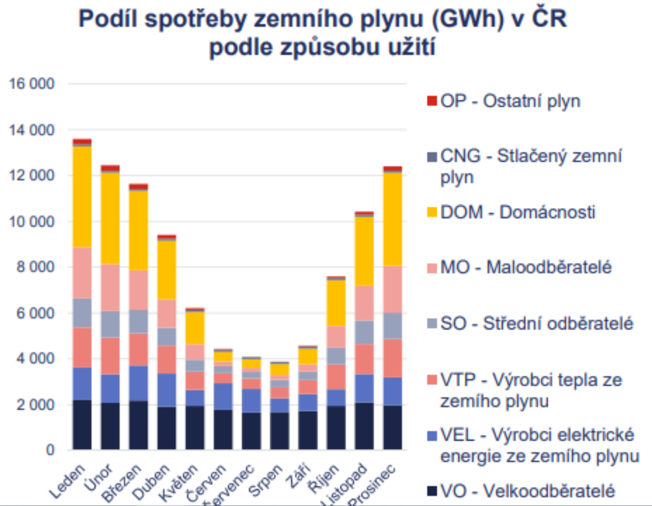
Substitution of natural gas from Russia



Source: Czech Heat Association (TSCR), presentation for Czech House of commons, May 2022

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 ?/!

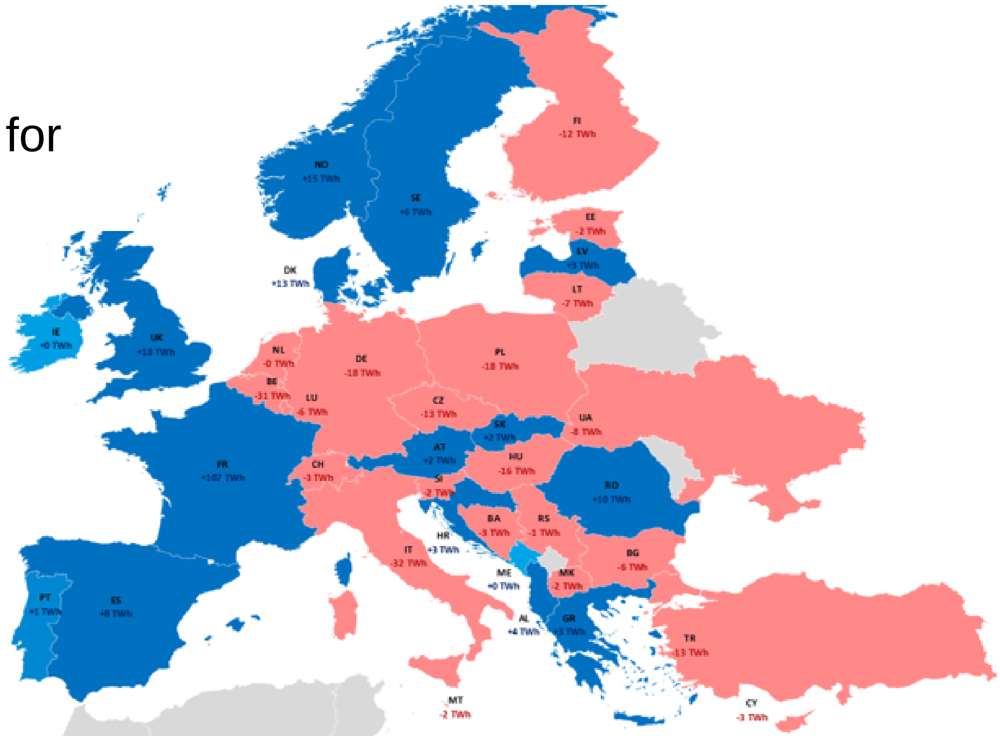
- NG substitute of coal power and heat production
  - E.g. Czech Republic and district heating branch (40% of heat to households, currently 2/3 from coal)

  - 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)

