SYSTEM ASPECTS OF RENEWABLE ENERGY SOURCES AND PROMOTION SCHEMES

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CONTENT OF LECTURE

⇨RENEWABLE (ENERGY) SOURCES

- ⇨ WHAT ? ⇨ RES definition
- ⇨WHY ? ⇨RES significance
- ⇨CURRENT STATE ? ⇨ EU goals
- ⇨HOW ? ⇨RES effective support

WHAT

⇨ WHAT ? ⇨ RES definition

RENEWABLE (ENERGY) SOURCES

DEFINITION:

- ⇨ **different possible definitions**
  - ⇨ ***e.g. those sources that – assuming gradual utilization – are able to be fully or partly recovered with or without man assisstance***
- ⇨ **Renewable sources utilization**
  - ⇨ **to cover energy needs (power, heat, liquid fuels for transport, cattle)**
  - ⇨ **material utilization (houses, matters of daily need, ships and boats, construction materials, etc...)**
  - ⇨ **food**

RENEWABLE (ENERGY) SOURCES

LEGAL DEFINITION:

EU Directive 2001/77 definition:

- ⇨ renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases);

- ⇨ '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;

Fuzzy border between non-traditional and renewable energy sources

- ⇨ e.g. what is still RES and what belongs to waste category

Sustainability criteria

- ⇨ widely discussed e.g. in relation to liquid biofuels
  - ⇨ ILUC – Indirect Land Use Change
- ⇨ but many of other examples of non sustainable options (e.g. maize and biogas stations – good example of the chain of impacts, e.g. wild boar problem)

ORIGIN OF RENEWABLE ENERGIES ?

Solar energy

⇨ Primary: solar radiation (solar constant 1 367 W/m^2)

⇨ Secondary: Wind energy, wave energy, biomass incl. residual biomass, (potential) energy of water (rivers)

Sun and Moon motion

⇨ Tidal energy

Decay of radioactive elements

⇨ Geothermal energy (+residual Earth energy from the Earth formation

WHY

⇨WHY ?

⇨RES significance

Question for the discussion

- One hectare of agriculture land used either for PV installation or to grow energy crop (e.g. plantation of fast growing trees)
  - What option brings more energy ?
    - How to calculate energy yields ?
  - Are contributions in GJ fully comparable ?
  - What are the savings of CO_2 emissions ?

ADVANTAGES OF RES COMPARED TO FOSSIL FUELS

Why RES has increasing importance in energy policies of developed countries ?

- ⇨ **Non fossil energy sources** – they do not contribute to GHG emissions or can directly contribute to their decrease (e.g. biogas or landfill gas utilization)
- ⇨ RES substitutes classical energy sources – fossil fuels
- ⇨ Biomass – is carbon neutral at principle (but deforestation and utilization of permanent grasslands results in additional C release to the atmosphere

ADVANTAGES OF RES COMPARED TO FOSSIL FUELS

- **Reduction of classical air emissions** – e.g. SO_2, NO_x
- **Reduction of waste** – e.g. solid wastes from burning
- **Saving of non renewable sources -** implication to intergeneration solidarity – concept of sustainable development - contribution towards sustainability
- **Symbol of increasing responsibility** of developed countries in 90's

ADVANTAGES OF RES COMPARED TO FOSSIL FUELS

- **Increases in local employment and income**
  - dominant role of biomass, biomass can help with solving of agricultural policy of EU – opens new business for countryside and agricultural regions
  - diversification of activities (reduction of dependency on fluctuating market with agriculture commodities)
- **Decentralized solutions (?reliability, safety)**
- **Increase of energy independency** - RES are generally accessible (important esp. for PES importing countries)
- **Diversification of energy sources and reduction of import dependency** - increased importance after September 11, 2001

DISADVANTAGES OF RES

- **(very) low density of energy** - large areas to collect enough energy are needed
  - e.g. can biomass substitute coal (fully) in the Czech Rep.?
  - What is the amount of energy collected from one hectare (biomass, PV) ?
- **dependency on external (natural, uncontrolled) conditions**
  - so called dependent production – one cannot mechanically compare kWh from RES and classical sources
  - instant, daily, seasonal fluctuations
- **typically cannot directly compete** with "classical" energy sources

Question for the discussion

- ⇨ What kind of problems potentially exists RES power integration into grid
  - ⇨ What are the cost related with the RES power integration
  - ⇨ What are the possibilities to reduce potential negative influence of RES integration

DISADVANTAGES OF RES

Economic implications:

⇨ Potential distortions of opened energy markets

⇨ needs harmonization of support schemes ??

⇨ Energy markets leads to appraisal (evaluation) of electricity based on its features

⇨ kWh from different sources have different value

⇨ cost of backuping, cost of dynamic services

⇨ Higher utilization of RES cause can decrease national economy competitiveness on global markets

⇨ see CZ case with uncontrolled PV boom

DISADVANTAGES OF RES

The economic and social system is based on centralised development around conventional sources of energy (coal, oil, natural gas and nuclear energy) and above all, around the generation of electricity

from Green Paper on Security of supply, EC, 2001

GROWING DEMAND FOR ENERGIES

⇨ Do we have enough energy for mankind ?

