The Second Bioeconomy Course
University of South Bohemia, May 2017

Potential of biomass for energy production, the perspective of biomass in Europe

Jaroslav Knápek

Czech Technical University in Prague,

FEE

Content

1. Biomass definition, CE and EU statistics
2. Biomass and the Czech Republic – basic figures
3. Biomass – sources of origin
4. Biomass advantages compared with the other RES
5. Biomass utilization
6. Liquid biofuels as the controversial option
7. Energy efficiency of biomass fuel cycle
8. Competitiveness of grown biomass
9. Selected opened questions

Biomass as the renewable energy source

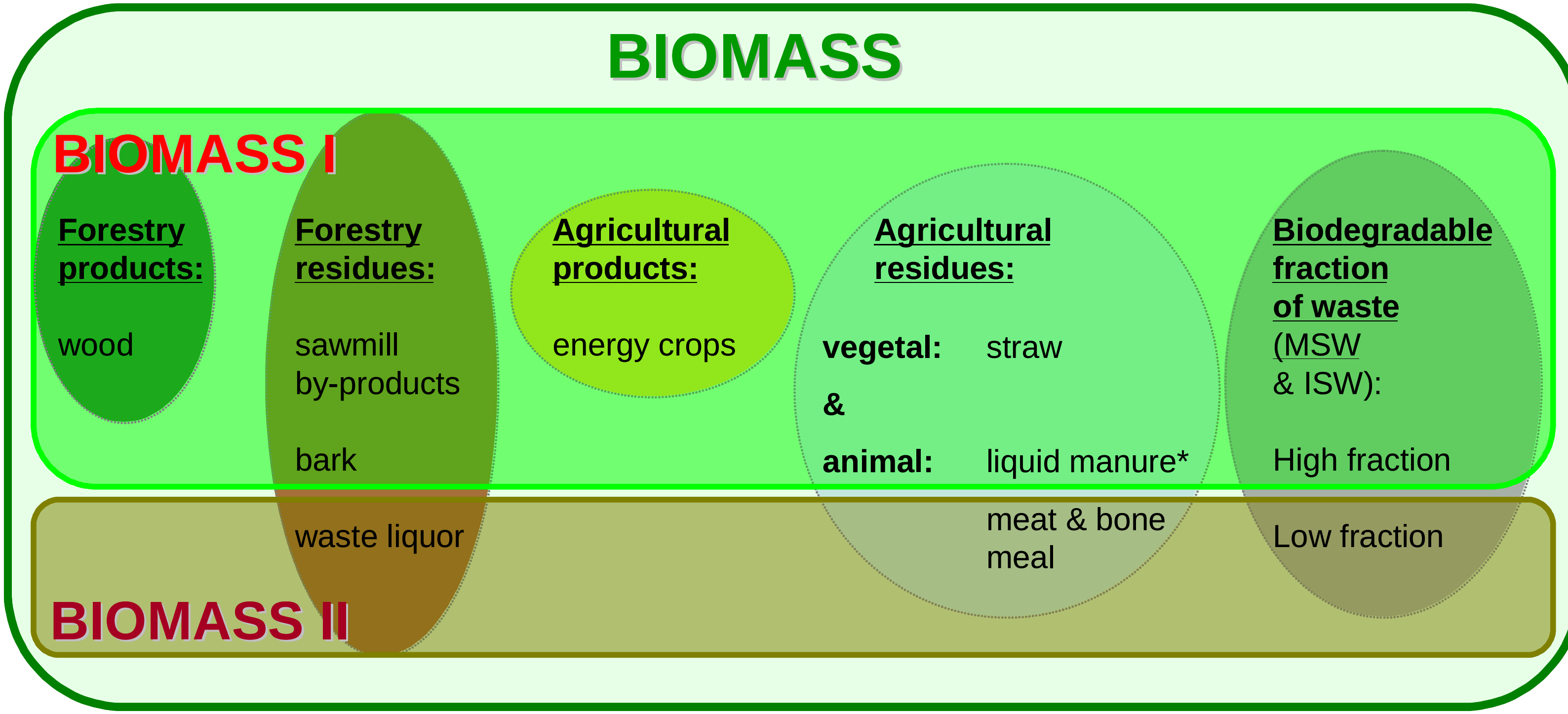
EU Directive 77/2001

"biomass' shall mean the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste"

Biomass as supported RES:

- ❑ sustainability criteria
- ❑ biodiversity and soil quality protection

Biomass categories



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

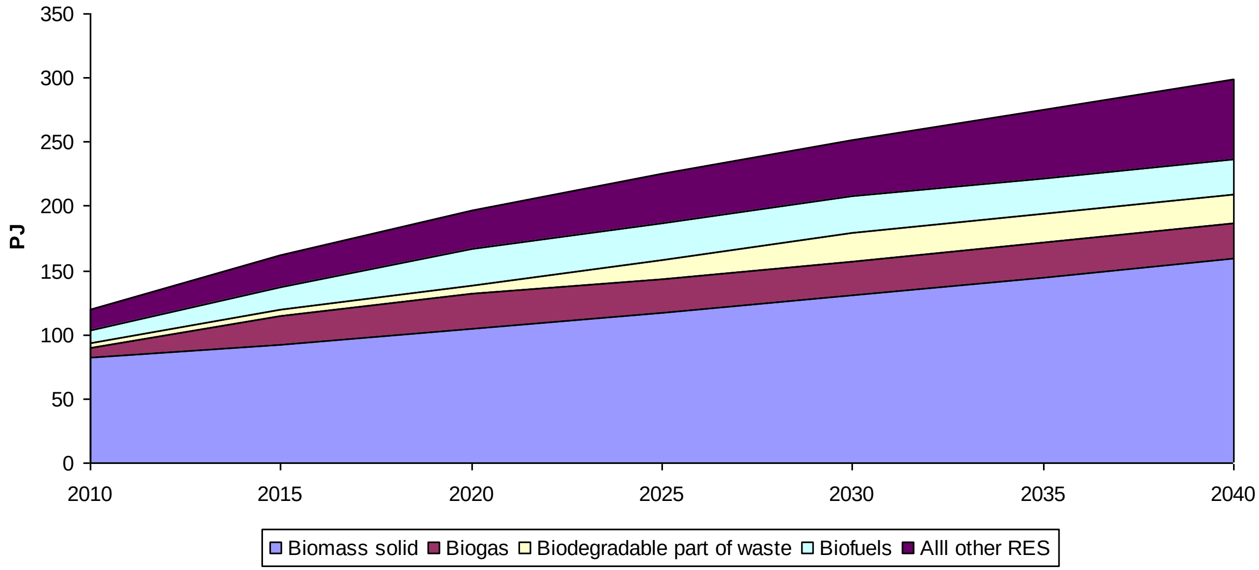
BIOMASS I … in accordance with definitions given by the *Renewables Act*

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

Present state – biomass plays the decisive role in RES strategies

EU28 ((2012)

- Total production of renewable energy reached 7423 PJ
- Biomass contribution: app. by 65,5% to total sum of RES