Changing balance in power generation

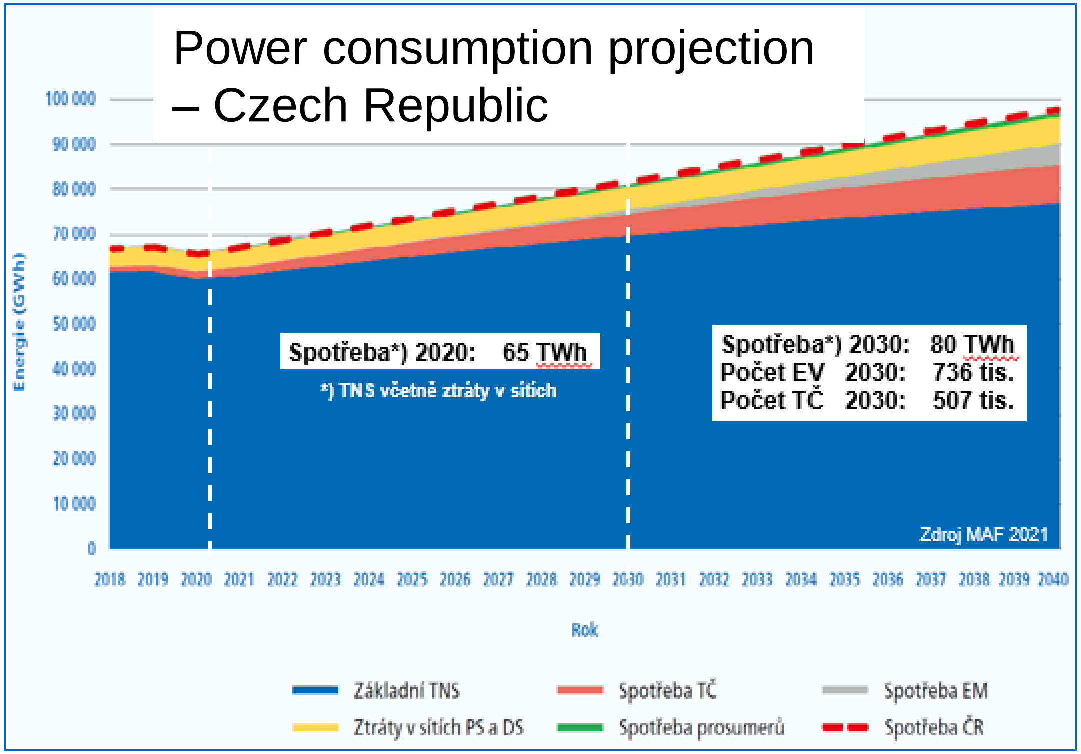
ENTSOE: power generation simulation for 2030



Only France has long term and stable positive power balance enabling export
Czech republic is switching from power export to power import

Source: CEPS, presentation for Czech House of commons, May 2022

Decarbonization leads to the increase of electricity consumption

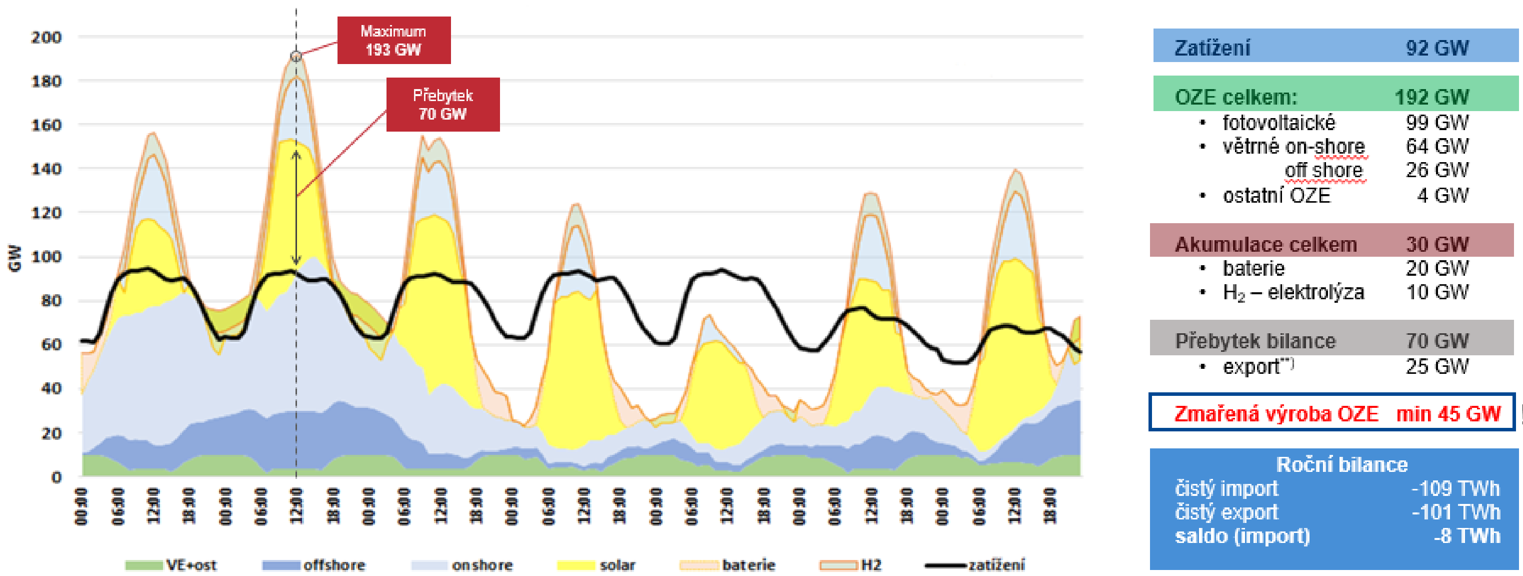


Basic domestic consumption (blue), heat pumps (red), electromobility (grey), losses in the grid (yellow)

Source: CEPS, presentation for Czech House of commons, May 2022

Dramatic changes in power generation pattern

Simulation of RES power generation in Germany in 2030 – max. June 12



Demand
RES total
PV
Wind on-hore
Wind off-shore
Accumul. Total
Batteries
Hydrogen
Surplus
Export
Not used power

Germany balance – volume and volatility will have significant impact on power market and grid functionning of other countries