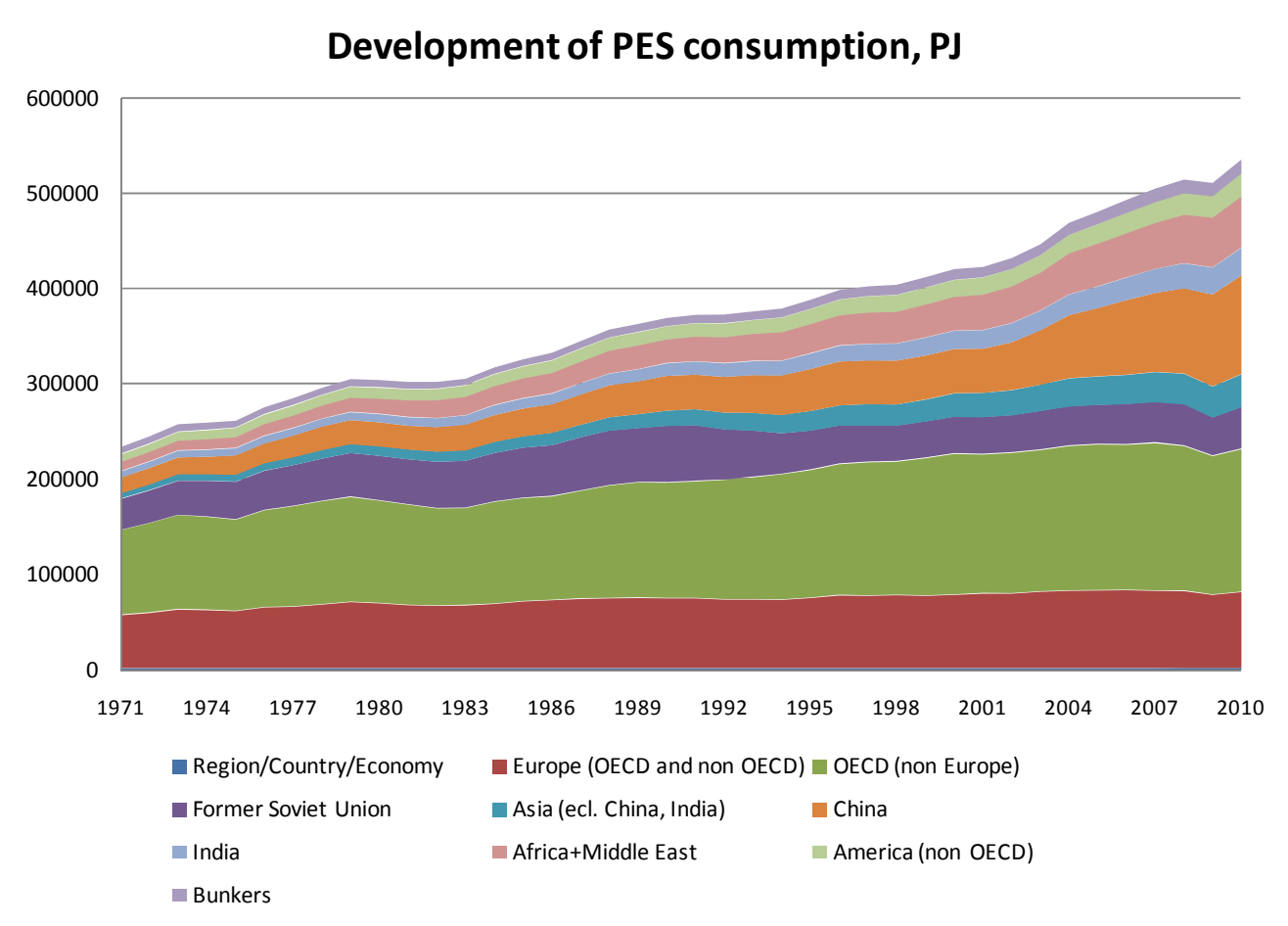
E.g. if potential black-put would exceed 72 hours (CZ analysis) the whole state society infrastructure would collapse

⇨ What is the current role of RES ?

⇨ What are the political aspects ?

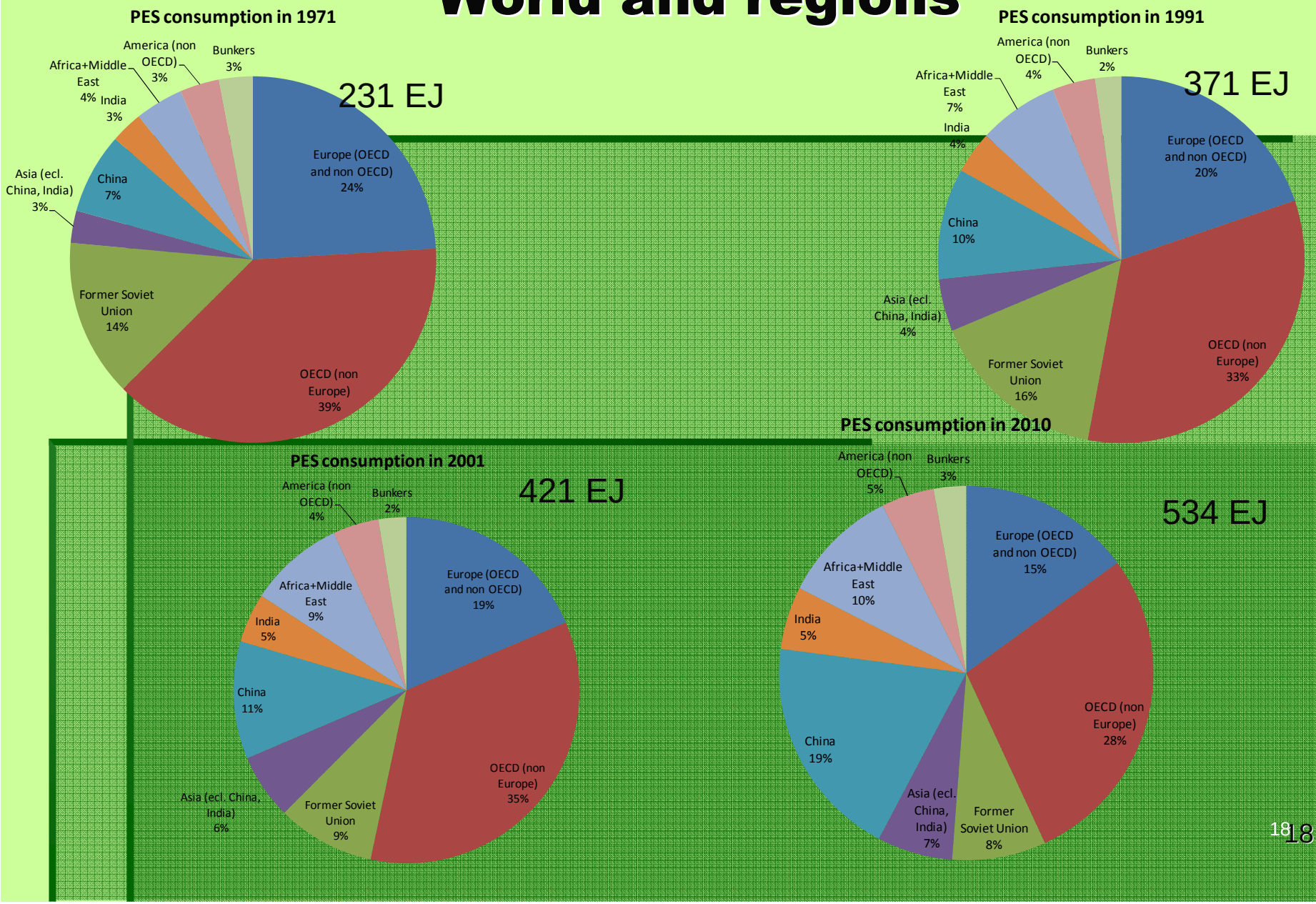
⇨ Is it safe to be dependent on import ?