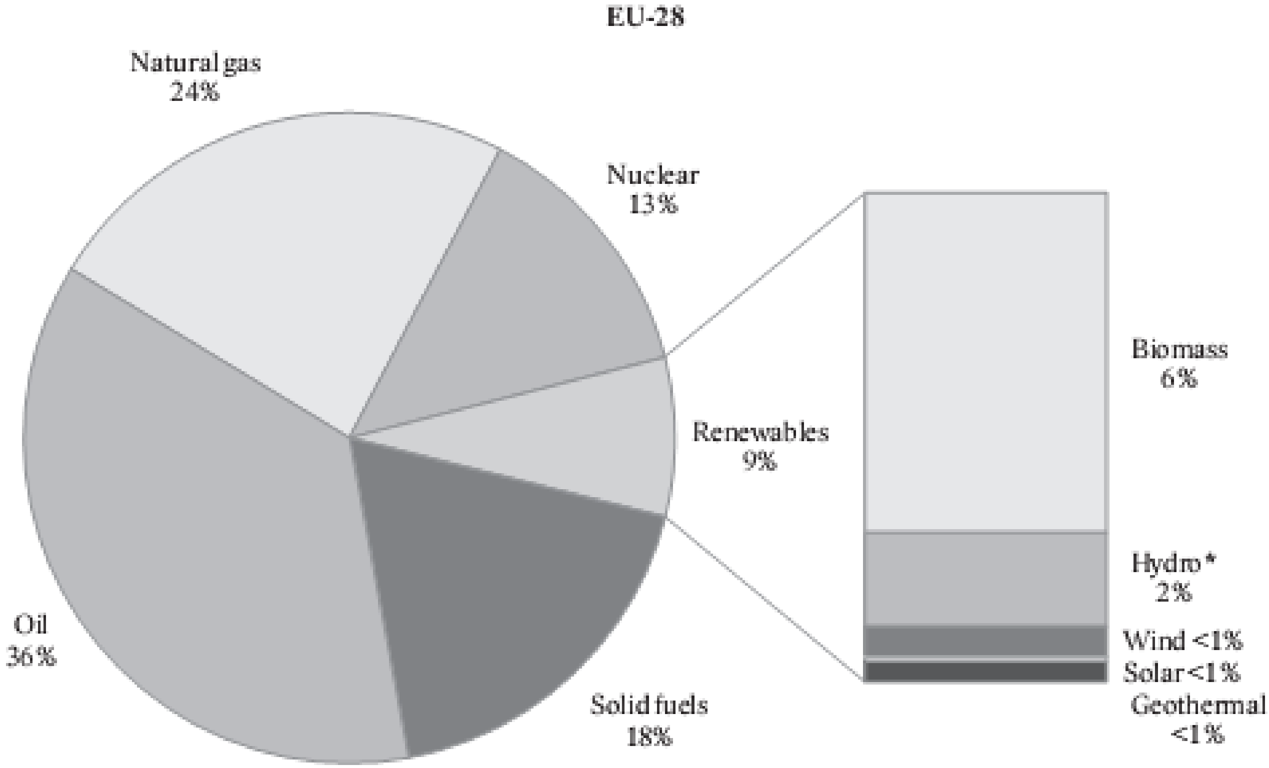


Biomass plays even more important role in the Czech Republic

Source: State energy policy, CZ

Significance of individual RES kinds

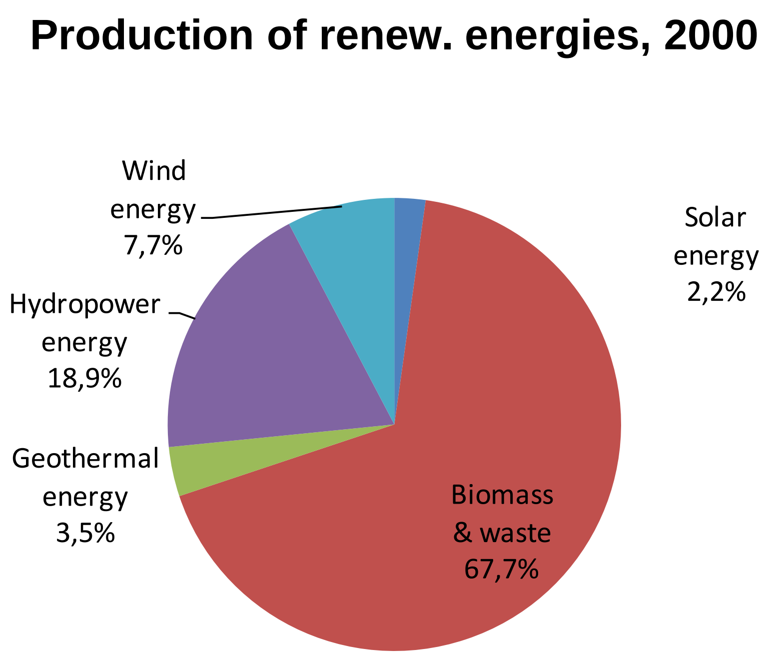
Share of RES on primary energy, EU 2012



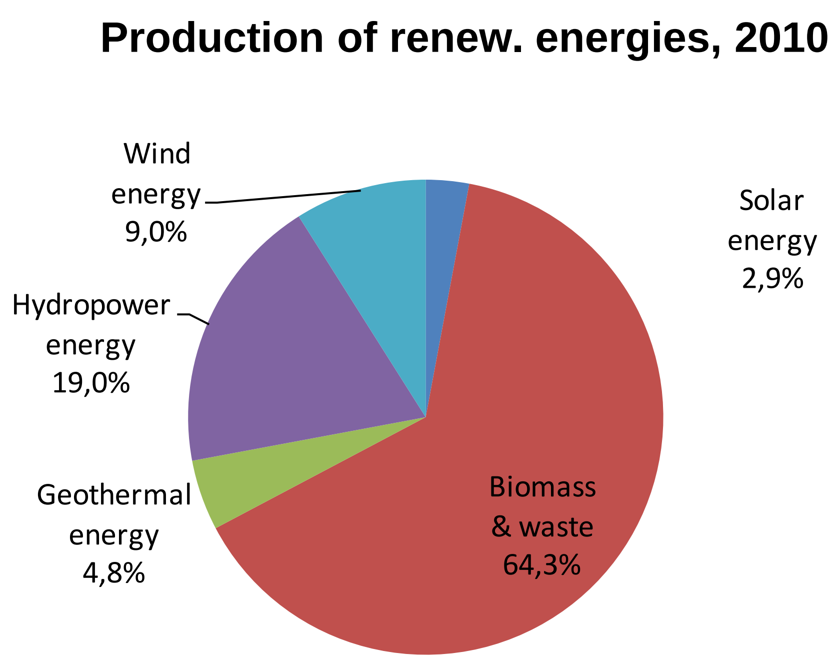
Source: EU Pocket book, 2014

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

Significance of individual RES kinds, EU



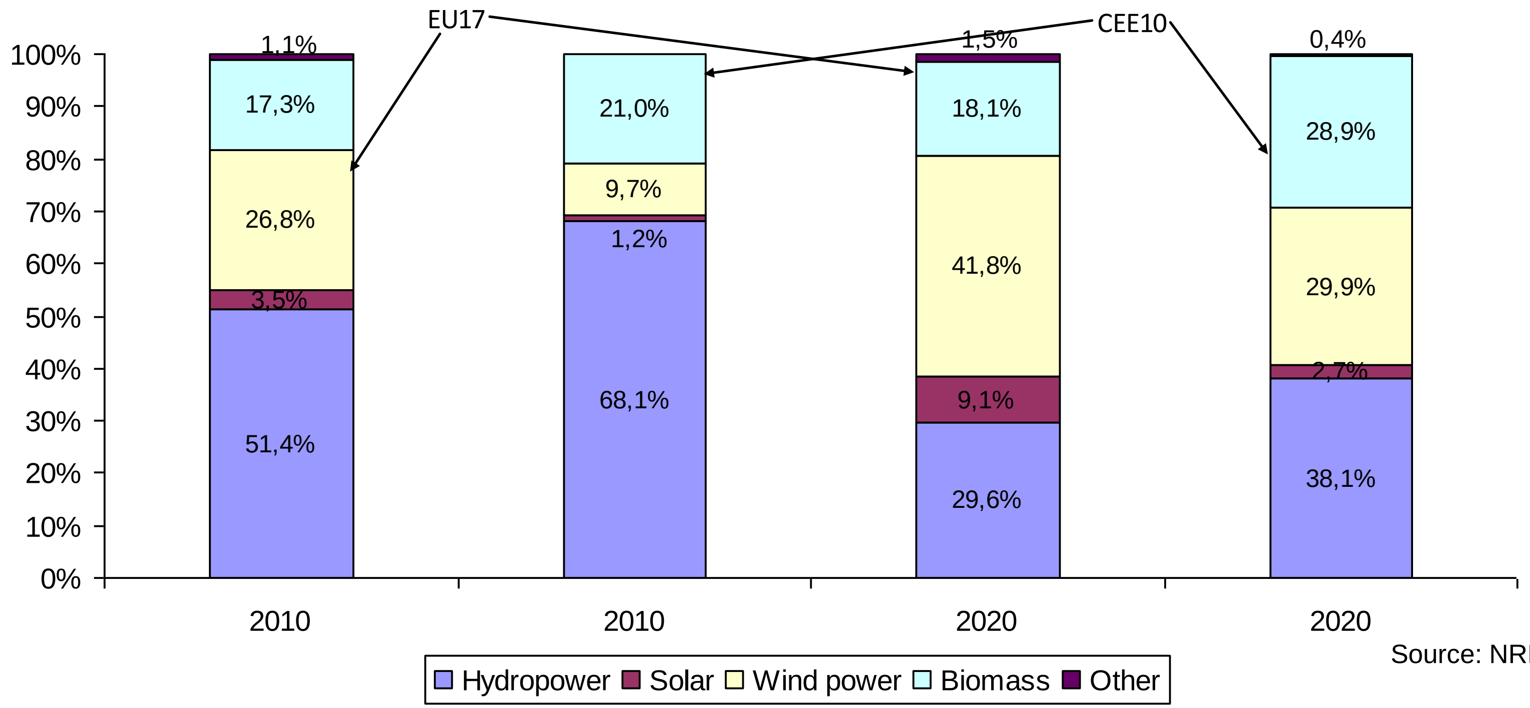
EU 27 RES statistics