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

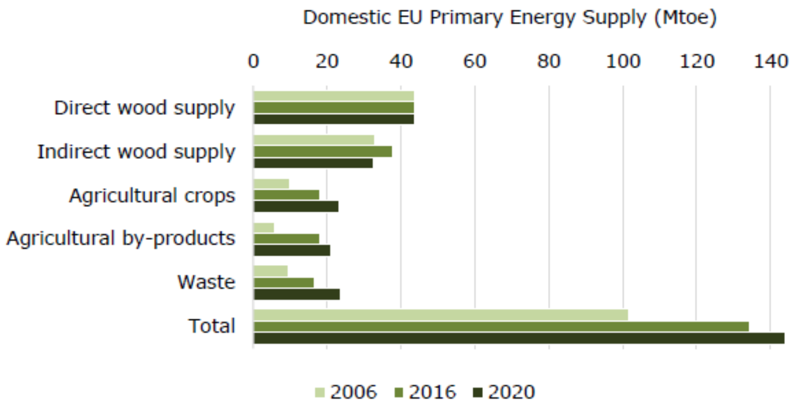
And crude oil ?

Termination of crude oil import from Russia is easier than is the case of NG

- Already agreed by EU (until the end of the year), few years exception for several countries (Slovakia, Hungry, Czech rep.)
- High investments into oil refineries technologies, limitations in pipelines capacities, Central highly sensitive

Source: Bartuška, presentation for Czech House of commons, May 2022

Coming back to biomass



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

Biomass was understood as important part of RES portfolio in decarbonization, but now is becoming more important as the „back up“ domestic source of energy

Biomass is inhomogeneous category – solid, liquid and gaseous forms, residuals from forest harvest, from agriculture (straw, grass, manure,…), wood processing industry, waste water cleaning, organic waste (part of municipal waste, unused food, etc.), and also intentionally planted – various kind of energy crop

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

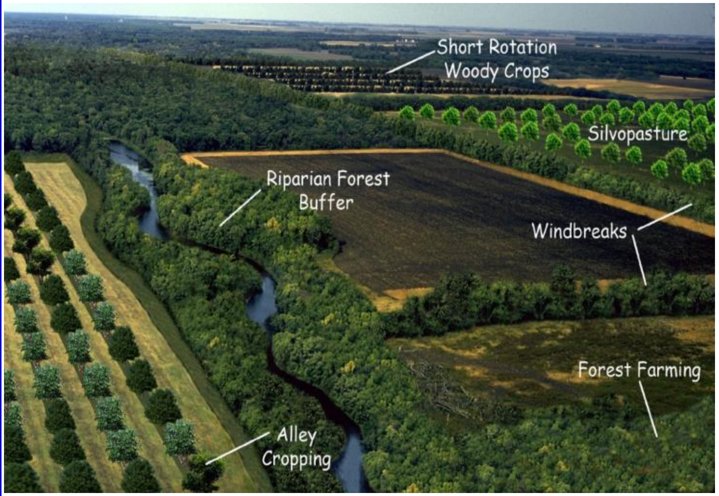
Major advantages:

- 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

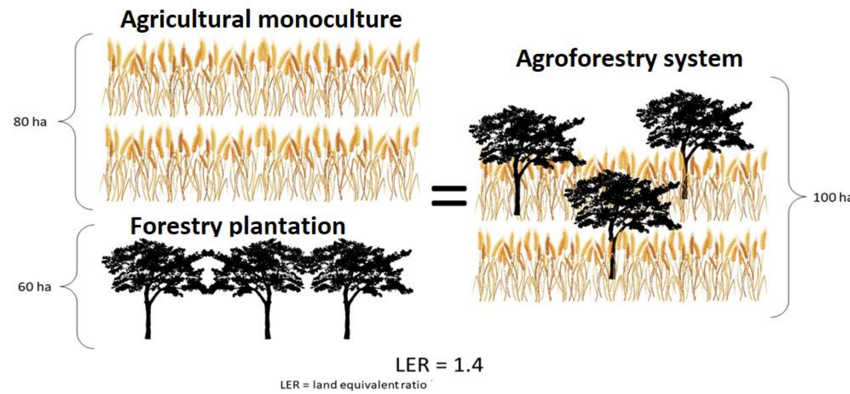
Major disadvantages:

- 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 – Agroforestry, example of the new trend



Main types of agroforestry systems USDA, 2010



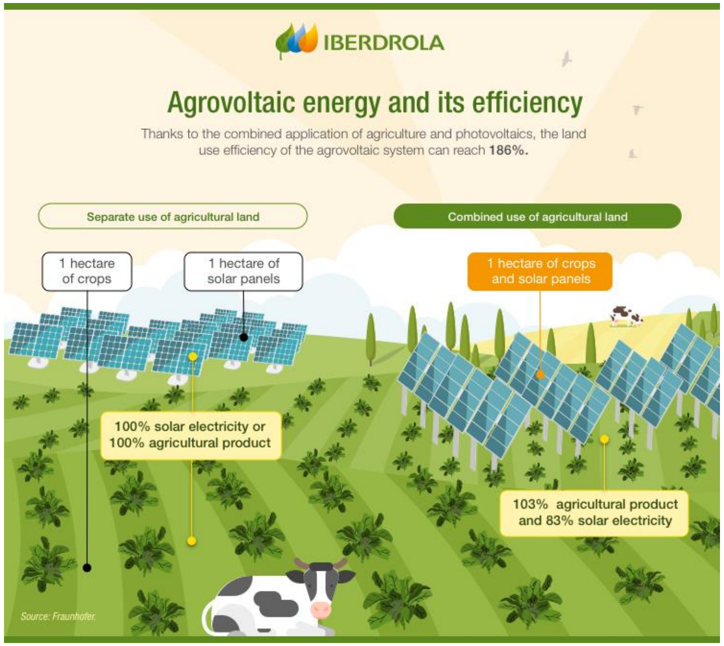
LER (*land equivivalent ratio.*) of value 1,4 means that 100 ha of AFS produces the same yields as 140 ha of trees and agricultural crops when grown separatelly. (Mead, Willey, 1990)

