CZ-AT Winter School
Prague, February 2020

Biomass in Europe

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Content

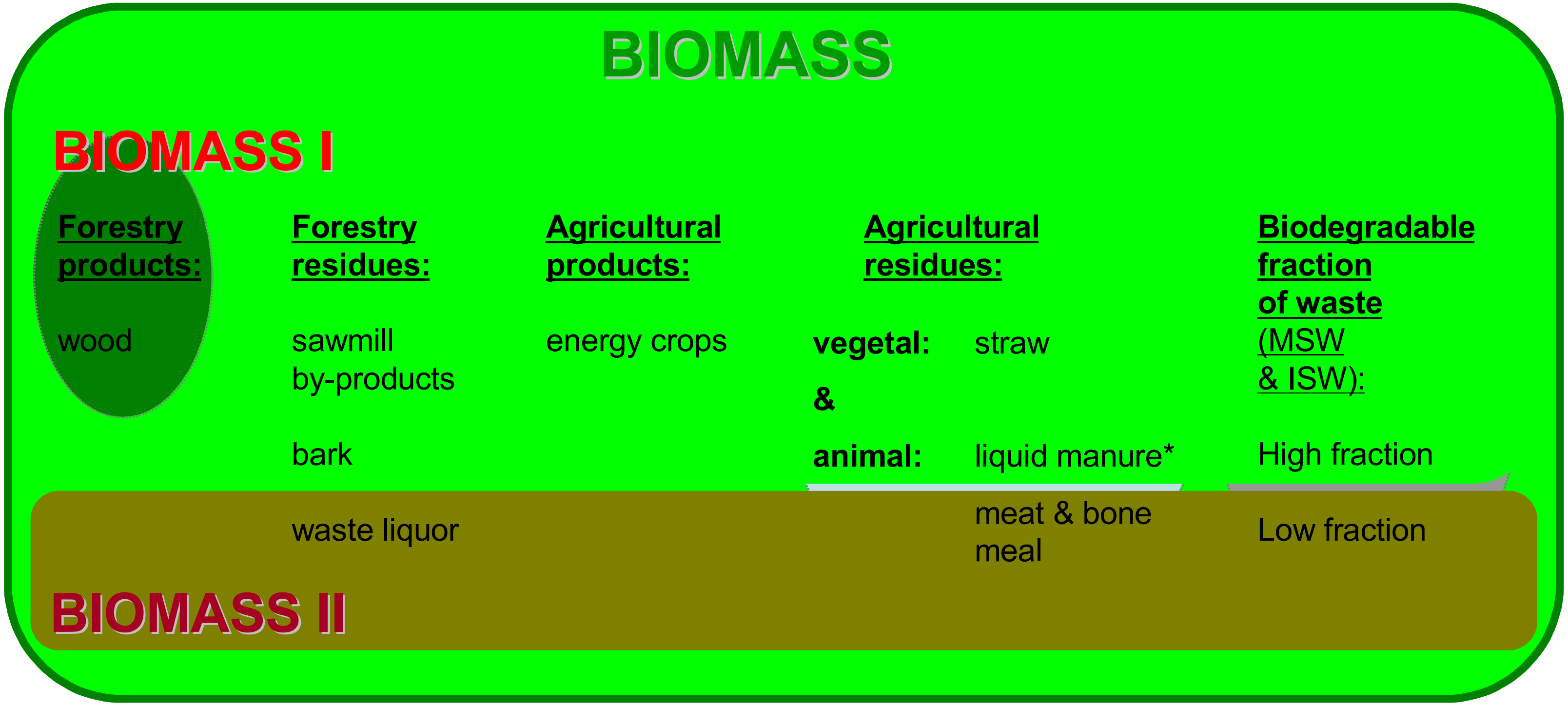
Biomass as the renewable energy source

Biomass - organic material of non-fossil origin, including organic waste - can be converted into bioenergy through combustion, either directly or via derived products.

Derived products from waste streams include the conversion of waste oil into biodiesel, animal manure and organic household waste into biogas and plant or plant waste products into biofuel.

[Eurostat 2017]

Biomass categories

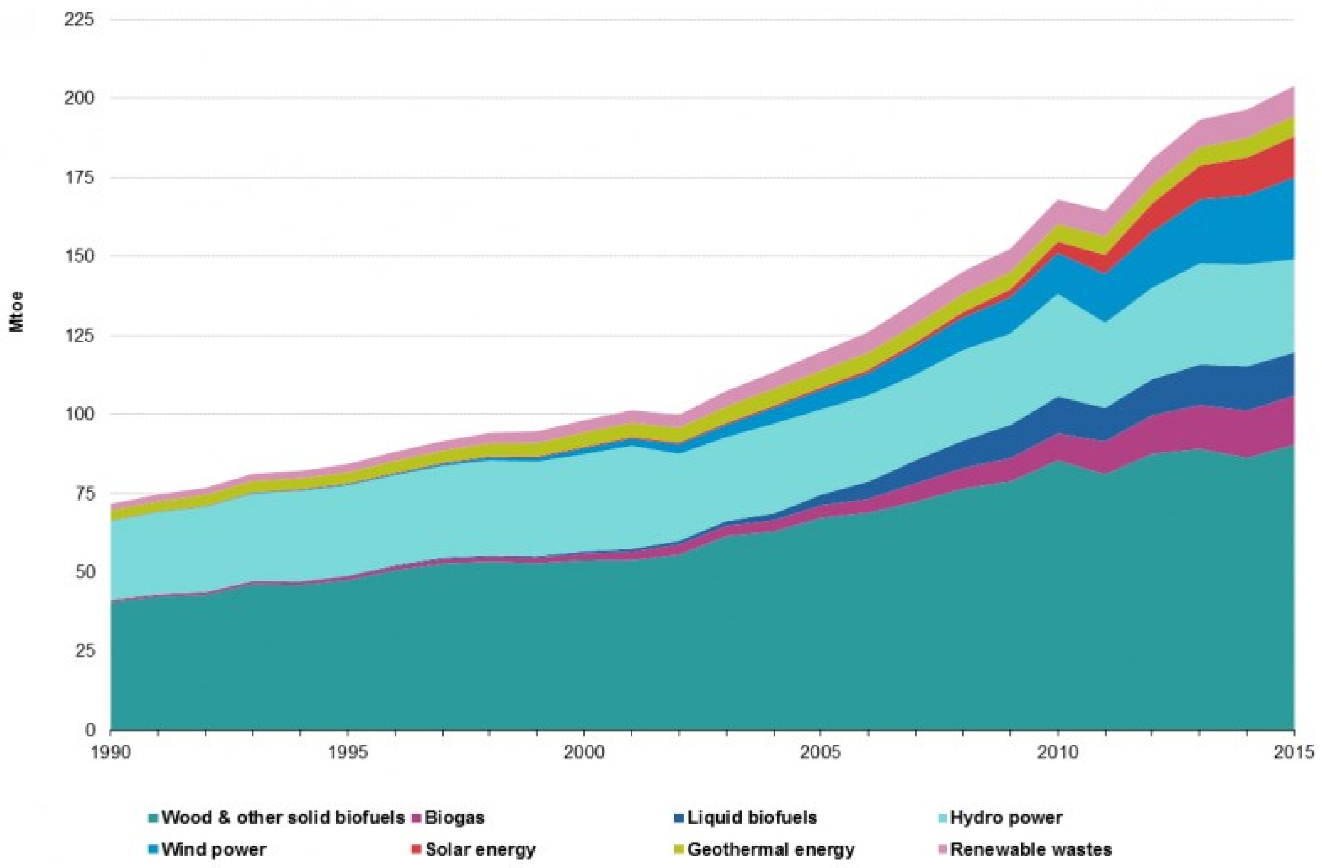


Note: BIOMASS ... in accordance with definitions given by the *EU-Directive 2001/77/EG* (BIOMASS = BIOMASS I + II)