RES as the primary energy



Biomass plays and is expected to play the decisive role

Source:Eurostat

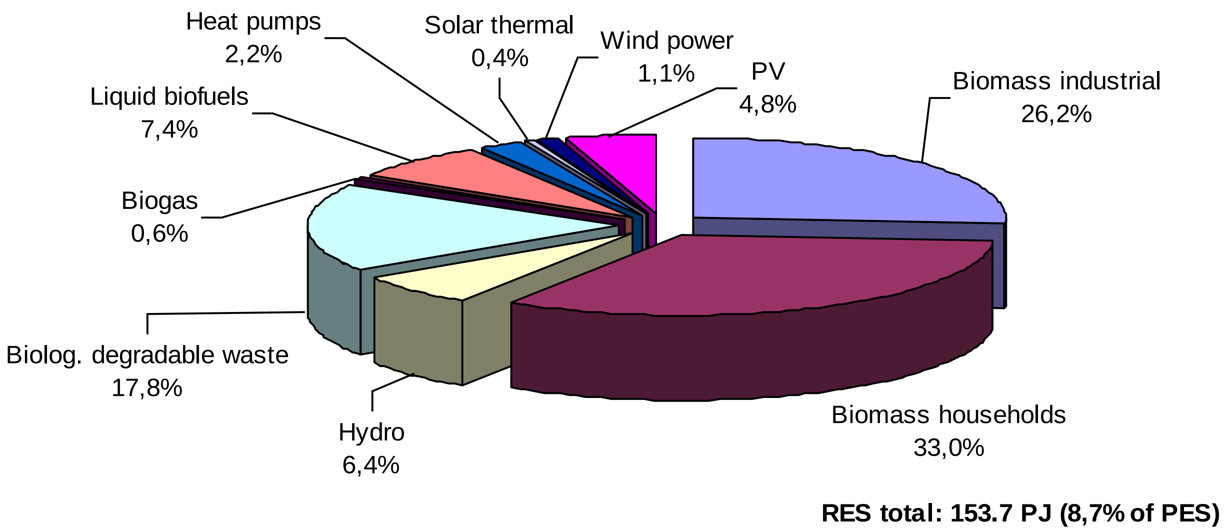
Role of biomass in different countries



Source: NREAPs

Biomass used for power generation – present state and expectation according to NREAPs

Biomass as the energy source – CZ case



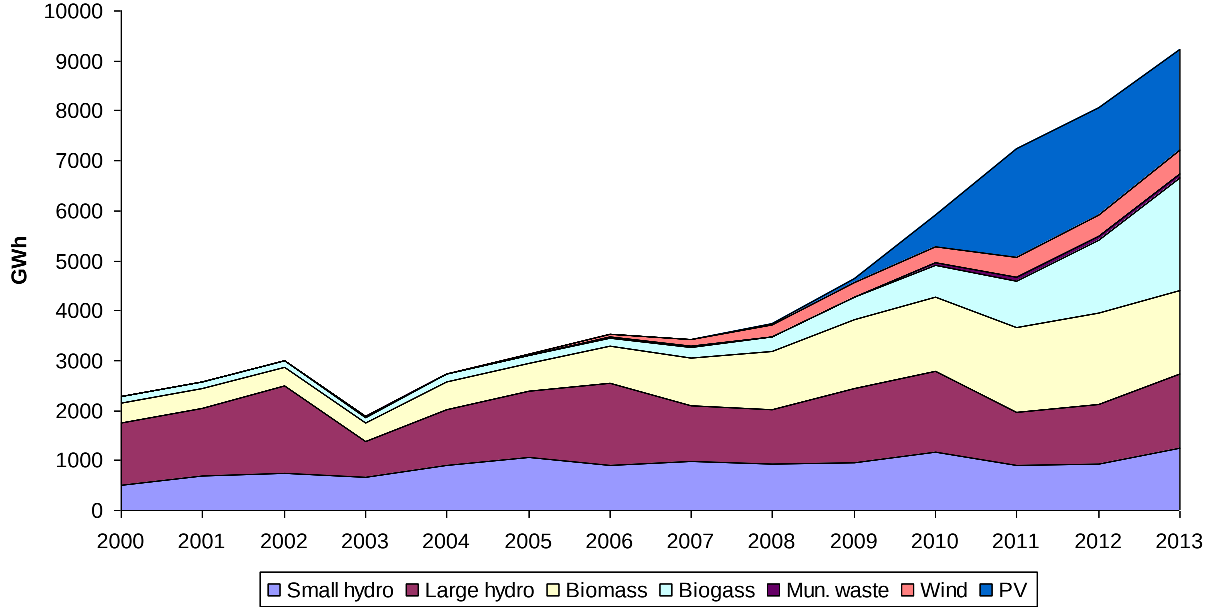
Individual RES categories contribution to the primary energy sources consumption in the Czech Republic in 2013 (Source: MPO2014)