TOTAL PRIMARY ENERGY CONSUMPTION

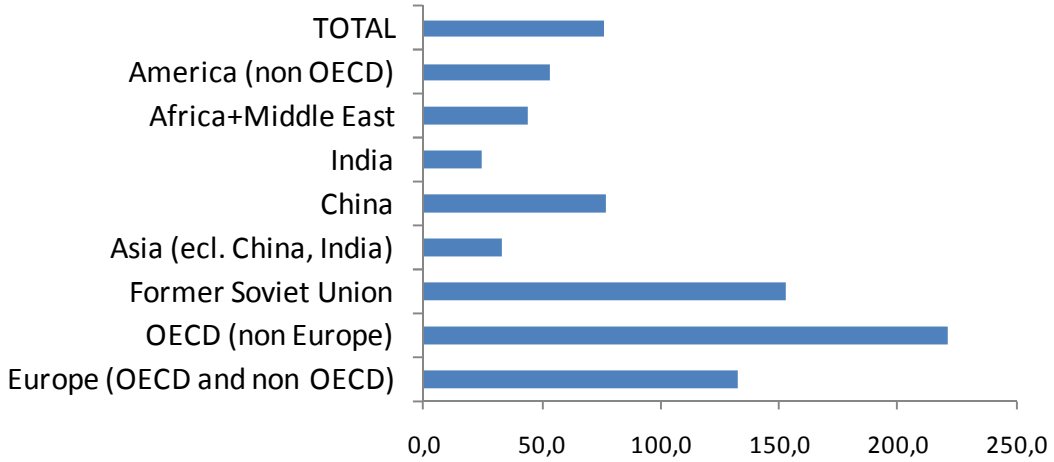


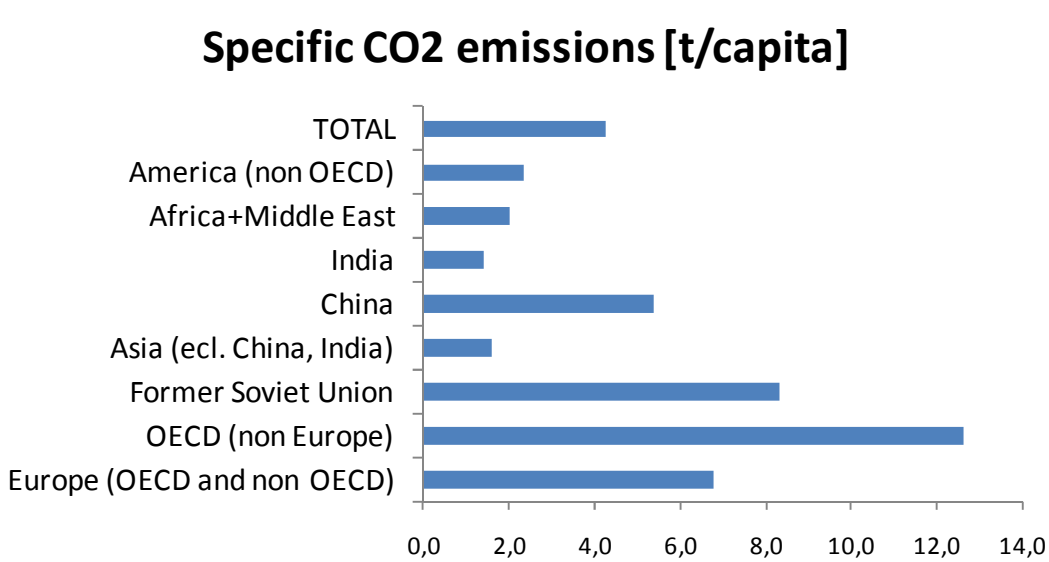
	1971/81	1981/91	1991/01	2001/10
EU28	1,6%	1,1%	0,5%	-0,1%
OECD	1,6%	1,4%	1,5%	0,2%
Rest of the world	4,0%	2,9%	1,1%	4,4%
Total	2,6%	2,1%	1,3%	2,4%