BIOMASS I … in accordance with definitions given by the *Renewables Act*

* liquid manure might also be used as fuel input for biogas-plants

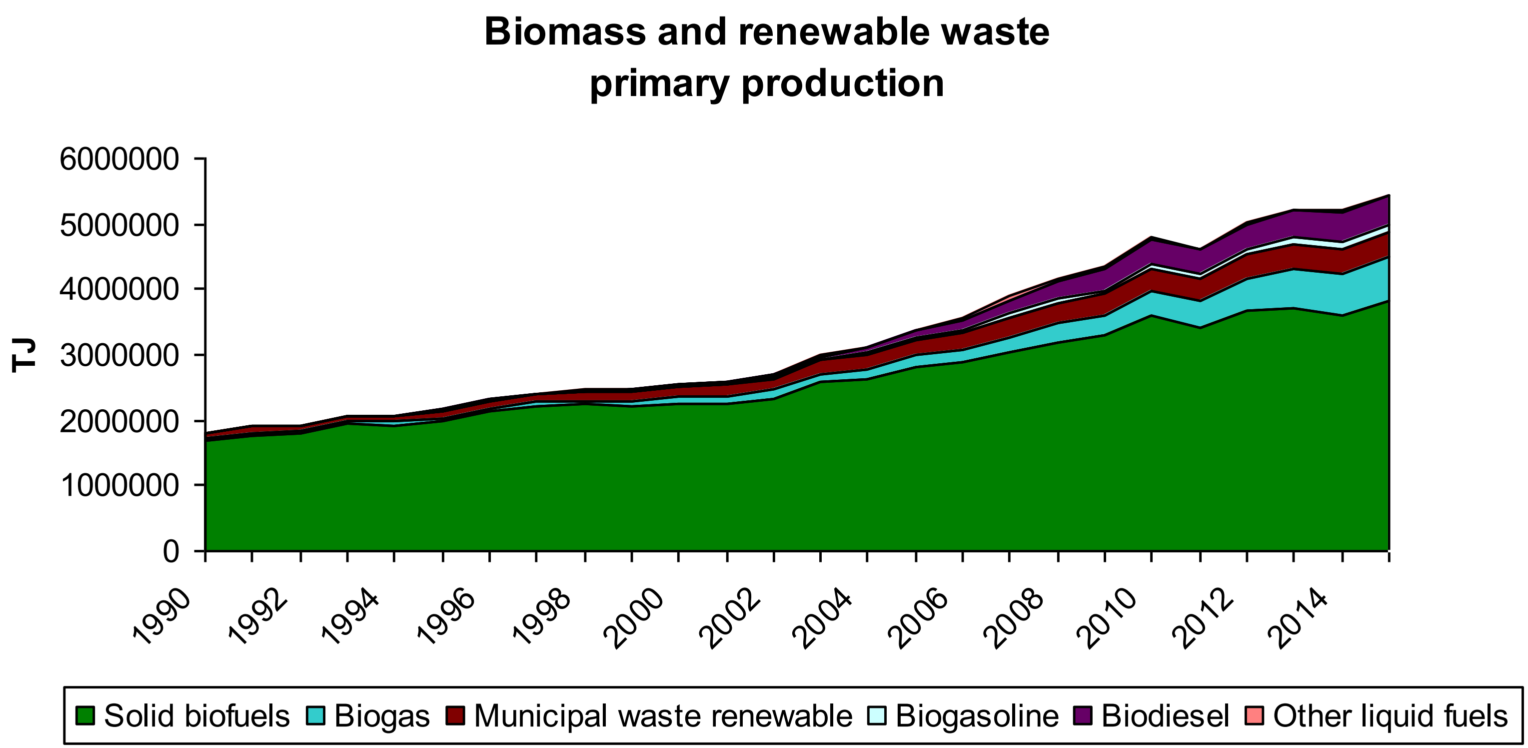
Development of RES energy in EU



Source: Eurostat

Share of RES energies in gross final consumption: 16.7% (2015)

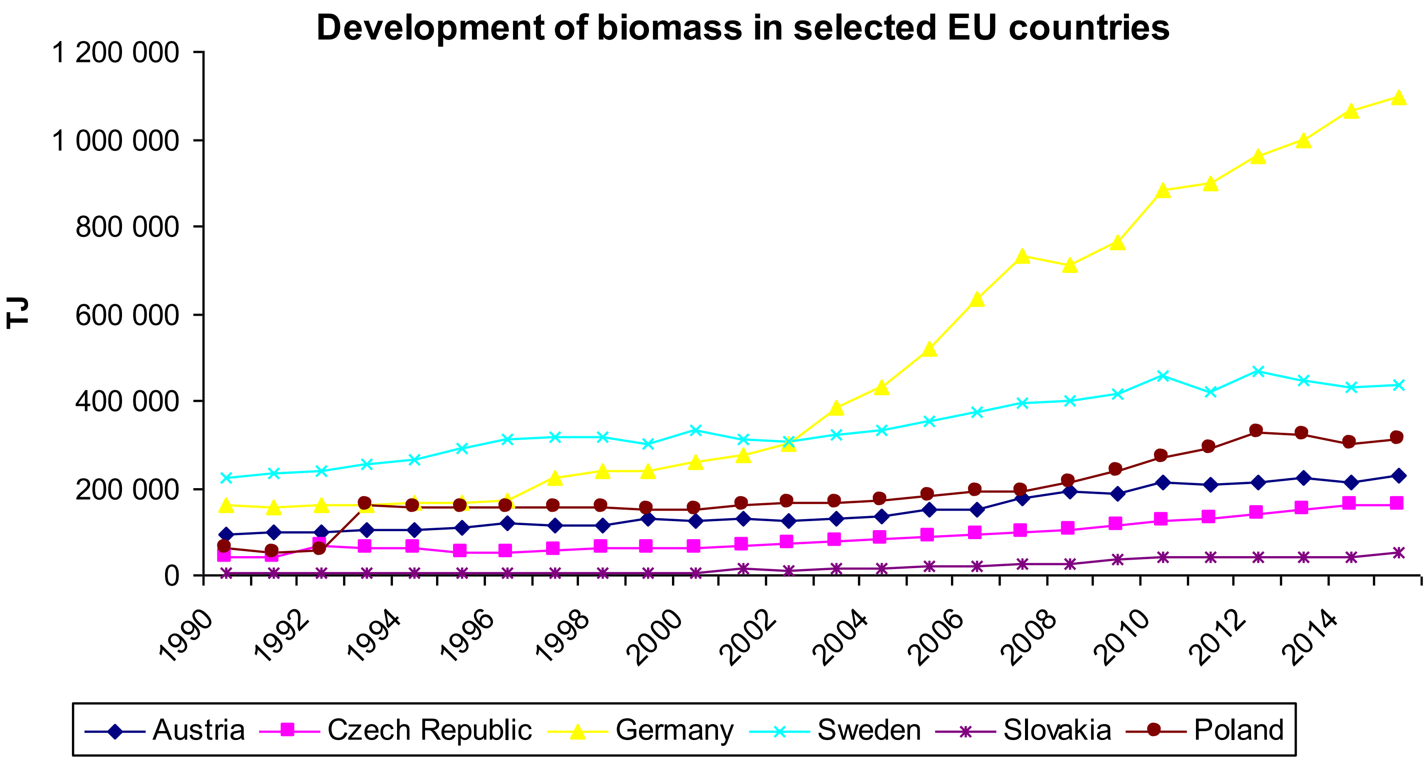
Development of biomass as renewable energy



Share of biomass on RES energy: 63.3% (2015)
(5451 PJ of 8610 PJ)