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**

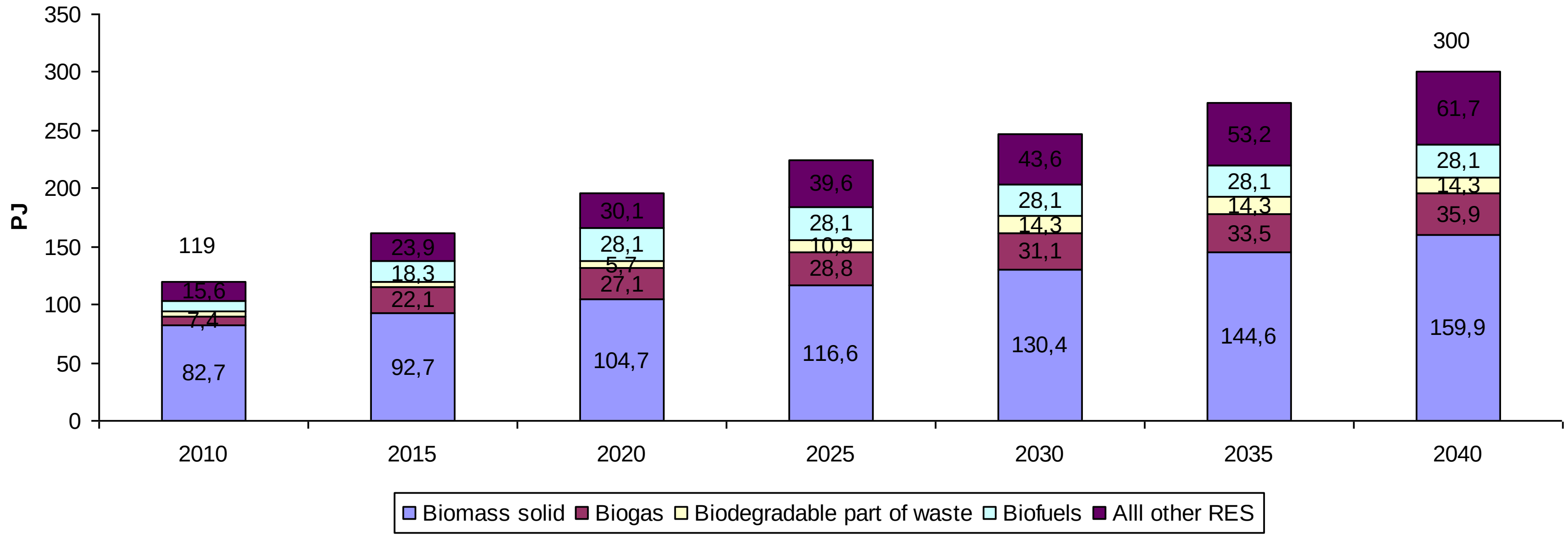
Structure of biomass consumption for energy purposes in the Czech Republic, 2013 (Source: MPO 2013)

Development of power generation using RES



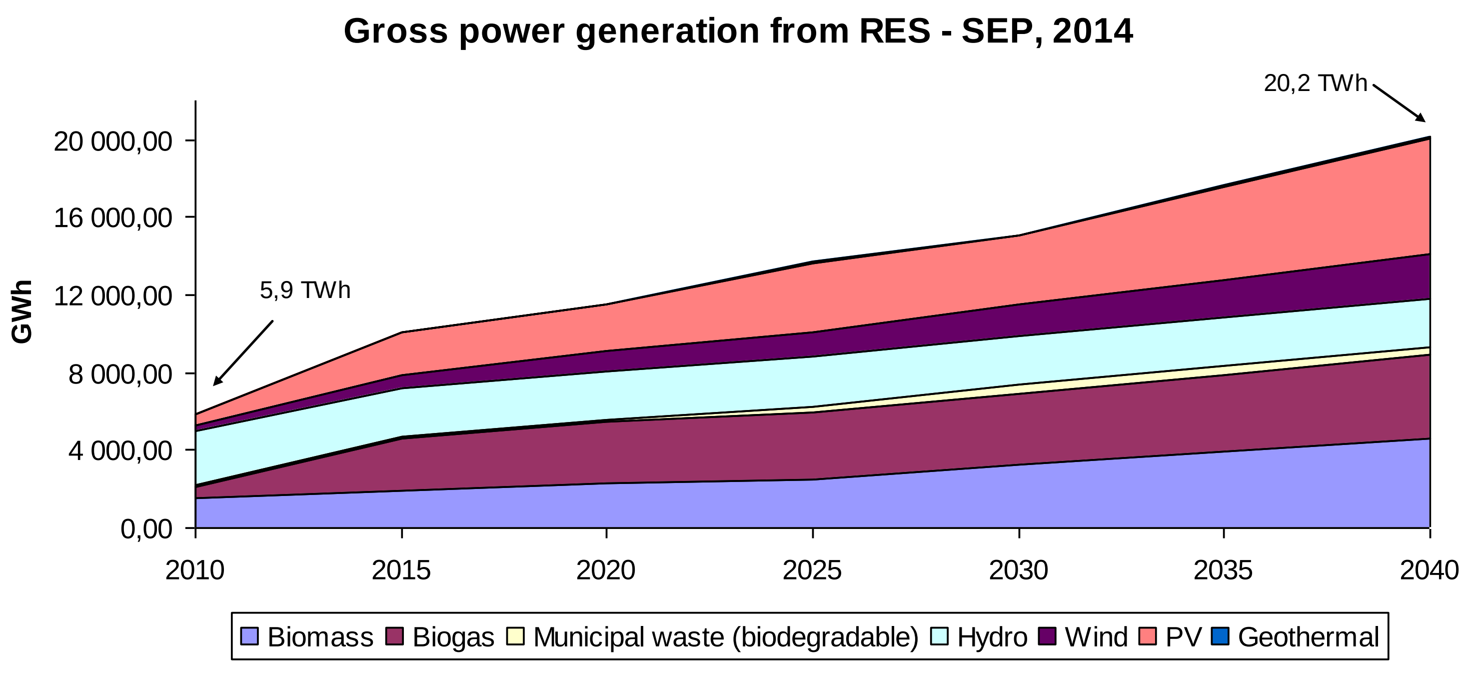
Development of power generation based on RES in the Czech Republic (Source: MPO)

Czech Energy Policy – the role of RES



Expected development of RES contribution to primary energy consumption in the Czech Republic (State Energy Policy – 2014 update)

Czech Energy Policy – the role of RES



Expected development of power generation from RES (Czech Energy Policy, 2014)

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

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

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

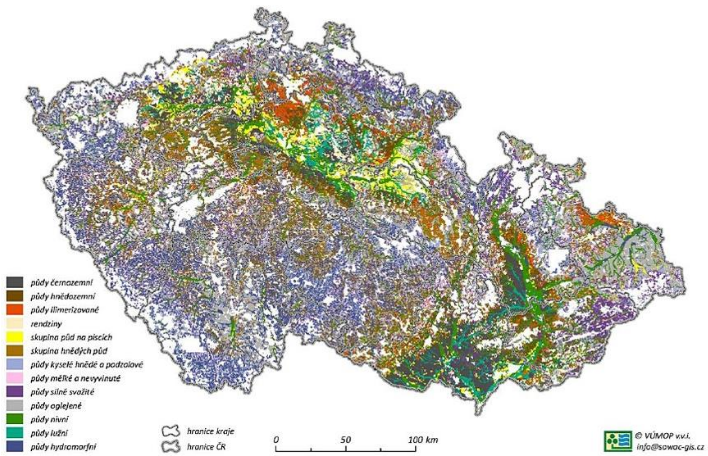
- residual biomass from conventional agricultural production (residual straw) – annual crop
- energy crop:
  - perennial (non wood) plants (reed canary grass, miscanthus, schavnat, etc.)
  - SRC plantations
- grass from permanent grasslands,

Forestry

- (fire) wood and forest residuals.