TOTAL PRIMARY ENERGY CONSUMPTION
World and regions

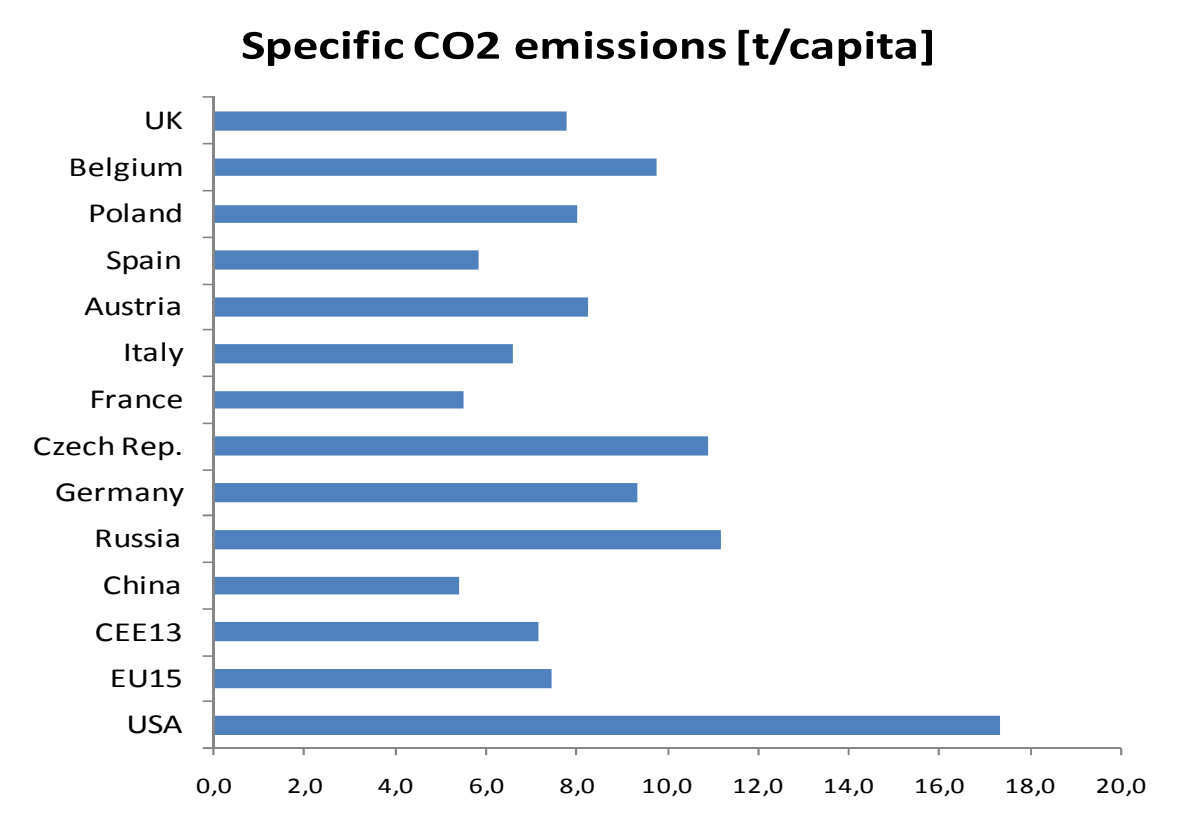


Uneven PES consumption and CO_2 emissions





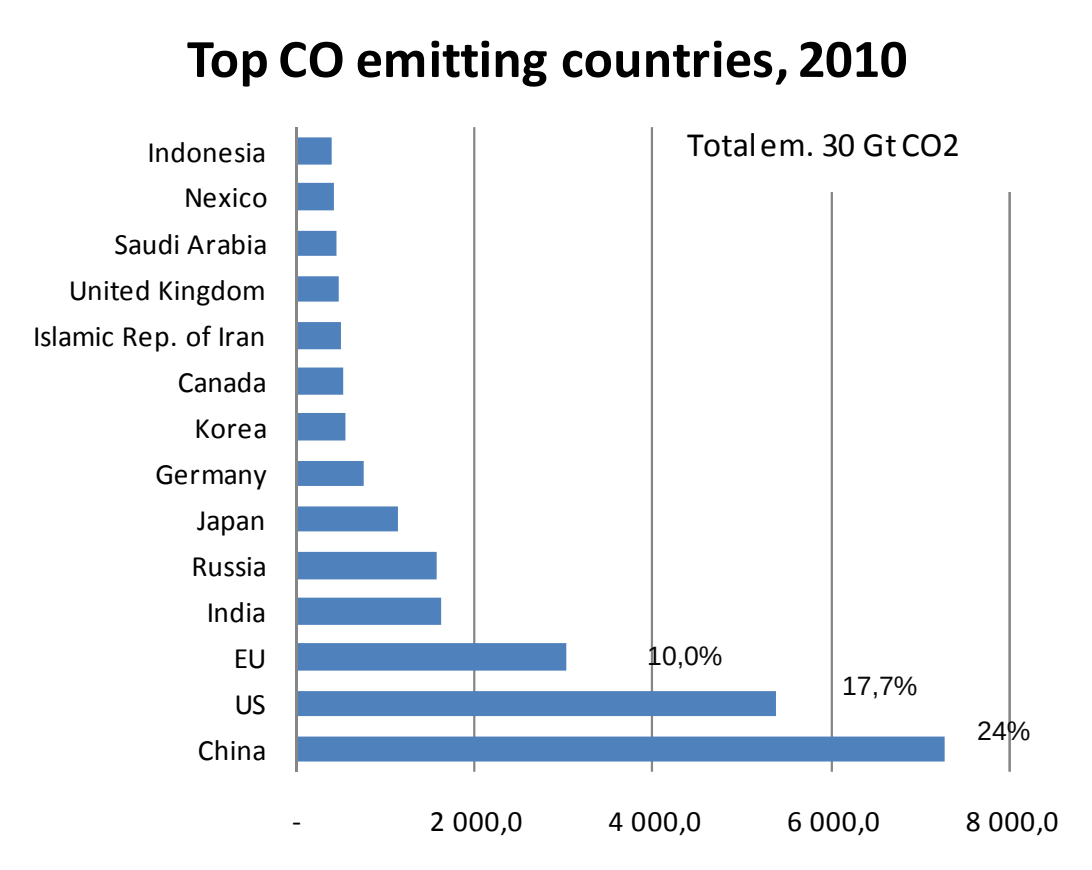
Uneven CO_2 emissions also in case of MDC



Factors:

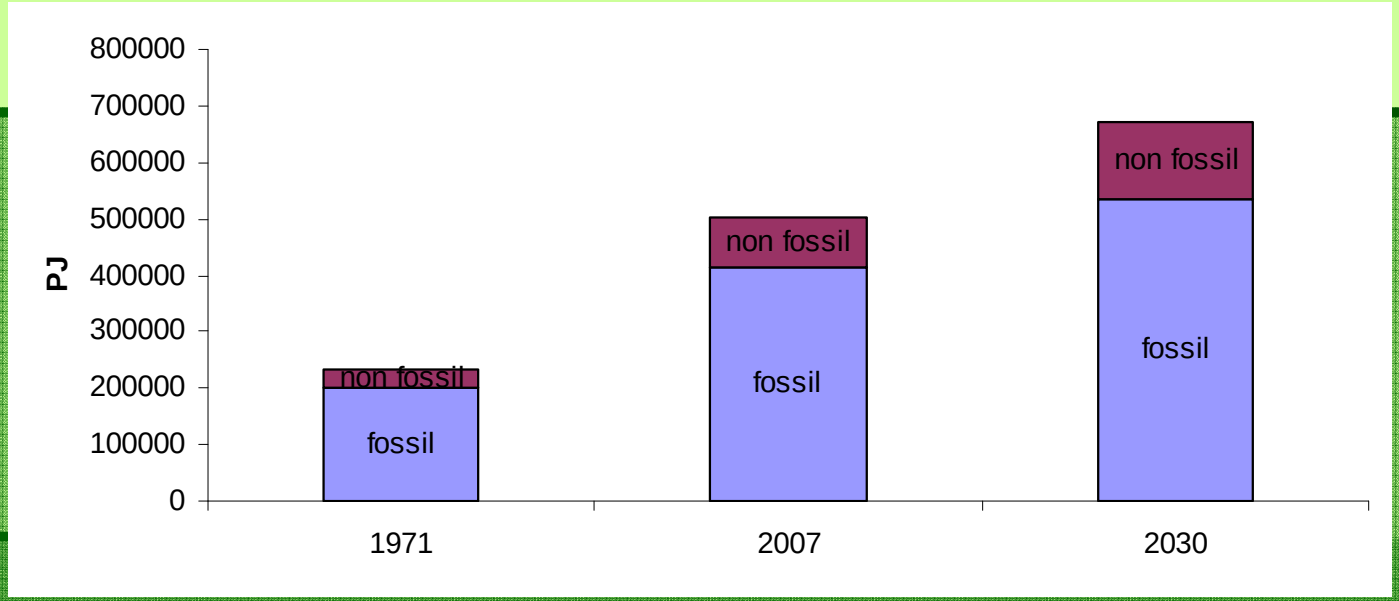
- structure of economy and its power (living standard)
- portfolio of PES used (coal 100% emissions, NG 60%)
- power export/import
- climate and other

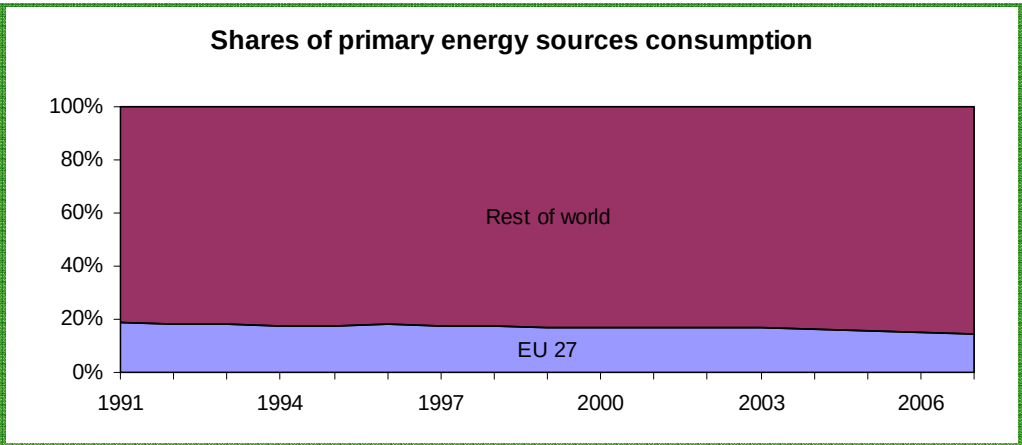
Top CO_2 emitting countries



EU can be the leading country in CO2 mitigation, but cannot stay alone !