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

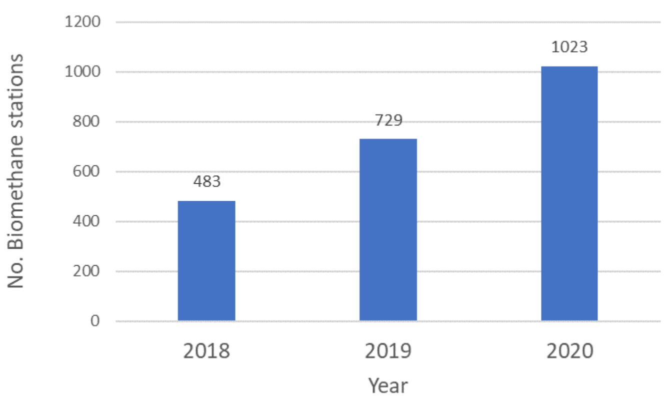


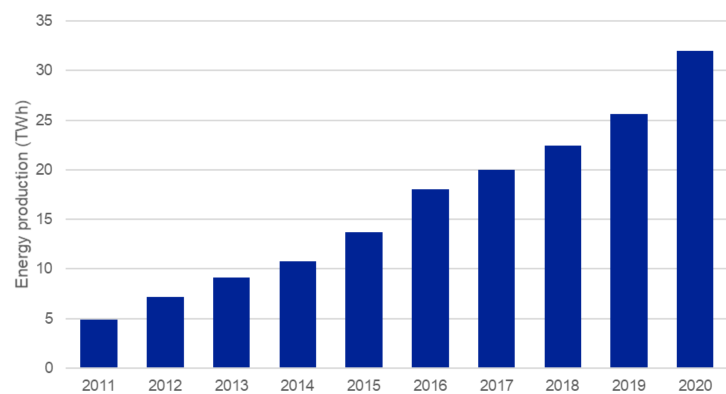
REPowerEU – biomethane targets

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

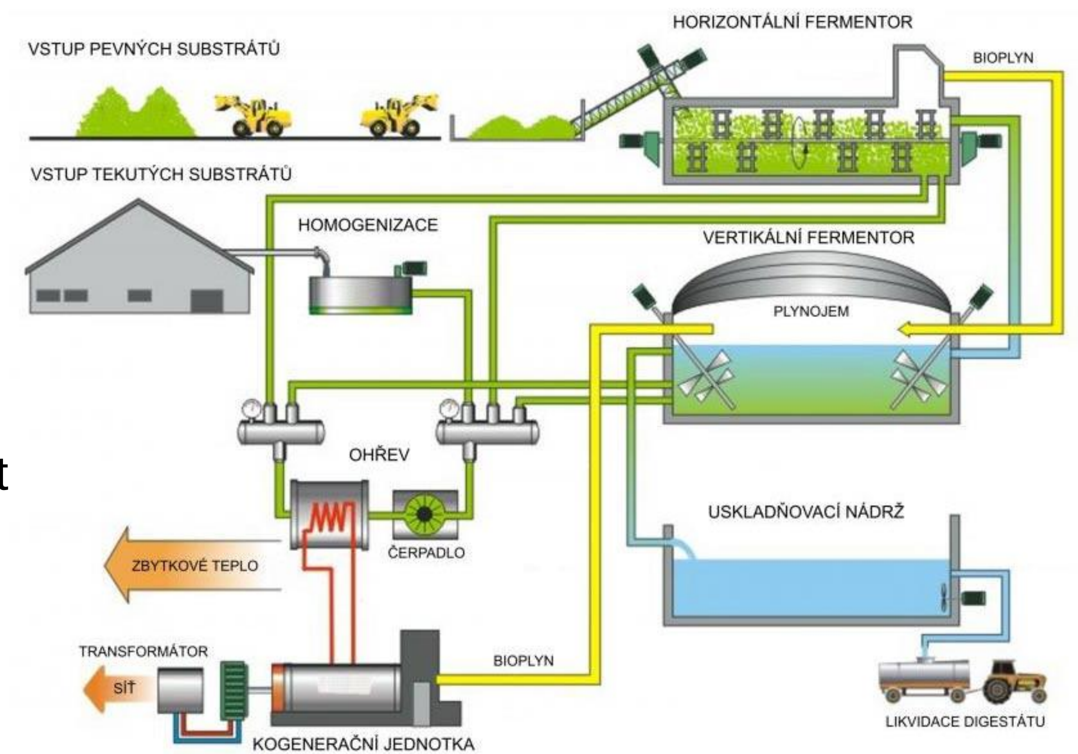




Source: EBA

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

Biomass to biogas



Fermentor

Biogas storage

Waste heat

Digestate

Cogeneration unit

Biogas / Biomethane / E-fuels

App. 52% of CH_4 (methane) in biogas (40-60%), also high share of CO_2 (30-50%)