Source: Eurostat

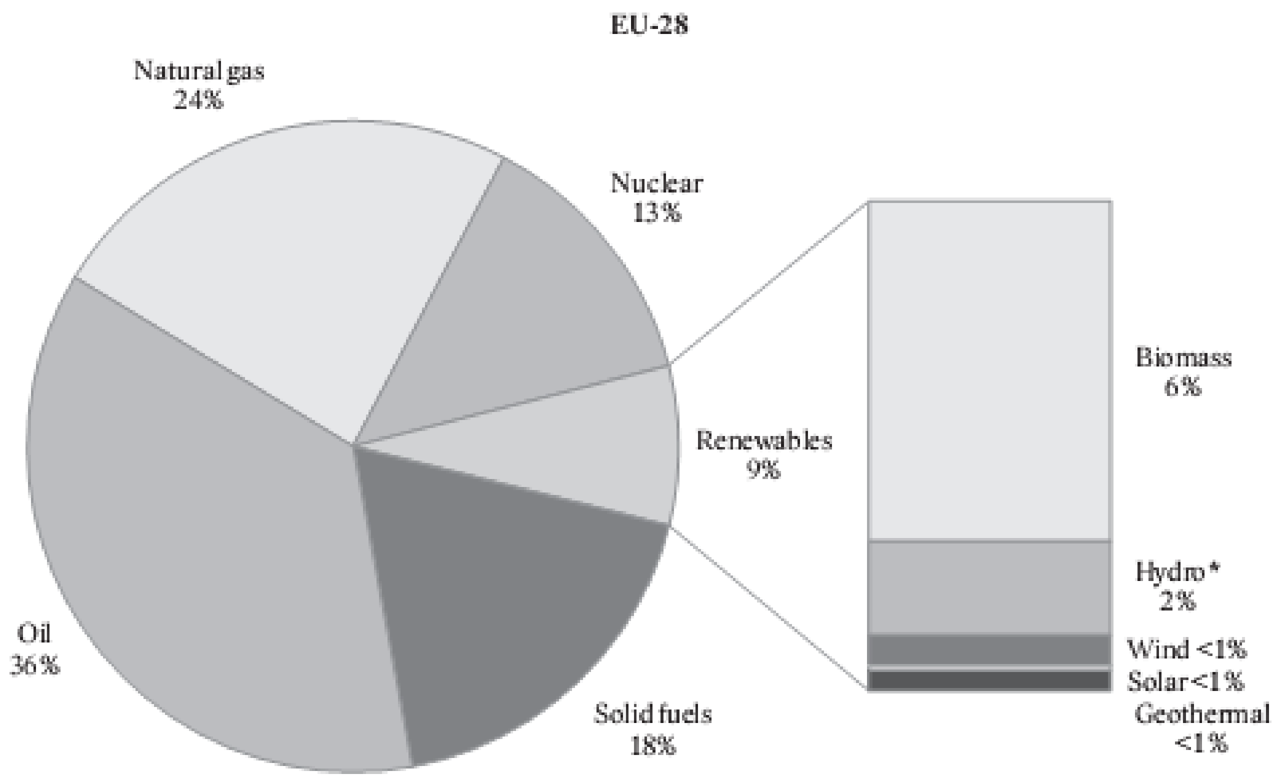
Development of biomass as renewable energy



Source: Eurostat

Significance of individual RES kinds

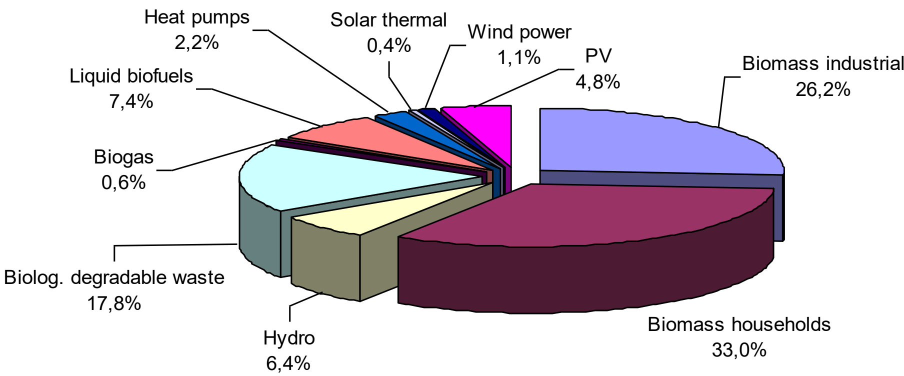
Share of RES on primary energy, EU 2012



Source: EU Pocket book, 2014

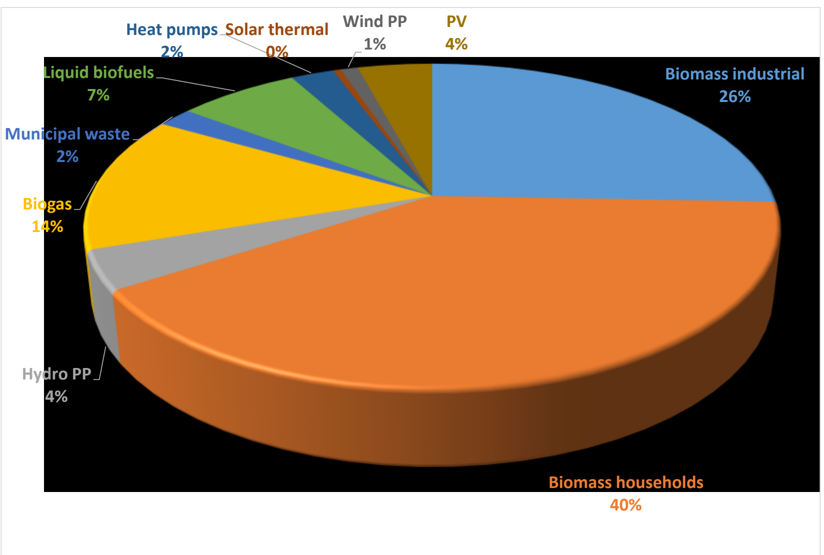
Fig. 2: Primary renewable energy sources in the EU-28 in 2012 in comparison to all other energy sources

RES shares on PES – CZ case



2013 (Source: MPO2014)

RES total 153.7, 8.7%



2016 (Source: MPO2018)

RES total: 184,8 PJ, 10.6%

RES consitribution on final consumption – CZ case

	Electricity	Transport.	Heating, cooling	Final energy consumption
2010	7,52 %	5,12 %	14,01 %	**10,48 %**
2011	10,61 %	1,18 %*	15,29 %	**10,91 %**
2012	11,67 %	6,15 %	16,14 %	**12,77 %**
2013	12,78 %	6,34 %	17,56 %	**13,85 %**
2014	13,89 %	6,90 %	19,35 %	**14,98 %**
2015	14,07 %	6,45 %	19,64 %	**14,99 %**
2016	13,61 %	6,42 %	19,87 %	**14,89 %**

RES shares in individual consumption categories in the Czech Republic in 2010-2016 (Source: MPO2018)

Types of biomass used – CZ case

Biomass type	Electricity (mil tonnes)	Heat (mil tonnes)	Total (mil tonnes)
Wood waste	0,868	1,252	2,120
Fire wood	0,000	0,052	0,052
Plant materials	0,097	0,061	0,158
Briquettes and pellets	0,096	0,075	0,171
Pulp extracts	0,334	0,996	1,330
Households			3,897
Biomass (energy) export			0,750
Biomass (energy) total			**8,478**

Structure of biomass consumption for energy purposes in the Czech Republic, 2013 (Source: MPO 2013)

Biomass and biofuels

1st generation biofuels

- raw material for their production is biomass with competitive utilization for food production (incl. forage for farm animals)
- bioethanol from corn, sugar beet, sugar cane
  - biodiesel (FAME) from rape seed
  - biofuels from palm oil
  - biogas and biomethane from maze silage

2nd generation biofuels

- non food biomass
  - residuals from forestry and from agriculture
  - biodegradable waste
  - energy crop (reed canary grass, miscathus, schavnat, etc.), but competition for the land with conventional production

3rd generation - algae

Biomass – various sources of origin

Fire wood – competition with the material utilization (paper production, furniture, passive houses, etc)

Residuals from agriculture and forestry for direct burning and biogas

- residual straw (part used for soil improvement and for farm animals)
- residuals from forestry - bark, small branches etc. (app 15%)
- grass from permanent grasslands
- manure (pigs, cows, etc.)
    - valuable input to biogas stations

Biomass – various sources of origin

Conventional crop used for energy purposes

- maize – biogass stations
- corn, sugar beet, sugar cane – bioethanol
- rape seed - biodiesel
  - manure (pigs, cows, etc.)
  - valuable input to biogas stations

Energy crop – perennials

- short rotation coppice (poplar and willows in CZ case)
- reed canary grass, miscanthus, schavnat
- energy grasses

Biomass – various sources of origin

Residuals from industry

- paper production residuals (pulp extracts, etc) – currently significant item in the statistics

- saw dust, wood waste – wood processing industry (furniture, construction elements, cask, items of daily use, etc.)