TOTAL PRIMARY ENERGY CONSUMPTION
An outlook – reference scenario

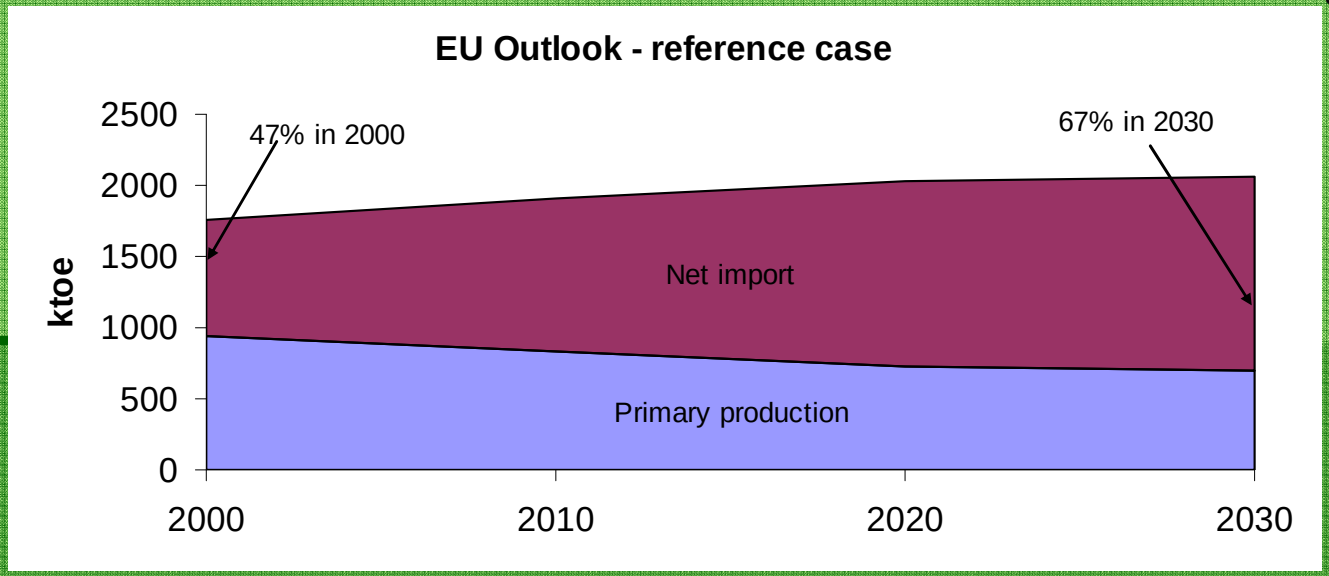




INCREASING DEPENDANCY ON IMPORT

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
All products	47,8	48,6	48,8	*50,2*	*51,6*	53,9	55,2	54,5	56,3	55,2	54,1
Solid fuels	30,5	33,7	33,1	34,9	38,1	39,3	41,0	41,3	44,7	41,1	39,4
Crude oil	75,6	77,7	76,4	78,7	80,9	82,4	84,0	83,5	85,0	84,2	85,2
Natural gas	48,9	47,2	51,1	52,4	54,0	57,7	60,8	60,3	62,3	64,3	62,4

Source: Eurostat

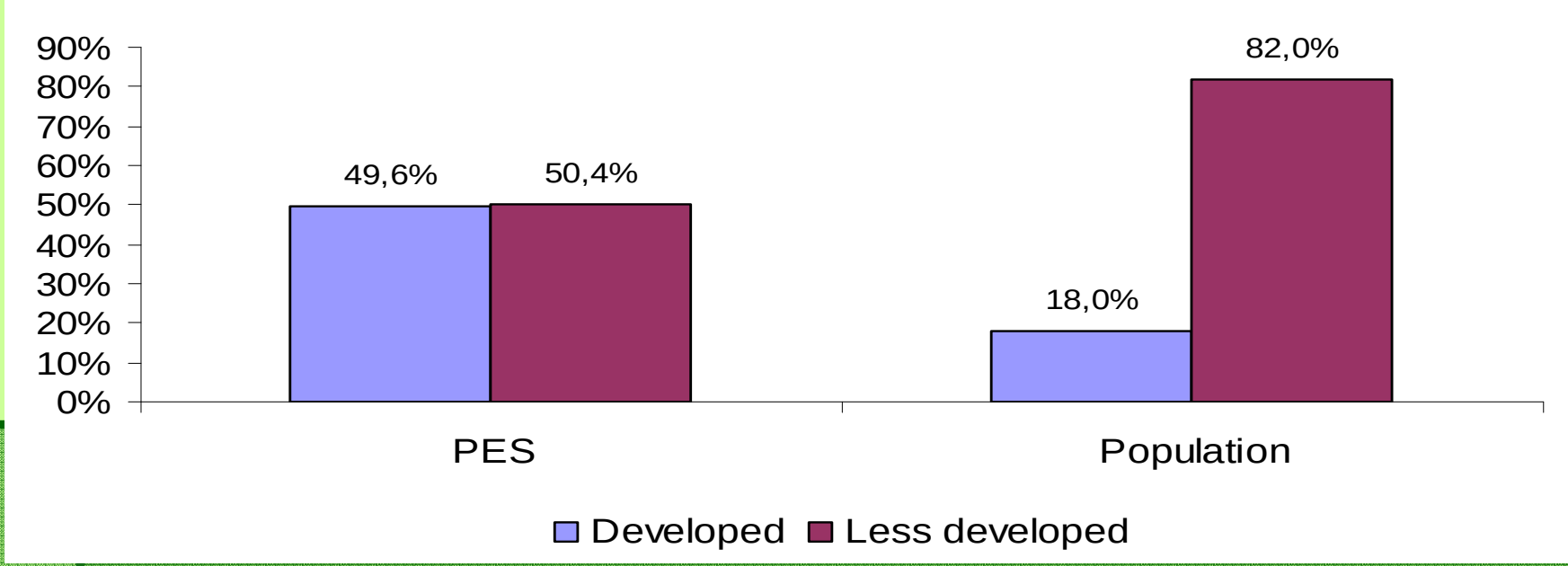


Import of PES plays very sensitive role in EU policy

⇨ EU depends on oil and gas import, from what countries ?

⇨ where are the new possible sources ?