- Biogas can be upgraded into quality of NG (e.g. membrane technology) – cogeneration unit is substituted with the separation unit
- Higher effectivity of biomass input utilization (energy content of biomass is transformed into biomethane), cogeneration unit in biogass plant generates electricity, but part of energy content in biomass is waste heat)
- Important source of concentrated CO_2 for e-fuels production
- Potential combination of biogas with green hydrogen - biogenic methanation (methanogenic bacteria)
- Biomethane can used locally or pumped into the grid

Biogas / biomethane plants – power flexibility

Biogas can stored (several hours) in standard storage facility

- Biogas plants can offer negative flexibility service (i.e. to immediately reduce their power output)
- No technical changes are required, just update of control system and the communication link to the aggregation platform
- Biomethane stations can be equipped with the cogeneration units and can flexible combine power generation and methane production (also using accumulation of gas)

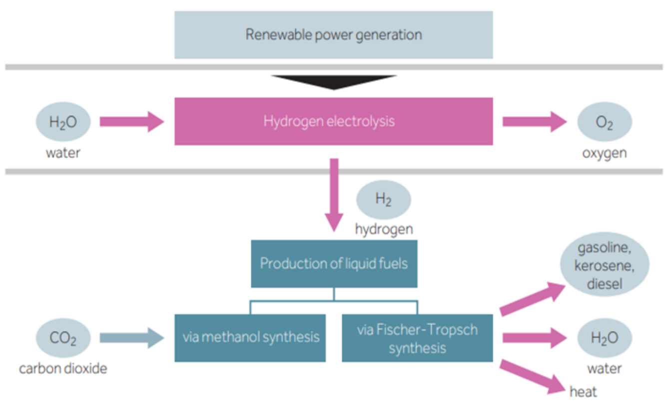
Biogas / Biomethane / E-fuels

E-fuels are synthetic fuels that are a combination of "green hydrogen" produced by the electrolysis of water with renewable electricity and CO2 captured either from a concentrated source (eg industrial flue gases) or from air (direct air capture, DAC).

E-fuels are also described in the literature as electric fuels, power-to-X (PtX), power-to-liquids (PtL), power-to-gas (PtG) and synthetic fuels

Figure 1: E-liquids production routes

Source: Frontier Economics (2018)



[2] Recent developments are evolving to a new technology (co-electrolysis) where CO_2 and steam are fed into a high-temperature (solid-oxide) electrolyser to produce syngas in a single step, increasing the efficiency of the process [Sunfire, 2019a].

Biogas / Biomethane / E-fuels

Table 1: Potential primary uses of e-fuels

	E-FUELS	PASSENGER CARS	HEAVY DUTY	MARITIME	AVIATION	OTHER SECTORS (NON TRANSPORT)
Gas	e-methane (CH_4)	X	XX	XX		XXX
	e-hydrogen (H_2)	XX	XX	X		X
Liquid	e-ammonia (NH_3)	X	X	XXX		
	e-methanol (CH_3OH)	XX	X	X		
	e-DME/e-OME	X	XX	XX		
	e-gasoline	X				
	e-diesel	X	XXX	XX		
	e-jet				XXX	

'X's are an initial estimate of the relative potential role of different e-fuels in transport segments (no 'X' = no envisaged potential).

Green = primary use; blue = secondary use; yellow = minority use. 'Other sectors' include industry, building and power.

Biogas / Biomethane / E-fuels

Figure 10: E-fuels can be stored economically, in large volumes and over long periods

Source: Frontier Economics (2018)

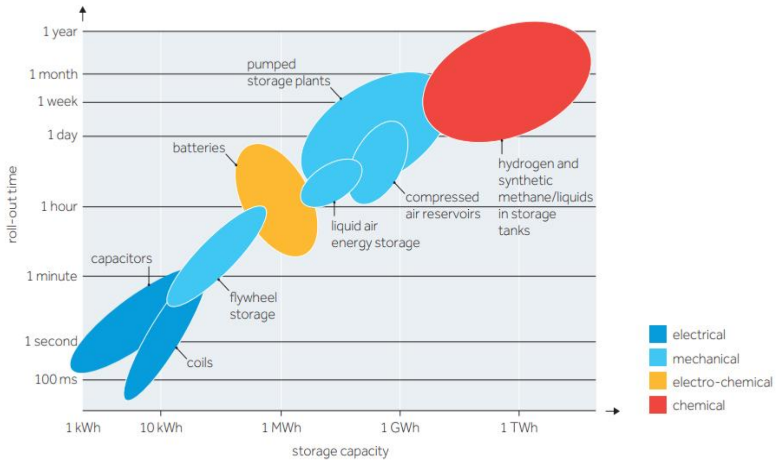
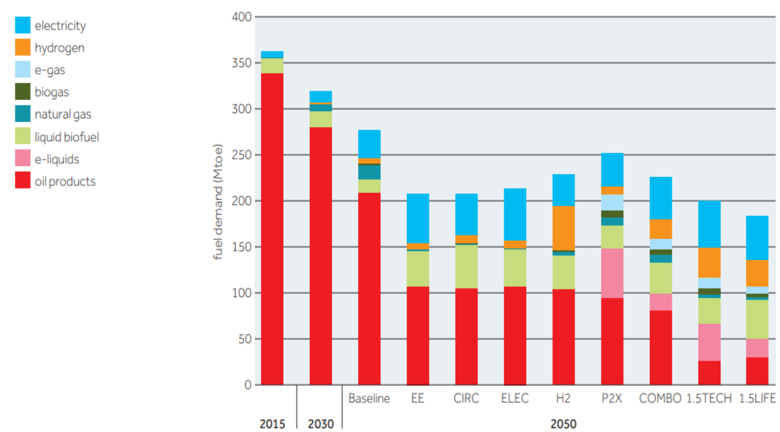