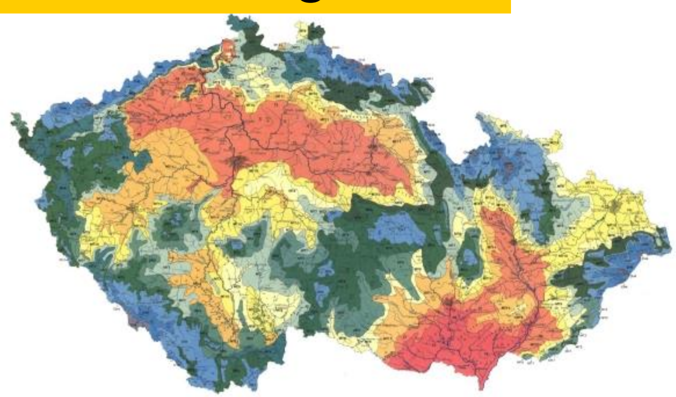
VSEU – soil and climate conditions on site

Soil types



+

Climate regions



Bottom up approach, land plots conditions

VSEU

XYYWZ

MSCU

X:10 dif. climate regions

(similar conditions for growth of agr. crop)

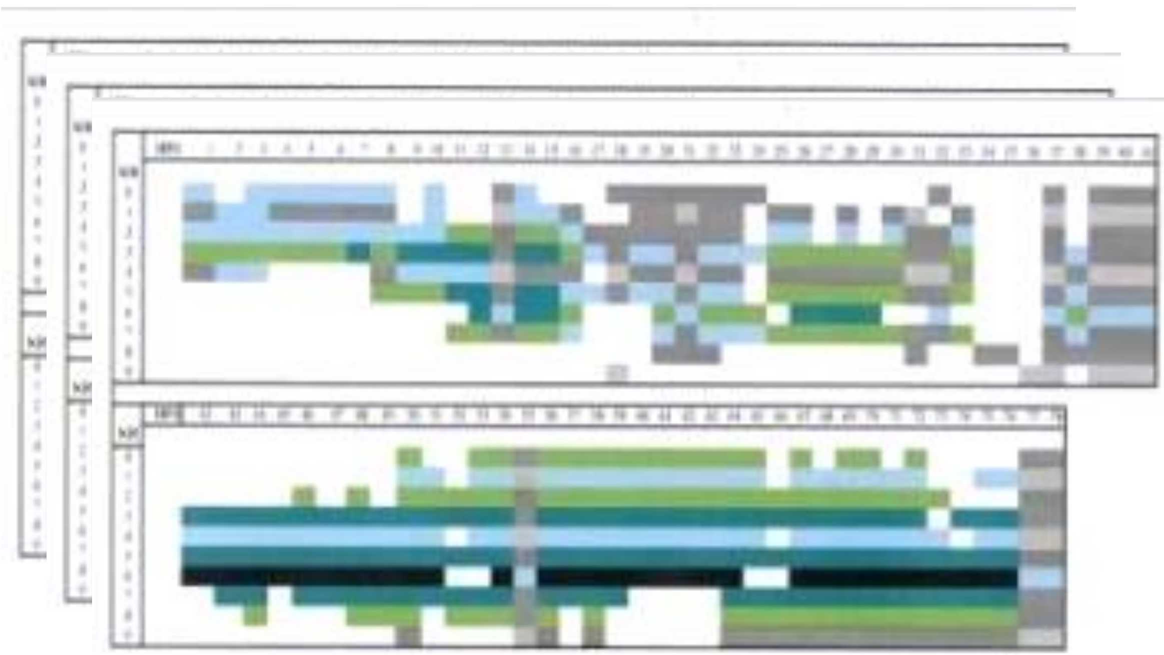
YY: main soil units

(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	-	-	-

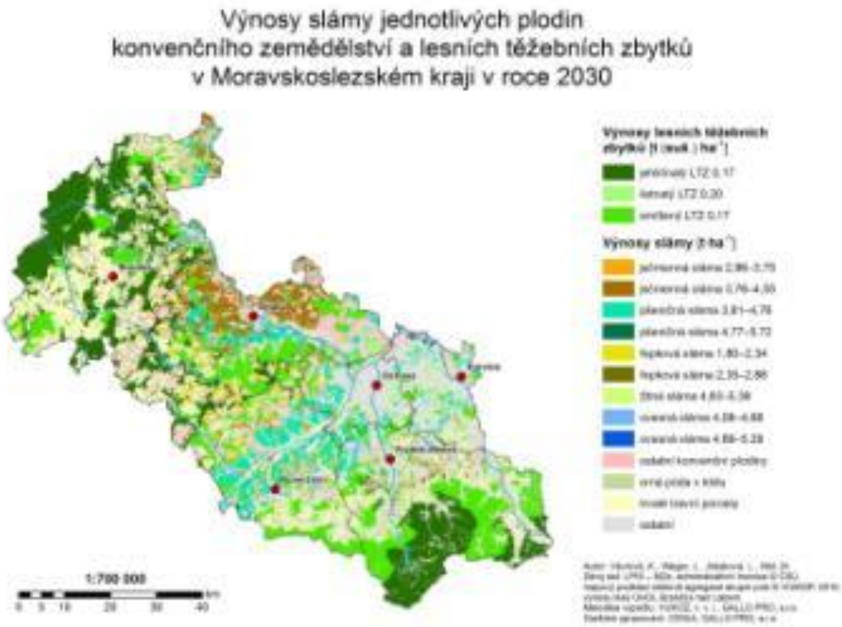
Data for conventional crop

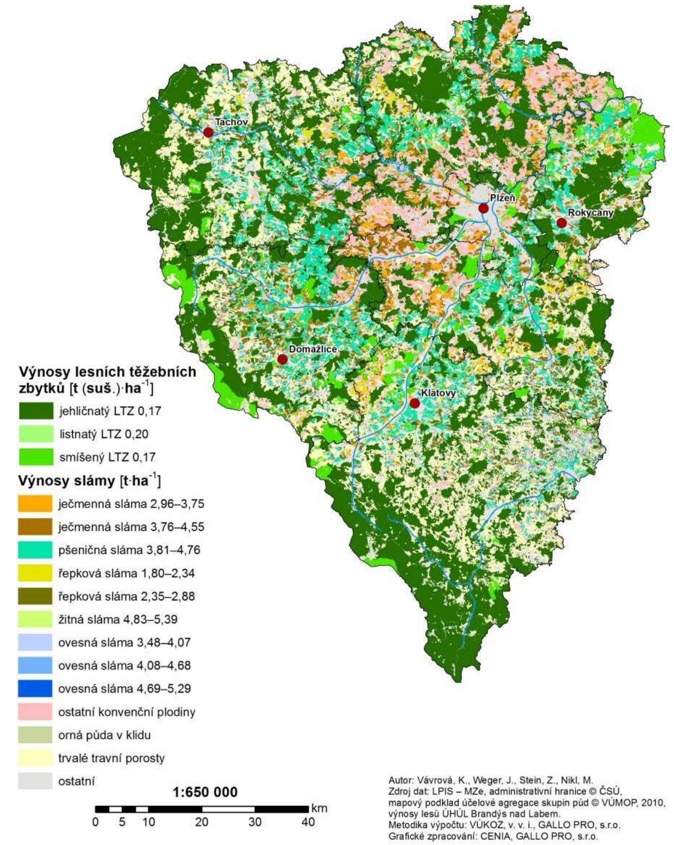
	Straw coeff.	HV in GJ.t^{-1} ,12 % moisture content
Wheat	0,8	15,7
Barley	0,7	15,7
Oat	1,05	15,7
Triticale	1,3	15,7
Rye	1,2	15,7
Rape seed	0,8	17,5