Residuals from households and other sources

- thermal utilization
- separation of biodegradable waste
- oil from Mc Donald, etc.

Biomass as the special RES

Several advantages of biomass compared with the other RES:

- long term experience with utilization
- can be easily stored or delivered to the point of consumption
- low dependency on immediate weather conditions - no quick fluctuation of its availability (in contrary to PV or wind), but its yield (from agriculture land fluctuate according to the given year conditions)
- can be (easily) transformed into (higher quality) biofuels
- can serve as fuel both for decentralized or centralized heat production

Biomass as the special RES

Several advantages of biomass compared with the other RES:

- can be easily added into coal and burnt with it – co-combustion (substitutes part of coal)
- can help to solve diversification of activities in rural areas
- can be the option for the excess arable land
- local production of solid biofuels (e.g. pellets) for decentralized space heating
- domestic source contributing to the energy security

Biomass as the special RES

Advantages of perennials (energy crop)

reduce soil erosion (e.g. maze problem)

- ❑ increase soil quality (increase of humus)
- ❑ suitable for greening, increase of biodiversity
- ❑ diversification of activities
- ❑ agroforestry

Wheat and walnut agroforestry plot (Restinclières - France)

Source: http://www1.montpellier.inra.fr/safe/english/agroforestry.php

Wheat harvest in a poplar agroforestry plot (Vézenobres - France)

Biomass as the special RES

But biomass has (as the other RES) relatively low energy density – large land areas are needed to substitute the significant portion of currently used PES

Question: Comparison of energy gain from one hectare of land used for PV and for biomass (e.g. plantations of short rotations coppice).

Assuming just energy equivalent and total sum of energy per one (average) hectare and (average) year what option brings higher contribution ?

What other factors have to be taken into account doing such comparison ?

Biomass availability in long run

- ***Do we have realistic plans for biomass future ?***

- ***How we can include individual constraints for biomass potential determination ?***

- ***What is the structure of biomass potential and its regional distribution ?***

- ***Can we mobilize biomass potential when needed ?***

Methodology for biomass potential determination

Specification of biomass potential

- high variability of current biomass potential estimates
- necessary to check where are the boundaries of potential
  - yields as the function of soil and climate conditions

Determination of biomass potential as the function of relevant parameters

- region selection (country, official regions, any region)
- land allocation for energy crop (relative)
- priorities for land utilization, available agrotechnologies
- environmental, legal and market limitations

Standard and additional biomass potentials

Standard biomass potential

- Biomass potential sustainable in longer run (i.e. all the legal, environmental and market constraints for biomass production and utilization are taken into account)
  - Biomass for primary energy sources balance

Additional biomass potential

- short term “boosting” of biomass potential
  - Additional biomass for periods with shortage of conventional fuels, some constraints are ineffective (period of several months up to one year - depends on season)

Biomass categories – agriculture land and forestry

Agriculture land

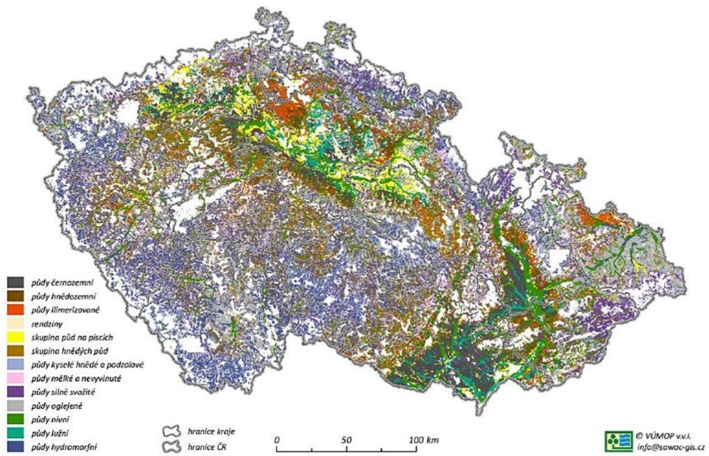
- residual biomass from conventional agricultural production (residual straw) – annual crop
- energy crop:
  - perennial (non wood) plants (reed canary grass, miscanthus, schavnat, etc.)
  - SRC plantations
- grass from permanent grasslands,

Forestry

- (fire) wood and forest residuals.

VSEU – soil and climate conditions on site

Soil types



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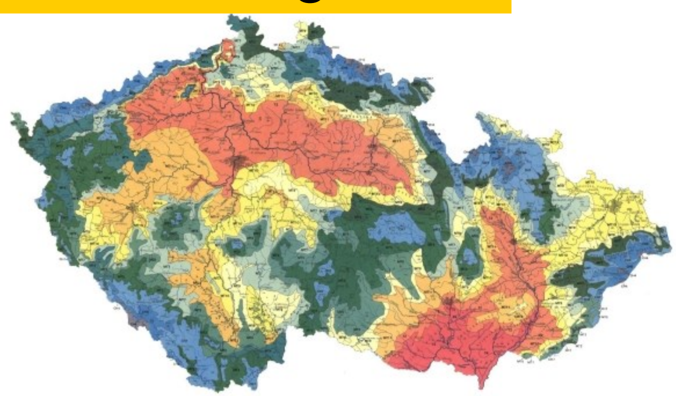
Climate regions



Bottom up approach, land plots conditions

VSEU

XYYWZ

MSCU

X:10 dif. climate regions

(similar conditions for growth of agr. crop)

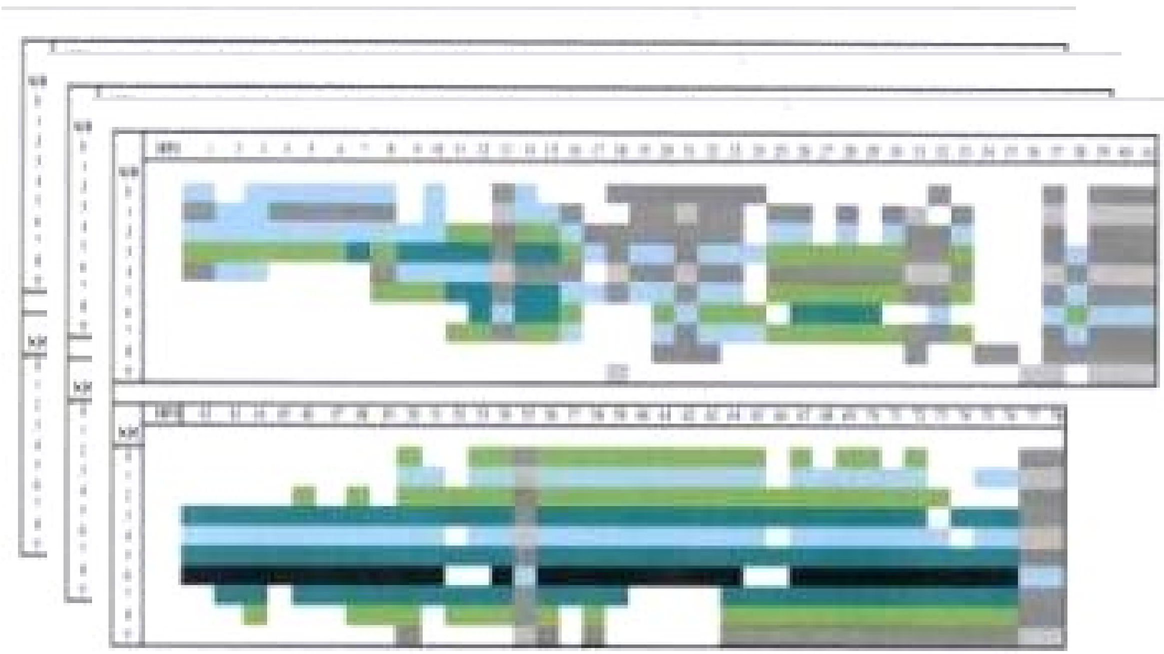
YY: main soil units

(soil type, subtype, soil matrix and the degree of hydromorphism)