Figure 8: Transport sector fuel demand in 2050

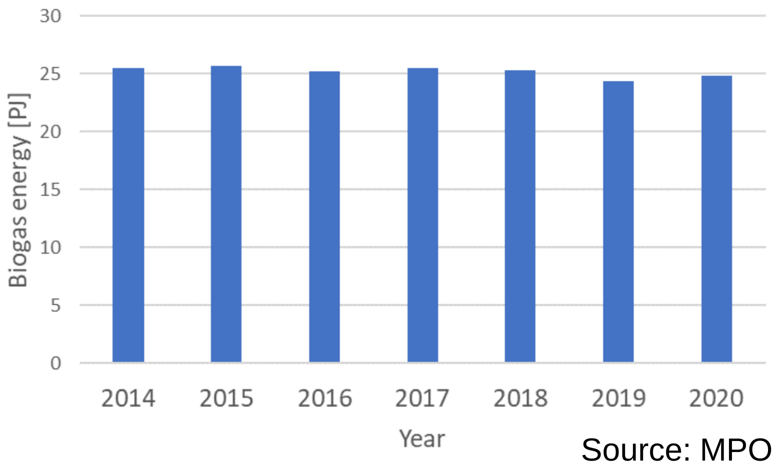
Source: European Commission (2018)



Biogas/biomethane reality in the Czech Republic

Development of biogas stations has been stagnating since 2014 and remains at the same level:

- 2020: 575 biogas stations of all types, only 1 biomethane station
- Feedstock from the agriculture – dominant role (400 plants in total)
- Primary usage for power generation (366 MW_e, of which 319 MW_e from agriculture biogas plants)
- 11.57% on energy from RES, 25% on gross power generation from RES



Source: MPO

Energy in biogas, all types of biogas plants, Czech Republic

2030 outlook: 0.6-1.2 bil. m3 of biomethan8-12% of current consumption

Biogas/biomethane feedstock

Biomass feedstock:

- Purposefully grown biomass on agricultural land,
- Residual and waste biomass from agriculture and food industry,
- Bio- and municipal waste and sewage sludge,
- Input substrates: significant part of the total cost of biogas or biomethane production (e.g. CR 40-45% of power production cost in biogas stations).

Trend in recent years:

- Preference for processing waste and residual biomass in order to avoid competition with food production on agricultural land
- But, number of currently operated BGP and BMP use purpose-grown biomass such as corn silage as an important input
  - IEA statistics: 70% of biomethane is currently produced from energy crops in Europe

Biogas/biomethane feedstock – CZ example

Input to biogas stations (2020)

- App. 10 mil. t in total (all types of input biomass)
- Residual and waste biomass from agriculture and food industry,
- Bio- and municipal waste and sewage sludge,
- Input substrates: significant part of the total cost of biogas or biomethane production (e.g. CR 40-45% of power production cost in biogas stations).

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Biogas/biomethane feedstock – CZ example, 2020

Biomass types	Consumption (t)	Consumption (%)
Maize	2 852 607	31 %
Haylage (grasses)	1 142 449	13 %
GPS sillage	332 717	4 %
Sugar beet residuals	180 386	2 %
Manure	4 195 706	46 %
Other (biowaste, corn, potatoes)	424 569	5 %
Total	9 128 434	100%

Key aspects of biomethane development

Availability of biomass feedstock

- Residual and waste biomass
- Land allocation for energy crop (as the feedstock)
    - Competition for the land – food production versus energy crop
    - Environmental constraints

Economic constraints for energy crop on agriculture land

- Biomass produced on agricultural land has a strongly local character, its price is not directly determined by the market, but on the basis of the opportunity cost principle - competition with land use for conventional crops
- The production cost of biomass for biomethane plants can create a significant barrier to development