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



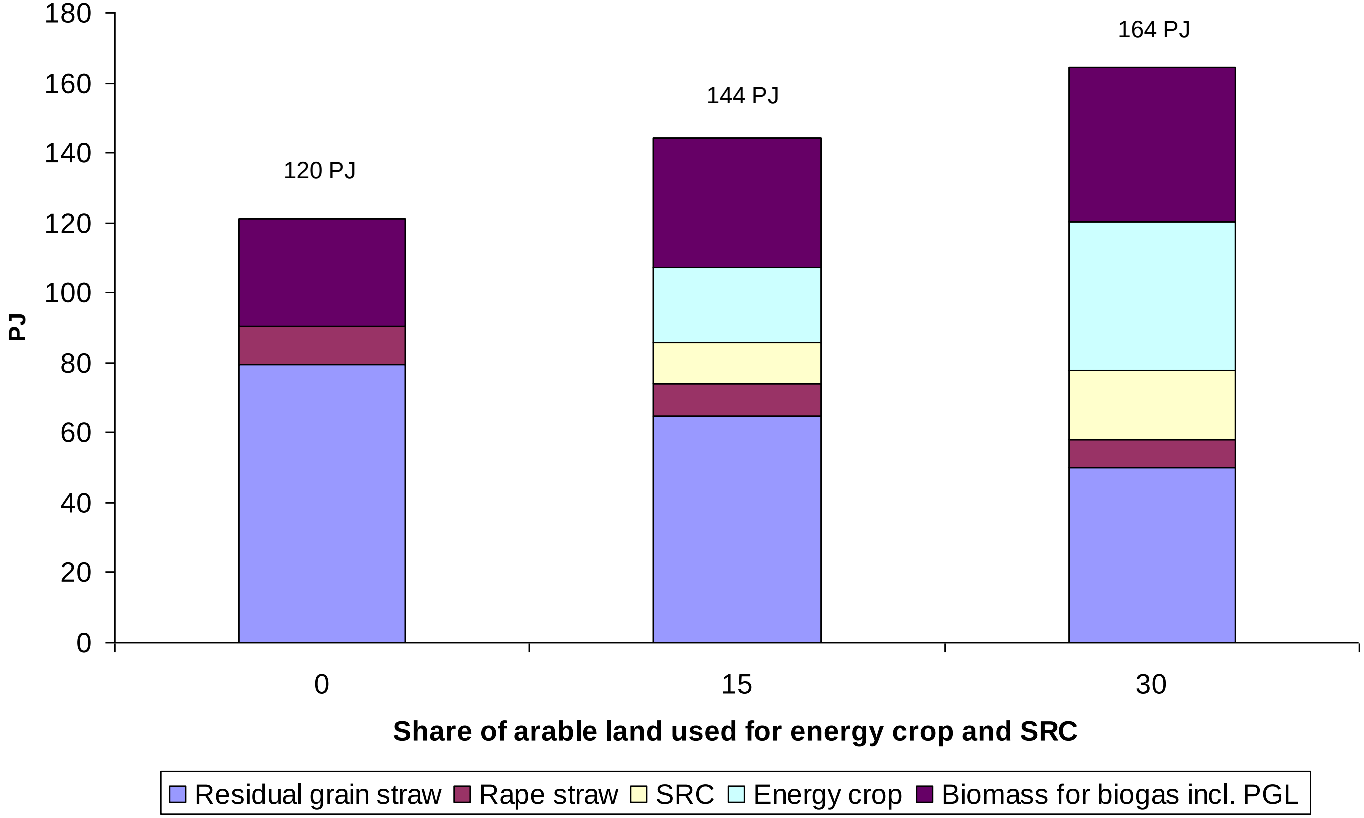


Note: GIS enable graphical presentation of biomass potential distribution in the analyzed area

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.)