W: comb. of slope and exposure

Z: depth of the soil profile and its skeleton

Typology of agricultural sites



Empirical data

Experimental plantations

Expert estimates

MSCU: Up to 550 valid combinations (climate + soil)

Identification of typical biomass yields for given conditions

Yield curves (5-7 for each conventional type of energy crop)

Typology of forests

- yields of biomass are based (as in case of agricultural land) on primary information about the soil conditions and forest type (set of forest types):

XYZ

X … forest vegetation levels 0-9 (e.g. 1 means oak forest up to 350 meters above the sea level)

Y … forest soil types A-Z

Z … index of forest type in given forest area

Up to 170 valid combinations of forest vegetation levels and forest soil types

- age of forest (forest production plans)

Examples of yield categories

Yield cat.	**SRC** [t (DM).ha^{-1}]	**Miscanthus** [t (DM).ha^{-1}]	**Schavnat** [t (DM).ha^{-1}]	**Reed canary grass** [t (suš).ha^{-1}]
K1	< 5,01	<5,01	<2,51	<3,76
K2	5,01–7,00	5,01–9,00	2,51–5,00	3,76–5,25
K3	7,01–9,00	9,01–13,0	5,01–7,50	5,26–6,75
K4	9,0 1–11,00	>13,1	7,51–10,00	6,76–8,25
K5	11,01–13,00	-	>10,00	>8,25
K6	>13,00	-	-	-

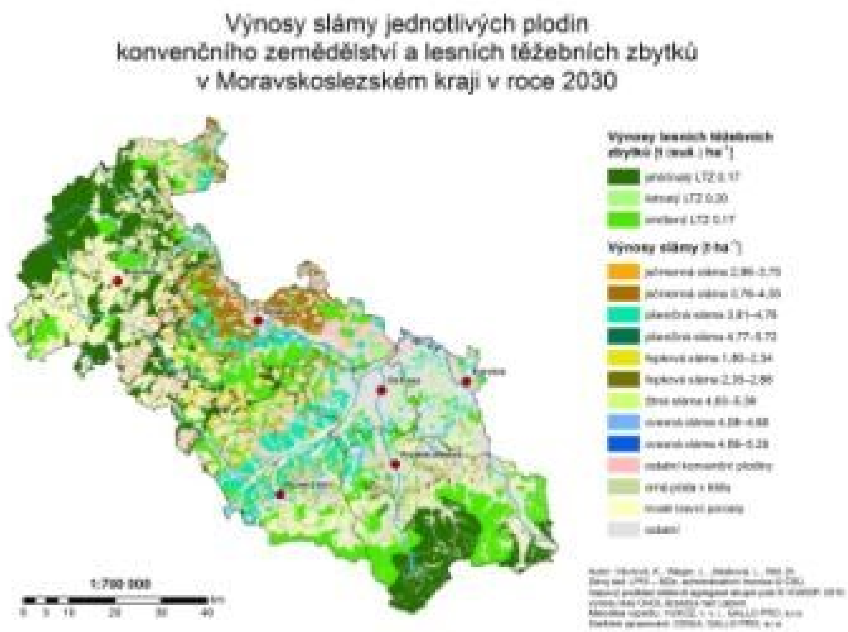
Data for conventional crop

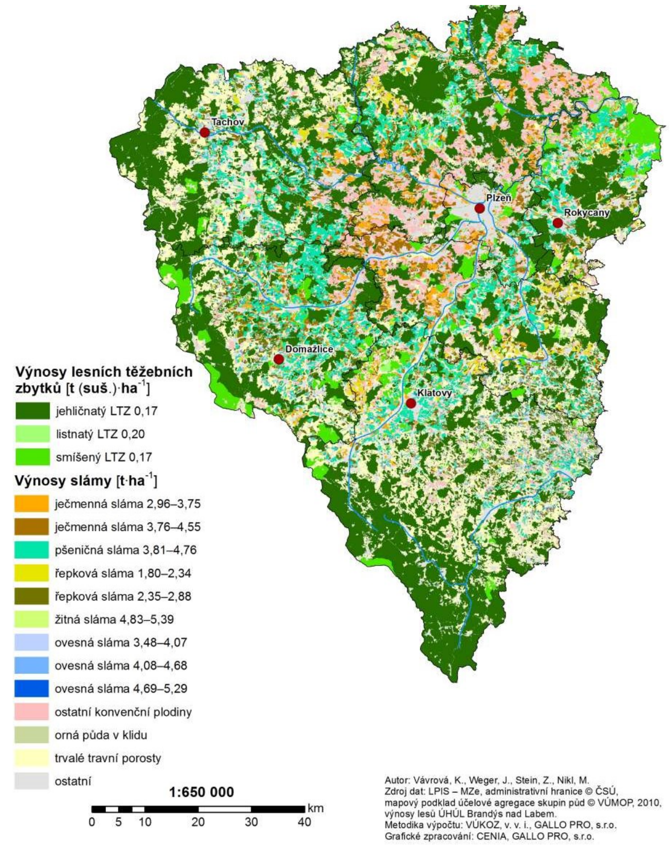
	Straw coeff.	HV in GJ.t^{-1} ,12 % moisture content
Wheat	0,8	15,7
Barley	0,7	15,7
Oat	1,05	15,7
Triticale	1,3	15,7
Rye	1,2	15,7
Rape seed	0,8	17,5

Order of needs for soil quality

1. Sugar beet
2. Maize for grain
3. Barley
4. Wheat
5. Rape seed
6. Maize for sillage
7. Triticale
8. Other forage
9. Rye
10. Oat
11. Other