UNEVEN ENERGY CONSUMPTION



⇨ share of developed countries on total source consumption differs significantly by source

UNEVEN ENERGY CONSUMPTION

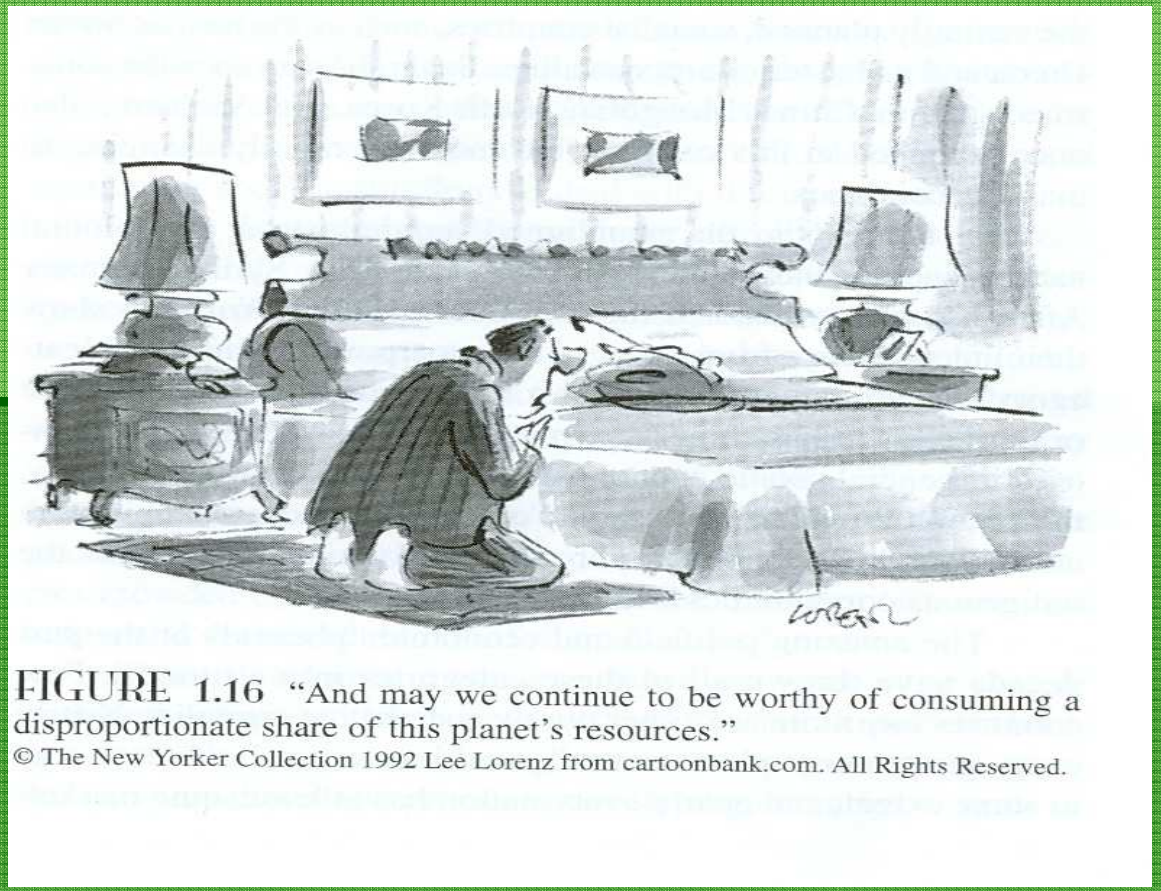


FIGURE 1.16 "And may we continue to be worthy of consuming a disproportionate share of this planet's resources."

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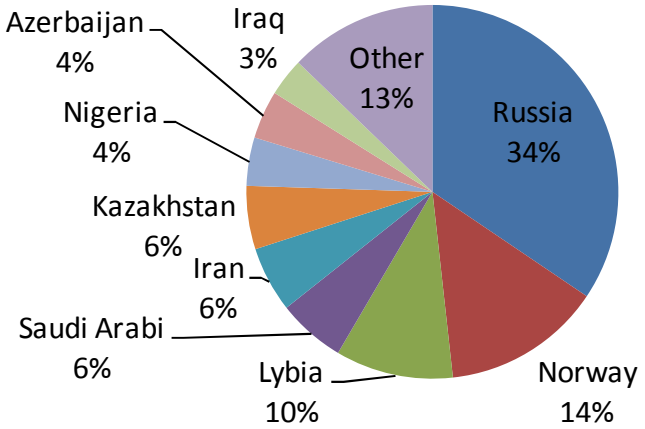
WE CANNOT FORGET FOR SECURITY AND RELIABILITY !

PES - SECURITY ISSUES

- From where do we import oil and gas ? What is political context ?

Struture of oil import into EU, 2010

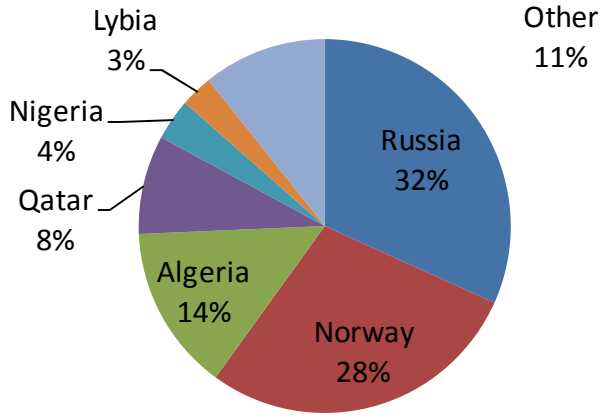


Obligatory emergency oil reserves for 90 days at least

What is the role of shale gas ?

Some countries have significant natural gas storage capacitites – e.g. Czech Republic up to 35% total year consumption

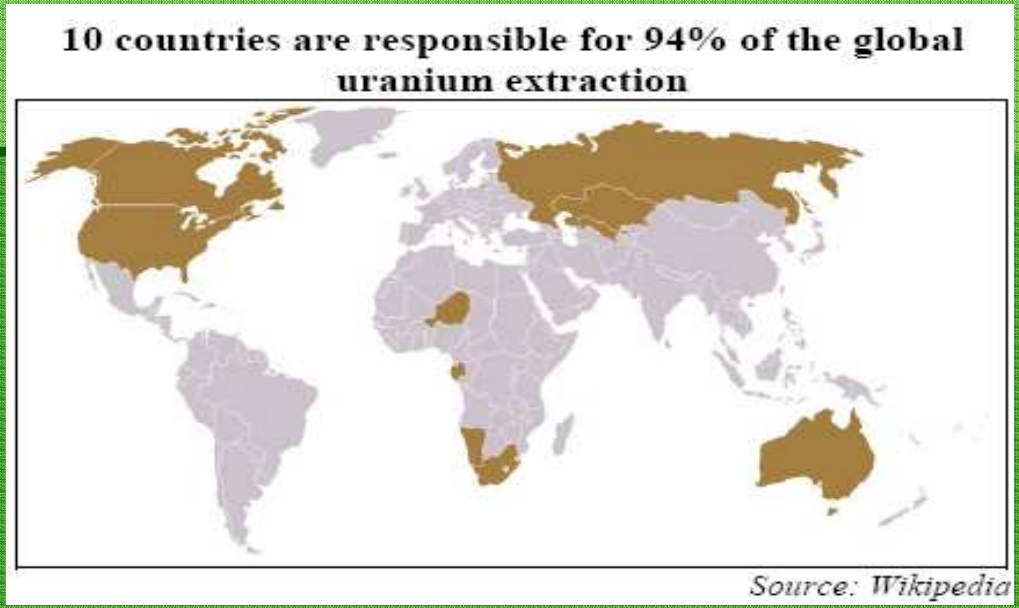
Structure of EU import of NG, 2010



NUCLEAR FUEL

Where are the reserves of urainum ?