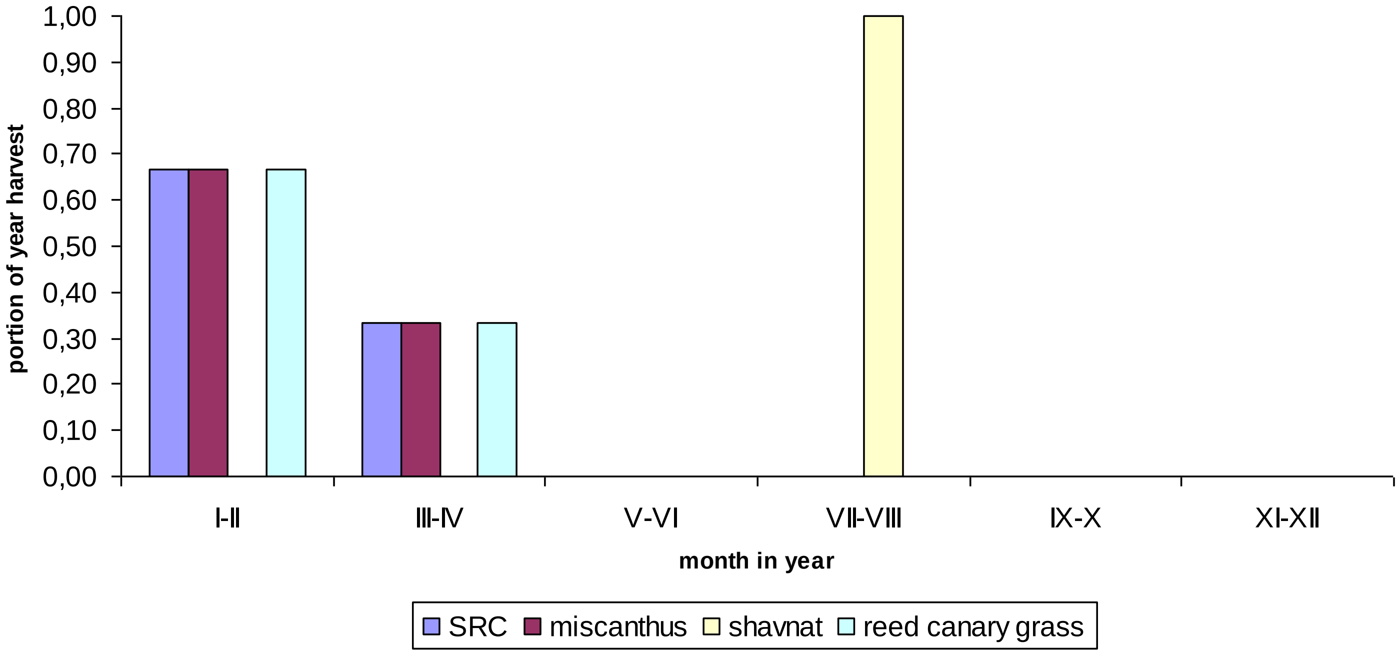
Coming back to biomass potentials - 2

- 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

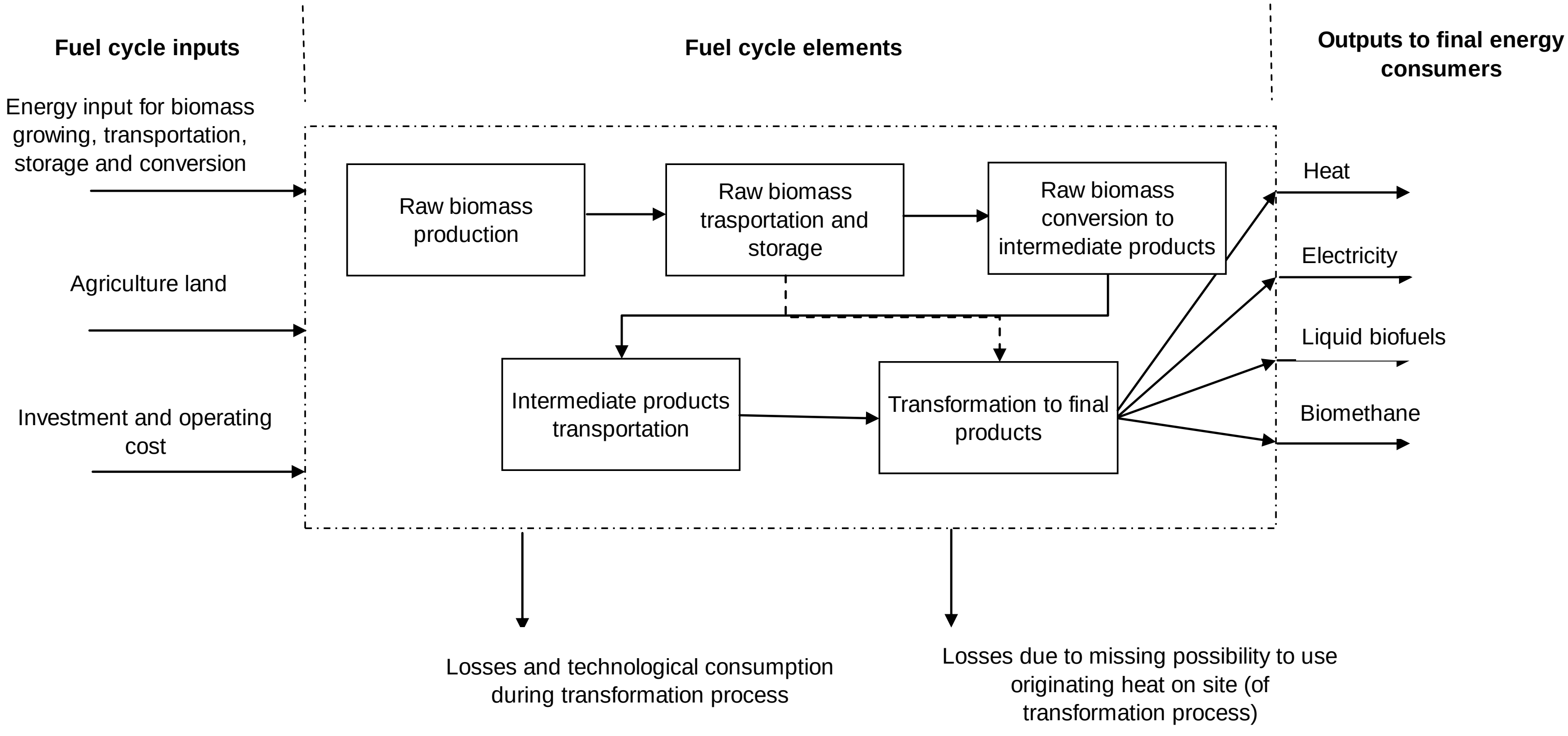
Energy efficiency of land utilization for “energy biomass”

Fuel cycle approach has to be applied

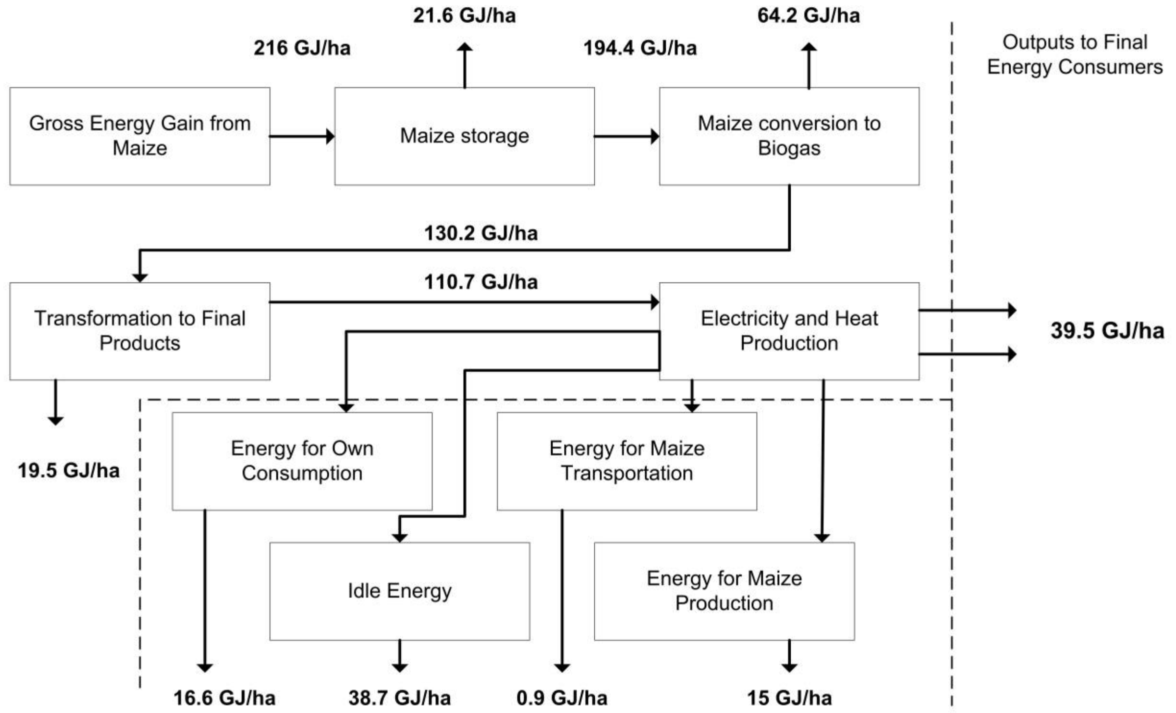
- ❑ losses in the fuel cycle should be taken into account (storage, transformation losses etc.)
- ❑ energy to the final consumers (out of energy branch consumers) plays role only !
- ❑ each biomass fuel cycle is unique – reflects conditions of biomass growing in given country and technologies used
    - ❑ coil and climate conditions in each country are unique – only limited possibility of results transfer to other countries

Energy efficiency of land utilization for “energy biomass”