Example - straw yields and forest residuals for two regions



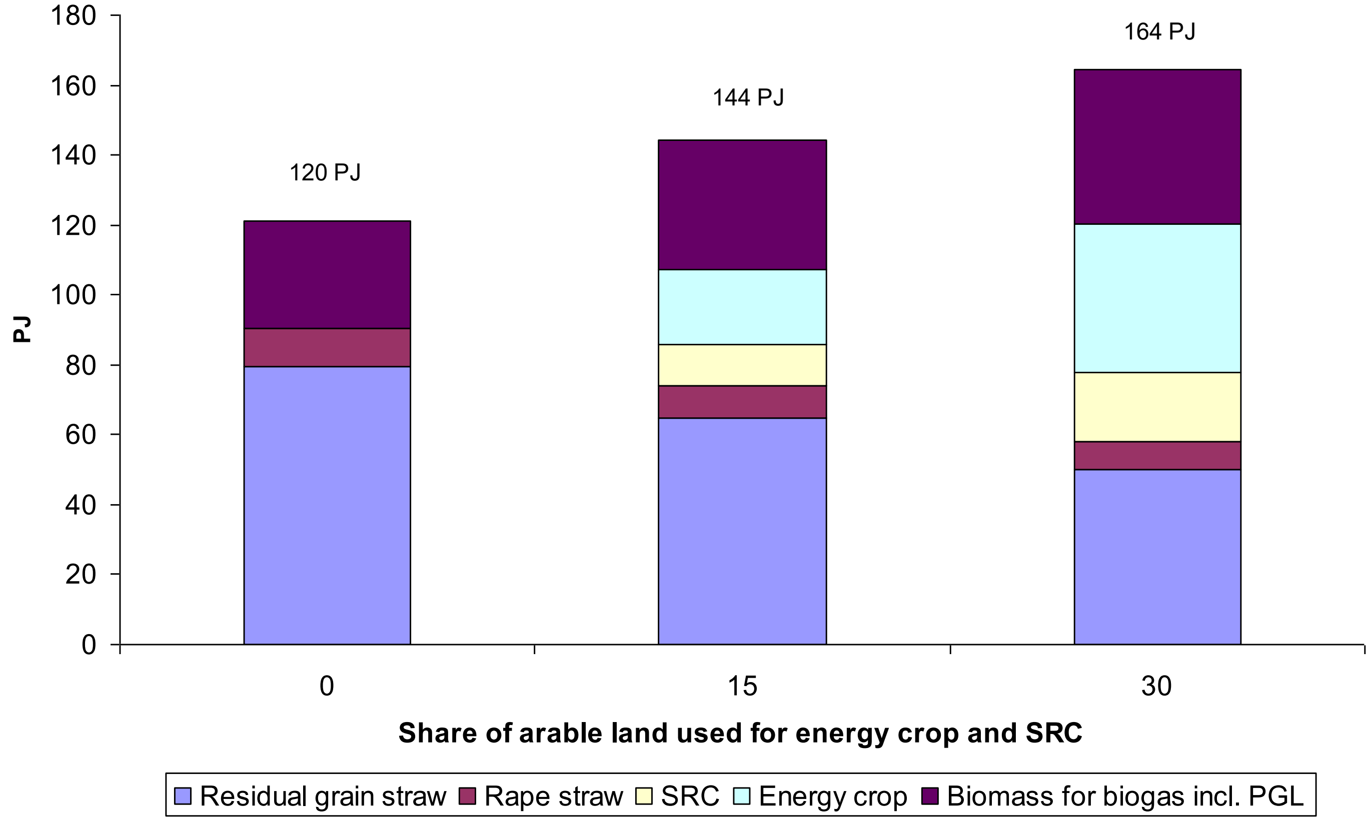


Note: GIS enable graphical presentation of biomass potential distribution in the analyzed area

Logic of algorithm

1. Information to prepare GIS model (VSEU and MSCU data for analyzed region, categorization of crop – typology of sites, plot database and other)
2. Area of arable land and distribution of the conventional crop, allocation of arable land to energy crop
3. Allocation of conventional crop to land plots according to the land parameters in the order of crop requirements for soil quality (optimum kind of crop is allocated to the given plot), yield assignment according to MSCU, application of straw to grain coefficient, correction for farm animals
4. Allocation of energy crop to land plots (similarly as above), yield assignment according to HPKJ unit (preference of conventional production)
5. Contribution from permanent grasslands (similar methodology)
6. Contribution from forestry based on forest production plans (reflecting the age and set of forest types)

Standard biomass potential as the function of land allocation for energy crop



Additional (short term) biomass potential

Sources of additional biomass potential

- part of straw which is ploughed into soil to keep the soil quality (changes of straw to grain coefficient),
- part of straw which is used for farm animals,
- shortening of rotation cycle o SRC plantations,
- increase of dendromass used for energy purposes (e.g. shortening of forest production cycle or change of categorization of harvested wood).

Note: “additional” means possibility of immediate reaction and strongly depend on the season, related with the growth cycle

Coming back to biomass potentials

- **Theorethical** – land available, climate, access to water etc.
- **Technical or geographical**: other area specific constraints are included – biodiversity protection, natural parks, preference of conventional crop, recreation, rotation of crop, etc.
- **Economic** – only such part of biomass potential which is competitive with conventional fuels under the given standard market conditions
- **Realistic** – also includes technological limitations – e.g. grass and biogas stations, burning of straw (creation of “glass” in boiler, etc.)

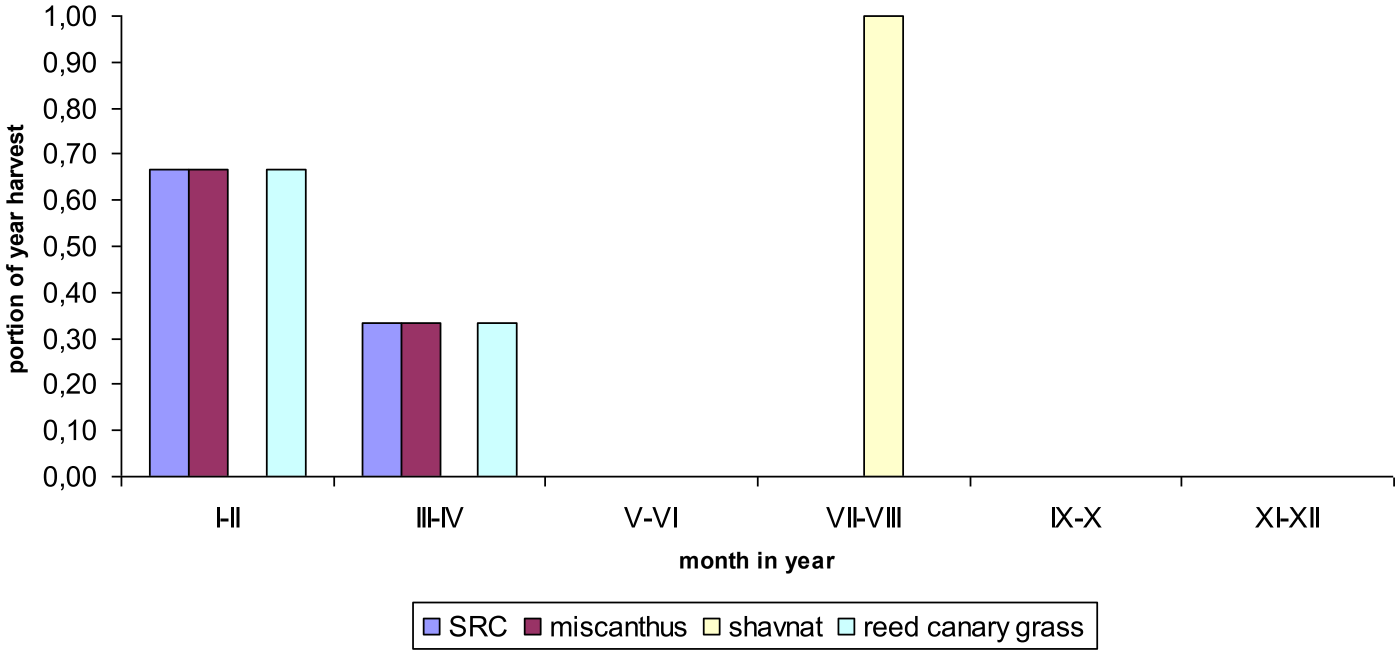
Coming back to biomass potentials - 2

- Long term sustainable potential – all constraints (agrotechnologies, environmental protection, etc.) are assumed
- Boosting of potential in short term

- Biomass potential is not constant over time
  - changes in land allocation for energy crop
  - optimization of agrotechnologies
  - new technologies of raw biomass transformation

Coming back to biomass potentials - 3

Biomass availability in year cycle



Coming back to biomass potentials - 4

Differences in regional biomass potential distribution (4% of energy crop)

Region	SouthMoravian	Vysočina
Area [km^2]	7195	6796
Agr. land share [-]	0,6	0,6
of which arable l. [-]	0,83	0,77
Standard pot. [TJ]	13 338	8 356
Boosting of pot.		
- total [-]	1,23	1,19
- straw [-]	1,15	1,16
- forestry [-]	2,95	1,42

Biomass as potential option on local level

Biomass is locally available source of energy

- can be substitute of fossil fuels (coal) in small villages
- primary reason: improvement of local air quality
- secondary reason:effective utilization of local source, creation of job opportunites
- system reason: reducton of PES import, reduction of CO_2 emissions

Space heating in small villages – Czech case

Total number of flats (CZ): 4.75 mil. (Census 2011)

- 47.4% of flats in family houses - local boilers and local in-house heating systems (78% in 2001 and 89% in 2011

- 51% in blocks of flats (residential buildings) - dominantly heated from the centralized heating systems (74% in 2001 and 80% in 2011)

- About 34% of boilers in family houses use solid fuels. About 9% of flats in family houses is heated by the stoves in individual rooms.