Biomethane feedstock – biomass production price methodology

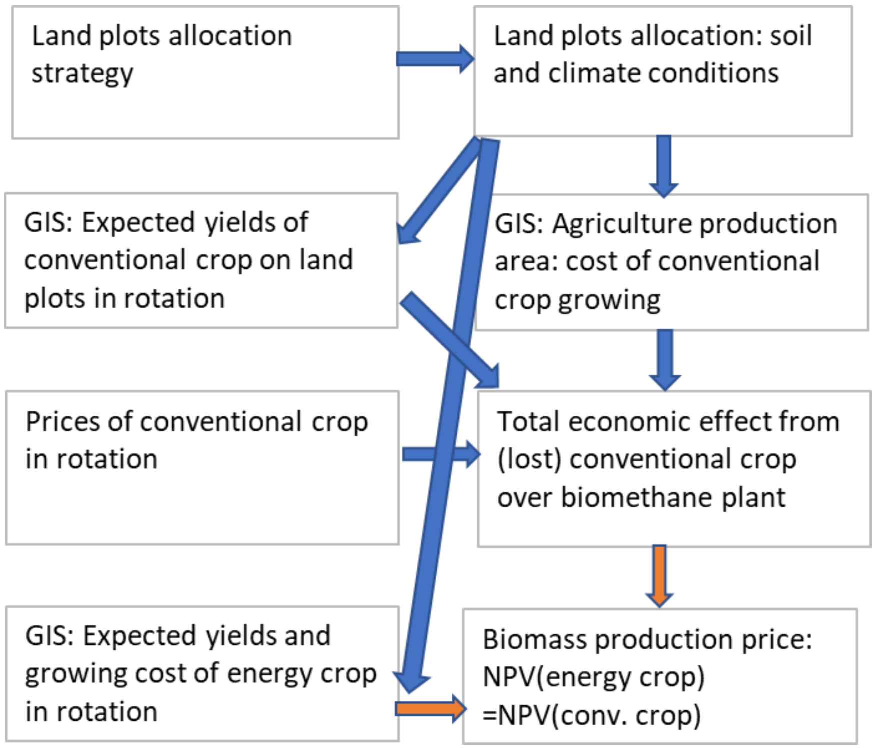
Opportunity cost principle

- Biomethane plant „blocks“ for its lifetime the use of part of the land around it for conventional production (which has a market valuation)
- Biomass from energy crops must provide at least the same economic effect over the biomethane plant lifetime as the conventional crop
- CF modelling, NVP calculation
- Necessity to respect conventional crop rotation cycle (according to the agriculture production areas)

Example of 6 year rotation cycle

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	...	Year 19	year 20
land plots 1	maize	crop 2	crop 3	crop 4	crop 5	crop 6	maize	crop 2	crop 3	...	maize	crop 2
land plots 2	crop 1	maize	crop 3	crop 4	crop 5	crop 6	crop 1	maize	crop 3		crop 1	maize
land plots 3	crop 1	crop 2	maize	crop 4	crop 5	crop 6	crop 1	crop 2	maize	...	crop 1	crop 2
land plots 4	crop 1	crop 2	crop 3	maize	crop 5	crop 6	crop 1	crop 2	crop 3	...	crop 1	crop 2
land plots 5	crop 1	crop 2	crop 3	crop 4	maize	crop 6	crop 1	crop 2	crop 3	...	crop 1	crop 2
land plots 6	crop 1	crop 2	crop 3	crop 4	crop 5	maize	crop 1	crop 2	crop 3	...	crop 1	crop 2

Biomethane feedstock – biomass production price methodology 2



$$c_{alt,1}: NPV_{BMS} = NPV_{CONV}$$
$$c_{alt,t} = c_{alt,1} \times (1+i)^{(t-1)}$$

over biomethane station lifetime, t=1,.., lifetime

Biomass production price modelling – key assumptions

Strategy of land alocation for energy crop:

1. Priority of land use for food production (energy crop: the least fertile land)
2. Priority of biomass production as input to the biomethane plant
3. Priority to minimize the cost of biomass production as input to the biomethane plant

Land plots distance from biomethane plant:

- Reduction of transportation cost, logistic constraints
- 10 km as the basic limitation of transportation distance

Feedstock requirement:

- Installed capacity of biomethane plant

Respect for real business conditions:

- Market prices for agro-operation cost, cost and prices escallation, taxes, nominal discount rate

Application of the methodology - case study for the Czech Republic

Biomethane/biogas plant in typical CE soil and climate conditions

- Luková u Lanškrouna (GPS coordinates: 49.875485N, 16.606669E)
- Biomass feedstock: equivalent for a BGP with an installed capacity of 770 kWe (12.5 th. of corn sillage, 13.2 th. of pig slurry)
- Biomass losses during harvest and storage: 10% (i.e. 13.9 th. t(FM)/year)
- Cost of conventional crop growing: average based on sample survey of 240-280 farms (year 2020)

Cost range (EUR/ha, year)				
Wheat (autumn)	Maize (silage)	Barley (autumn)	Alfalfa	Rape seed
1,029-1,156	1,266-1,353	935–1,066	606-673	1,351–1,494

- Market prices of conventional crop (average 2016-2020)