Fuel cycle approach has to be applied

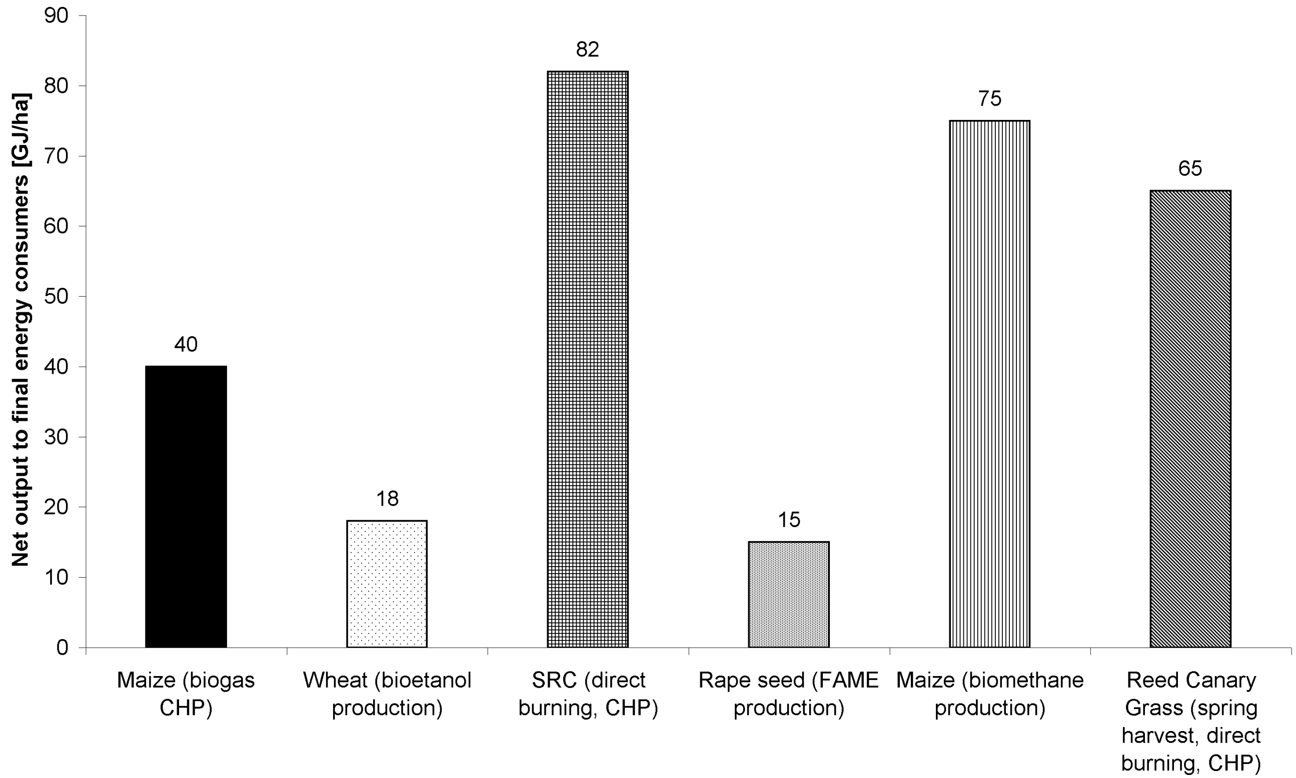


Example of fuel cycle – biogas station



Looking to the useful output from biogas plant fuel cycle – is it the effective way of scarce resources utilization ?

Comparison of several biomass fuel cycles



What are the primary goals of RES utilization ? To diversify PES, to reduce CO2 and other emission, etc. It make sense to search for cost and energy effective strategies

Energy efficiency of land utilization for "energy biomass"

Agriculture land is the (only real) scarce resource !

- necessity to define "optimum" strategy of biomass development – not all the options are reasonable from the energy efficiency point of view

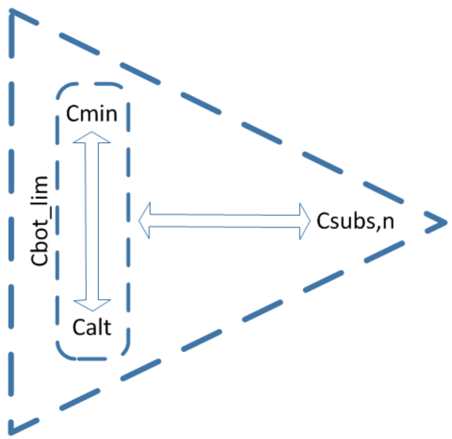
- **"cannibal" effect**
  - land used for food production cannot be used for energy purposes and vice versa
  - increased prices of conventional crop push prices of grown biomass for energy purposes up – rule of the same economic effect not depending on who is customer – biomass is not and esp. will not be cheap source

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)

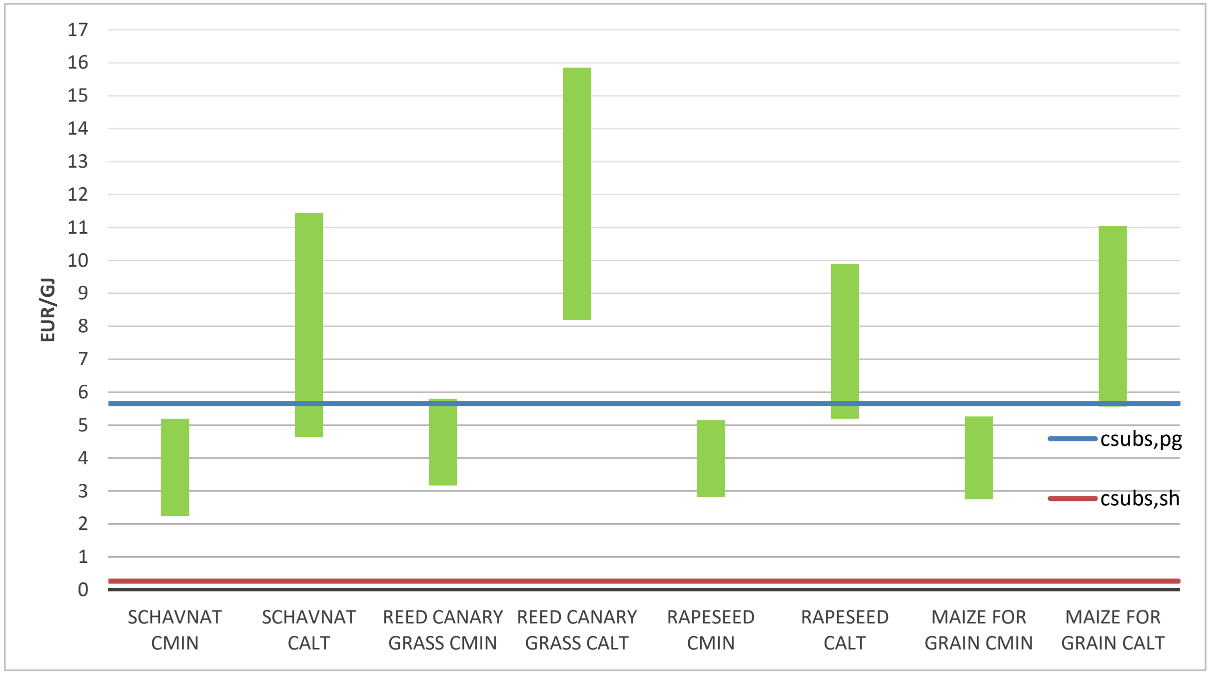
• Cost of technology change

• 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!