- An important type of solid fuel is domestic brown coal - between 27% and 33% in villages with less than 1000 inhabitants

Space heating in small villages – Czech case 2

Biomass is important fuel esp. in small villages under 2000 inhabitants

- there are 24% of all inhabited flats (CZ).
- local biomass (fire wood, wood briquettes, pellets) is used for heating in 21% flats,
- coal in 25% flats (villages under 2000 inhabitants).
- share of biomass and coal is even higher in case of smaller villages below 1000 inhabitants (24% and 29%, respectively).
- biomass plays minimum role in the cities over 20 ths. inhabitants with share only about 1%

Case study for village Z

typical rural village Z in the Bohemian-Moravian Highlands (Českomoravská vrchovina)

- the average altitude of 605 meters and its cadastre comprises of 304 hectares of agricultural land and 55 hectares of forests.
- 180 registered inhabitants and 92 houses of which 88 were inhabited family houses and 2 residential houses in 2016.
- 22 houses are used for recreational purposes.
- age of buildings is equally distributed in a range from 10 to 100 years and their current total energy consumption for heating is around 6500 GJ/year and 7200 GJ in pellets

Case study for village Z – biomass potential

- residual biomass (straw, smallwood, firewood):
  - realizable potential: 6367 GJ/year
  - available potential: 3707 GJ/year (deduction of biomass for soil care and animal feed)
  - potential of energy crop (on 10% of agriculture land: 2420 GJ

- Solid biofuels (pellets/briquettes) can cover significant part of energy requirement for space heating, after improvement of building energy efficiency even the whole needs

Pellting/briquetting

- raw biomass should transformed into solid biofuels
- wide range of biolers and even stoves for pellets (starting on the level of kW)
- briquettes mostly for bigger boilers or special applications

- Heating value: 15.5 MJ/kg
- Pelleting technology can be used not only for energy purposes but also to produce forage for animals or other producccts

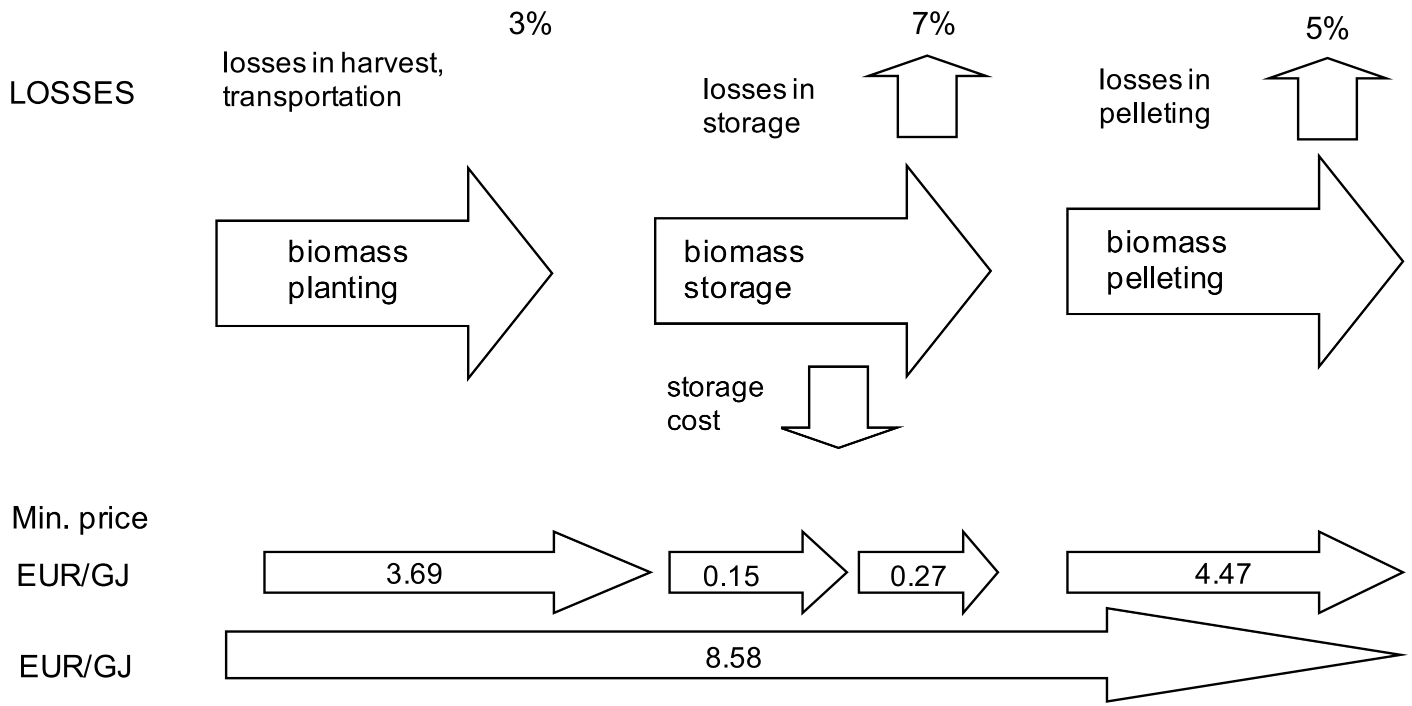
Pellting technology for local scale

- annual production capacity app. 700-1200 t of pellets
- Investment cost: 200 th. EUR
- Operational cost: electricity 26 th. EUR/year
- Labor, maintenance and other 36 th. EUR

- Utilization of local biomass
- Distribution within village
- Project is not primarilly entrepreneural project (low rate of return)
- Methodology of minim price applied (from condition NPV=0)
- Price of raw biiomass – energy crop – is derived from reference economic models for individual types of energy crop

Pellting – results of economic analysis

Reed canary grass example



Structure of the minimum price of bio pellets and the influence of energy losses, reed canary grass, yield curve of 6.25 t(FM)/ha,year

Pellting – results of economic analysis 2

Biomass source	Raw biomass EUR/GJ	Pelleting EUR/GJ	Briquetting EUR/GJ	Storage EUR/GJ	Losses EUR/GJ	Total pellets EUR/GJ	Total briquettes EUR/GJ
Res. straw	2.14	4.47	6.69	0.15	0.14-0.25	6.9-7.01	9.12-9.23
Forest residuals	3.7-4.8	4.47	6.69	0.15	0.25-0.36	8.57-9.76	10.79-12
SRC planations	2.7-5.3	4.47	6.69	0.15	0.25-0.37	7.57-10.29	9.79-12.51
Miscanthus	3.3-7.5	4.47	6.69	0.15	0.14-0.25	8.06-12.37	10.28-4.59
Reed canary grass	3.2-5.8	4.47	6.69	0.15	0.14-0.25	7.96-10.67	10.18-2.89
Schavnat	2.2-5.2	4.47	6.69	0.15	0.14-0.25	6.96-10.07	9.18-12.29

Minimum prices of bio pellet and bio briquette local production [EUR/GJ], VAT is not included.

Pelleting – impact on CO2 balance

Specific (direct) CO_2 emissions in tons per a ton of the produced pellets from intentionally grown biomass

	Raw biomass	Transportation	Pelleting	Total	Total
	tCO_2/t	tCO_2/t	tCO_2/t	tCO_2/t	$kgCO_2/GJ$
Reed canary grass	0.020-0.041	0.007	0.078	0.106-0.127	6.8-8.2
Miscanthus	0.015-0.037	0.007	0.078	0.100-0.122	6.5-7.9
Schavnat	0.014-0.036	0.007	0.078	0.099-0.121	6.4-7.9
SRC plantations	0.011-0.022	0.013	0.078	0.102-0.113	6.6-7.3

Pelleting: specific consumption of electricity 143 kWh/t

CO2 emissions: 0.546 tCO2/MWh – derived from Czech fuel mix for power generatrion

Fuel for agriculture operations: 43 – 61 l/ha

(Standards for agriculture and food production. Available at http://www.agronormativy.cz/stromvyhl;jsessionid=9D6314CD01C73B6D40960BCF10CE010B?snid=146&sntype=2)

Pelleting – impact on CO_2 balance

Specific CO_2 emissions in tons per a ton of brown coal for local space heating

Extraction tCO_2/t	Transportation tCO_2/t	Burning tCO_2/t	Total tCO_2/t	Total $kgCO_2/GJ$
0.0120	0.0070	1.7500	1.7690	101.1

Specific (direct) emissions of CO_2 from the brown coal used for local space heating are app. 14 times higher in comparison to the emissions of CO_2 from locally produced pellets. In other words, 1 ton of pellets (of heating value 15.5 MJ/kg) substitutes 0.886 ton of brown coal which results in savings of 1.56 tCO_2.