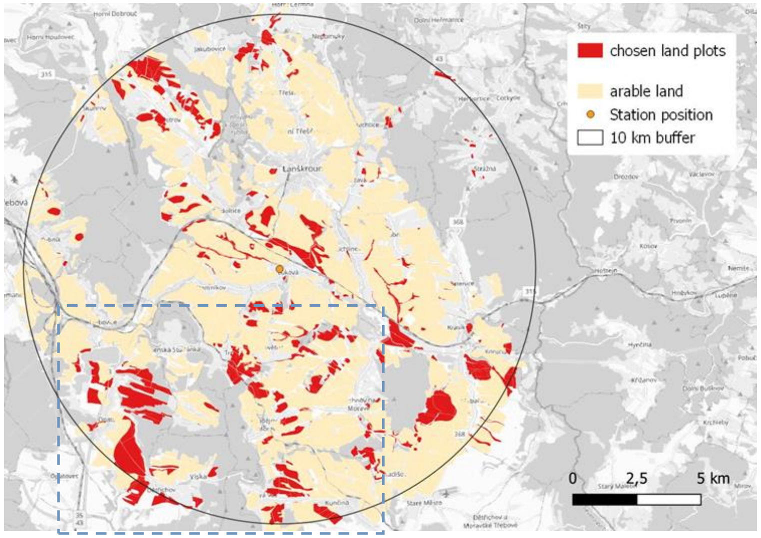
Average prices of commodities (EUR/t)				
Wheat	Rye	Barley (autumn)	Alfalfa	Rape seed
161	161	178	37	394

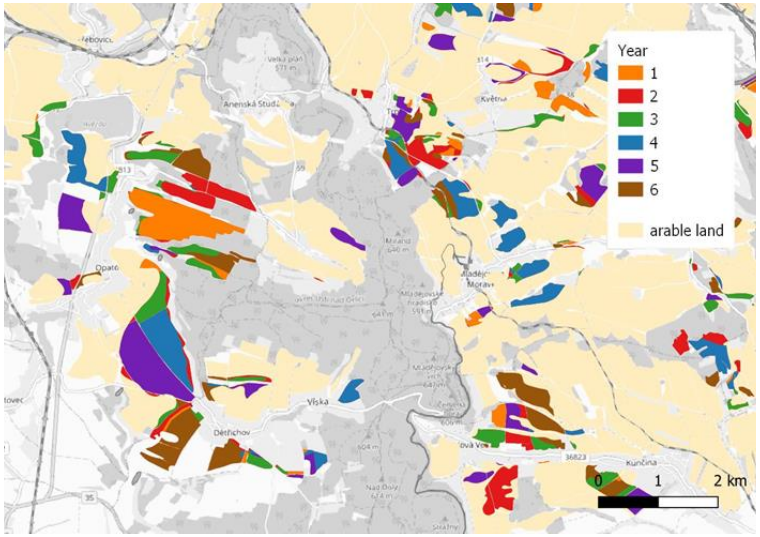
- Average cost/prices escalation: 2.5%, discount rate:10%

Results of the case study

Land allocation strategies:

1. Priority of food production (conventional crop)
2. Priority of biomass production





Land allocation for maize production within 10 km from the biogas plant Luková, approach 1

Results of case study - 2

Different land allocation strategies lead to differences in the amount of land needed for biomass (maize) cultivation

	Min in year	Max in year	Total in 6 years	Reduction
	[ha]	[ha]	[ha]	%
Strategy 1	372	388	2283	-
Strategy 2	321	323	1932	-15%

Different land allocation strategies lead to the different average biomass prices and to different variability of prices

	Land allocation	Land allocation
	Strategy 1	Strategy 2
calt,1 [EUR/t(FM)]	29,4	25,6
calt,1 reduction	-	-12,9%
calt1,min [EUR/t(FM)]	23,5	23,9
calt1,max [EUR/t(FM)]	35,3	31,4

Note: calt,1 is biomass production price in the 1st year of biomethane / biogas station lifetime, then it must be escalated by 2.5% per year

Discussion and policy implication

- E.g. Czech Republic: average composition of the input substrate is 40-60% corn silage, 0-20% grass sillage, 30% livestock manure, and 10% various types of available residual and waste biomass

- Discussed transformation of biogas stations into biomethane stations will require the creation of conditions to achieve competitiveness with imported natural gas

Factors influencing production cost of biomethane and its competitiveness:

- Investment cost into biomethane station
- Annual installed capacity utilisation
- Cost of biomass feedstock
- (Agriculture) subsidies (both conventional and energy crop)
- Prices of emission allowances
- Market prices of natural gas (or other substitutes)

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Discussion and policy implication - 2

Factors influencing biomass production cost:

- Yields of conventional and energy crops
- Land allocation strategy
- Prices on commodity markets (wheat, barely, …)
  - Growth of these prices leads to growth of biomass production price
- (Agriculture) subsidies and their link to land management practices
- Changes in agrotechnical practices, e.g. to reduce the ecological burden of intensive farming
- Risks associated with growing energy crops and ensuring their (local) use

Biomethane plant case study

Demonstration of biomethane production cost

- Biomethane plant: 1.109 mil. $m^3(CH_4)$/year
- Investment cost: 3.24 mil. EUR
- Feedstock cost: 29.4 EUR/t(FM)
- Expected IRR: 6.3%
- Biomethane production price: 0.88 EUR/m^3 (app. 95 EUR/MWh – commodity)
  - Share of feedstock cost: app. 48%

Current prices of natural gas exceed this level (e.g. May 6, 2022: Power Exchange Central Europe 100 EUR/MWh)

- But this very high price is caused by exceptional circumstances and it is questionable what the gas price will be in the longer term - e.g. at the beginning of November 2021 the price was 48.5 EUR/MWh.

Thank you for your attention !