Pelleting – impact on CO2 balance

Specific (indirect) CO_2 emissions in tons per a ton of the produced pellets from intentionally grown biomass

• Indirect CO2 emissions are related esp. with energy consumed for fertilizers production.
• one kg of nitrogen (N) requires energy equivalent of 1.4-1.8 l of diesel fuel
• average annual consumption of N per hectare for energy crop is 50 kg N/ha, year – 2.86 GJ/ha,year
• P,K fertilizers – about 50% of energy

	Direct emission tCO_2/t	Indirect emission tCO_2/t	Total emission tCO_2/t	Total emission $kgCO_2/GJ$	Total saved CO_2 $kgCO_2/GJ$
Reed canary grass	0.11-0.13	0.03-0.07	0.14-0.19	9.0-12.3	92.1-88.8
Miscanthus	0.1-0.12	0.02-0.05	0.12-0.17	7.7-11.0	93.4-90.1
Schavnat	0.1-0.12	0.03-0.07	0.13-0.19	8.4-12.3	92.7-88.8
SRC plantations	0.1-0.11	0	0.1-0.11	6.5-7.1	94.7-94.0

Competitiveness of locally produced pellets

minimum prices of the produced pellets fairly higher than the prices of domestic brown coal – at least by 1/3.

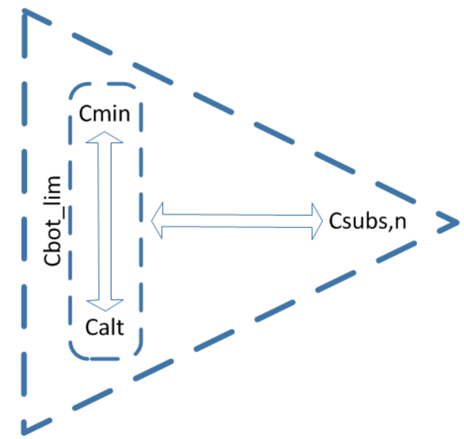
Possibilities how to increase the competitiveness
• Significant increase of an ecological tax imposed to brown coal (currently it is only 0.31 EUR/GJ of a high heating value).
• Support of the purchase of pellets/briquettes production technology
• Support of the purchase of bio pellet/briquette boilers – a current market price of a pellet boiler is higher by app. 1000-1500 EUR compared with the coal boiler
• Direct support of an agriculture land utilization for non-food production
• Massive information champagnes informing householders about the advantages of solid biofuels against the coal.

Biomass price – three different points of view”

Agriculture land is the scarce resource !

Biomass potential and real contribution to PES balance:

- Agrotechnologies
- Biomass yields – soil and climate conditions
- Economic competitiveness
- Land used for food production cannot be used for energy purposes and vice versa



Biomass price and competitiveness:

- Biomass price modelling – economic effectiveness of the project
- Competition with conventional agri production – farmers will require the same economic benefit from land utilization
- Substitution of fossil fuels – customers will accept only such price of biomass which ensure the same cost from fuel utilization

Biomass price – three different points of view" - 2

Biomass price modelling – economic effectiveness of the project

- Identification of all needed processes during the plantation lifetime

- Cash flow simulation

- Minimum price calculation
    - To find such price of biomass to get NPV=0 (in this case farmer/investor will have rate of return equal to discount rate

- Similar approach as in case of FIT calculation for RES power generation

Biomass price – three different points of view" - 3

Intentionally grown biomass – competition with conventional agricultural production

• Farmers will switch to the new business only when they will realize at least the same economic benefit as in case of conventional agri production

• Increased prices and subsidies (SAPS) of conventional crop push prices of grown biomass for energy purposes up

• Conventional products have very high profitability

Biomass price – three different points of view” - 4

Profitability of conventional crop – Czech case

	Area [ha]	% of total arable land
Wheat	835,941	34%
Barley	350,518	14%
Rapeseed	389,298	16%
Maize for grain	100,453	4%

Source: ČSÚ 2014

Crop type	Costs [EUR/ha]	Market price [EUR/t]	Yield [t/ha]
Wheat	839	165	5.59
Barley	706	166	4.75
Rapeseed	1233	362	3.17
Maize for grain	1048	163	7.95

	Net profit [EUR/ha]	Net profit [%]
Wheat	253	30%
Barley	367	52%
Rapeseed	107	9%
Maize for grain	345	33%

VÚZE: 2016, ČSÚ 2015,

Biomass price – three different points of view" - 5

Substitution of fossil fuels with biomass (pellets and briquettes)

- Price of biomass on the field

- Cost of storage, transportation and processing into solid biofuels

- Energy losses (biodegradation)

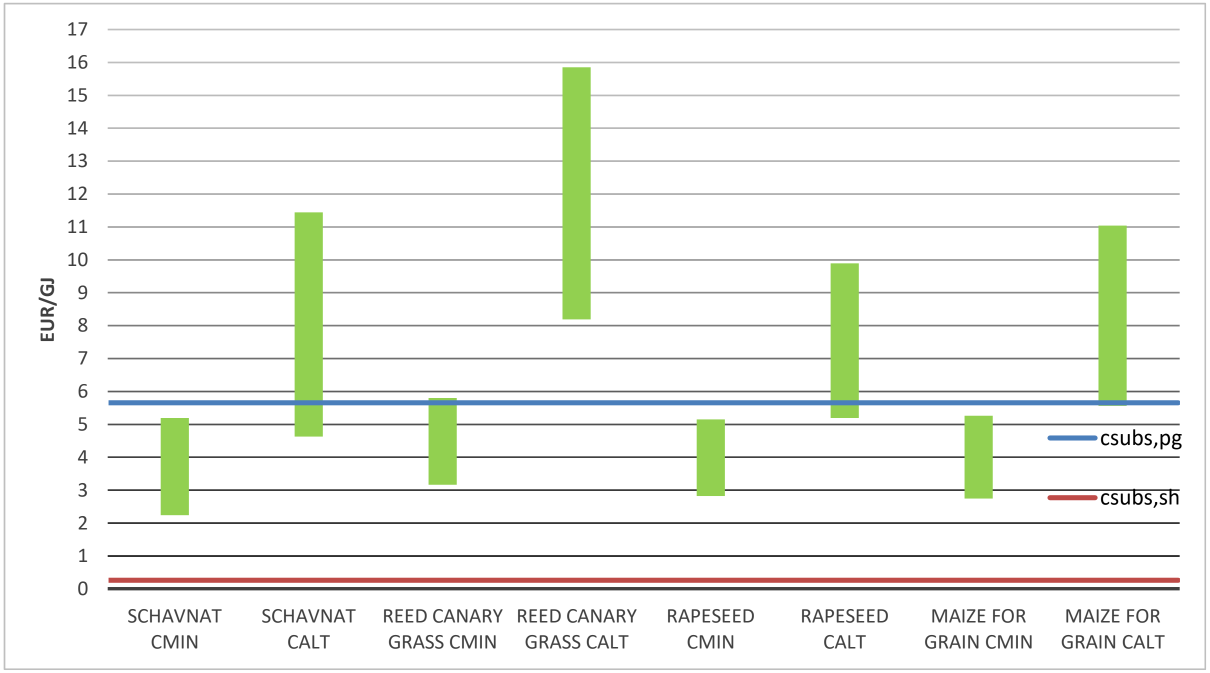
- Cost of technology change

- Czech Republic: domestic brown coal is still massively used for local space heating and for power and heat production

Biomass price – three different points of view" - 6

Current situation:

• Significant impact effectivity of conventional agricultural production on prices of grown biomass



Opened questions

- Biomass potential (short and long term) assuming all the limitations (food security, biodiversity protection, soil protection, etc., sustainability criteria)
- Optimized agrotechnologies for energy crop (still at the beginning)
- Role of liquid biofuels, also with respects to development of shale gas
- Role of GMOs
- Development of burning technologies
- Support of local utilization of biomass
- **Impact of energy crop on soil quality and positive/negative impacts to ecosystems**

Thank you for your attention !

Děkuji za pozornost!