- 1st EU country is on 12th position only (Czech Republic) !
- relatively easier to build strategic reserves



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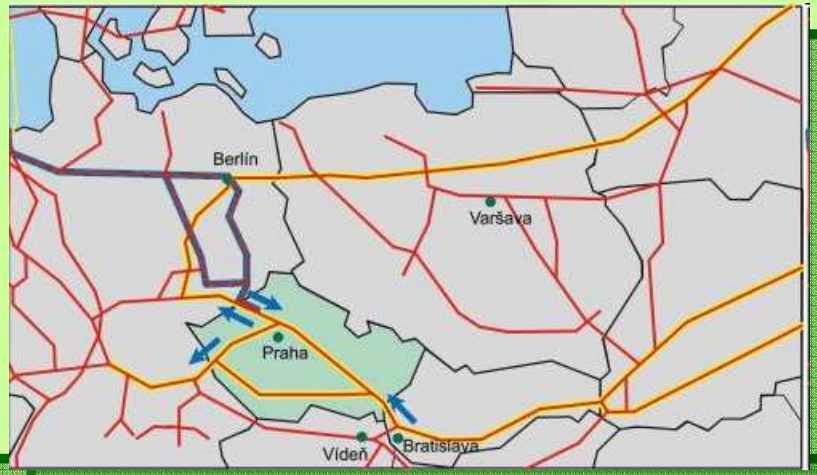
TRANSPORTATION SECURITY AND RELIABILITY

How to get oil and gas from producing sites to the consumers ?

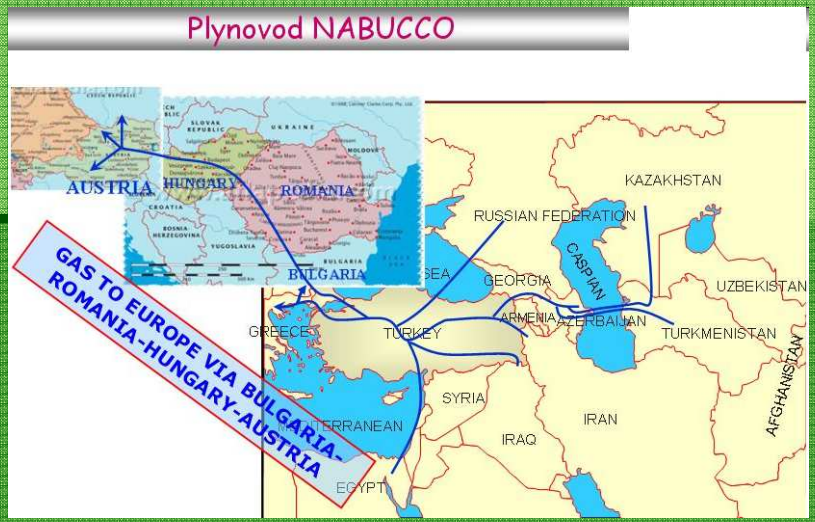
Oil pipelines in Europe

TRANSPORTATION SECURITY AND RELIABILITY

Natural gas pipelines in Europe



Why we had troubles in beg. of 2009 with natural gas from Russia ?



Projects

- NordStream (from Russia to Germany through Baltic sea)
- SouthStream (from Russia to SouthEast Europe through Black Sea)
- new facilities for LNG

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CURRENT ROLE OF RES IN EU

EU targets:

- ⇨ **White paper:** doubling the share of renewables in global energy consumption from 6 % in 1997 to 12 % in 2010
- ⇨ **EU Directive 2001/77:** increase of share from 13,9% in 1997 to 22,1% in 2010 – power generation
- ⇨ **Climate – energy package to 2020 (4 directives)**
  - ⇨ 20/20/20 target
  - ⇨ 20% GHG reduction (2020 against 1990) – possibly 30% in case of effective world action
  - ⇨ 20% RES energy share on final energy consumption – differs by country
  - ⇨ 10% of biofuels
  - ⇨ **New RES directive 28/2009, NREAPs as the road maps for individual countries**

CURRENT ROLE OF RES IN EU 2

EU targets:

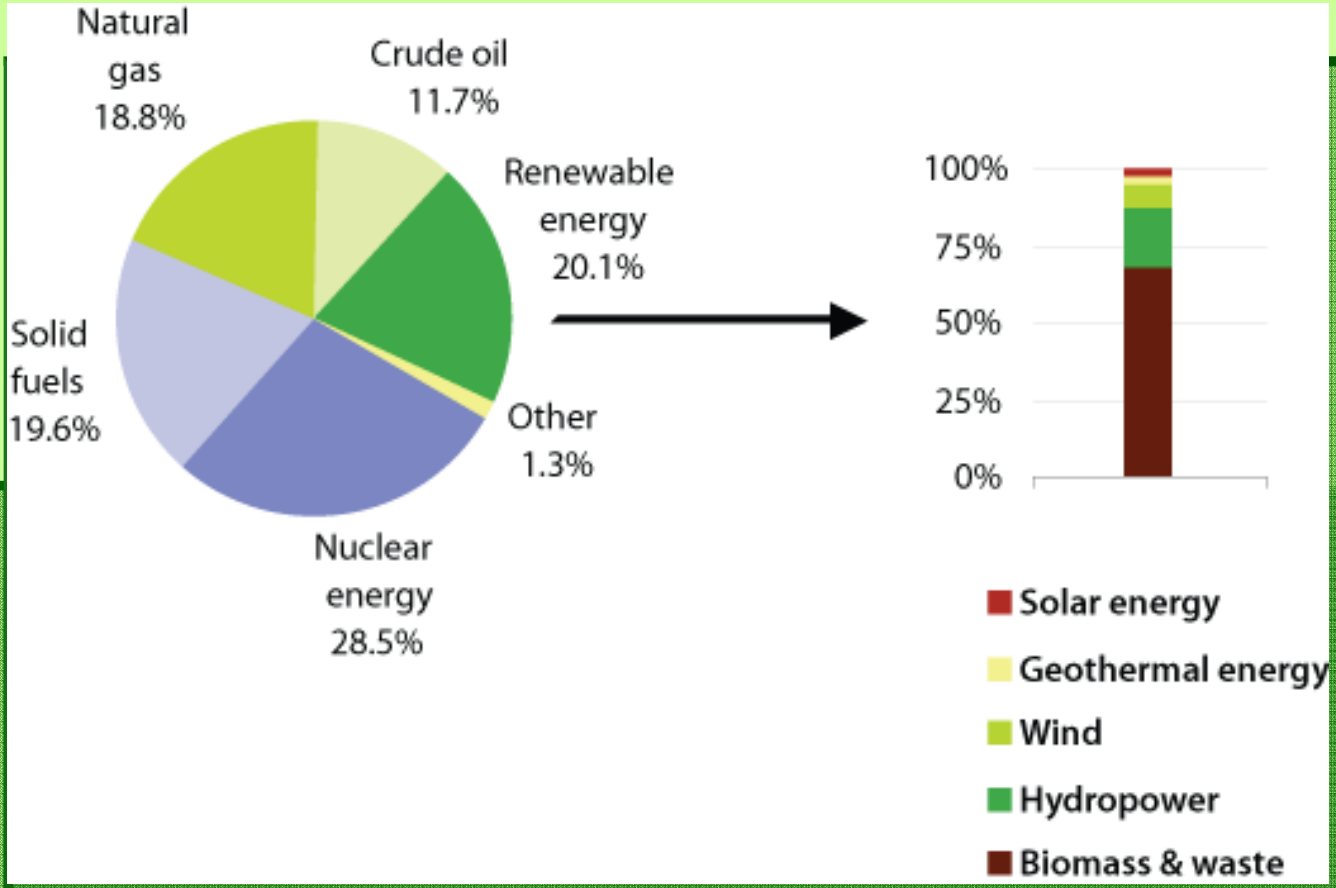
- **Goals to 2030 (January 2014)**
  - 40 % GHG reduction
  - 27% share of RES
    - expected RES share for power generation: 45%

- Wide discussion on the logic of the two (redundant to some extent) targets

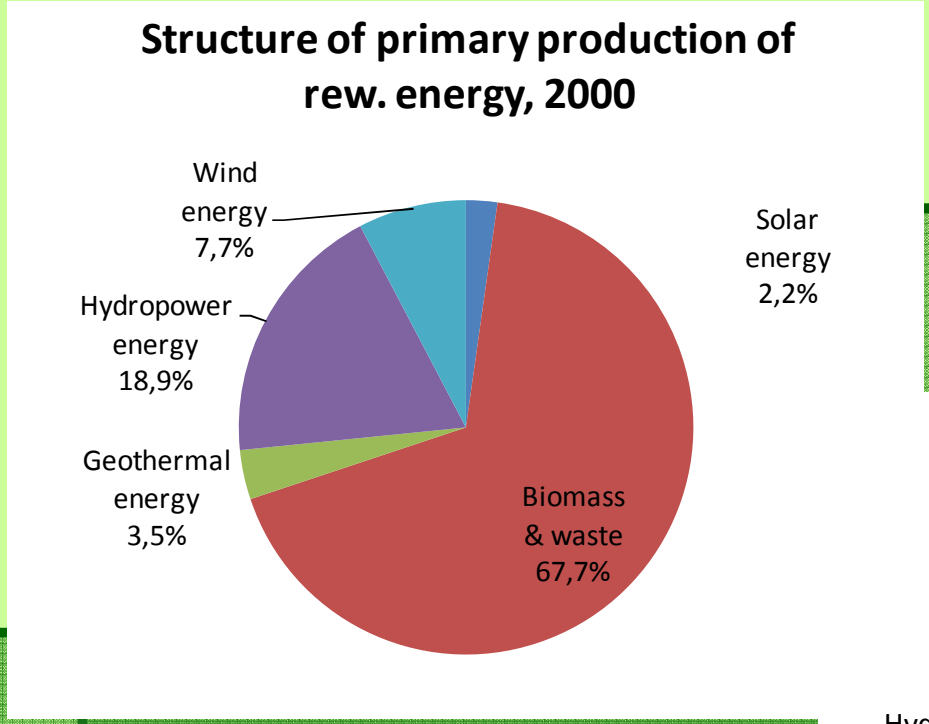
- Even much more ambitious targets in Energy Road Map to 2050

Significance of individual RES kinds

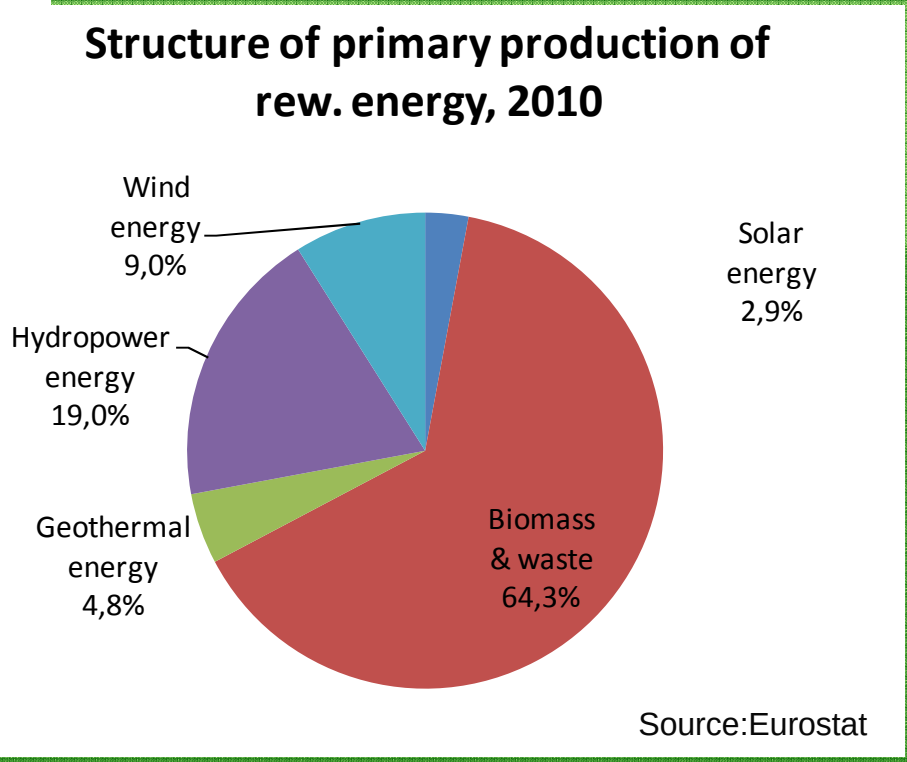
Share of RES on primary energy, EU 2010 Source:Eurostat



Significance of individual RES kinds, EU



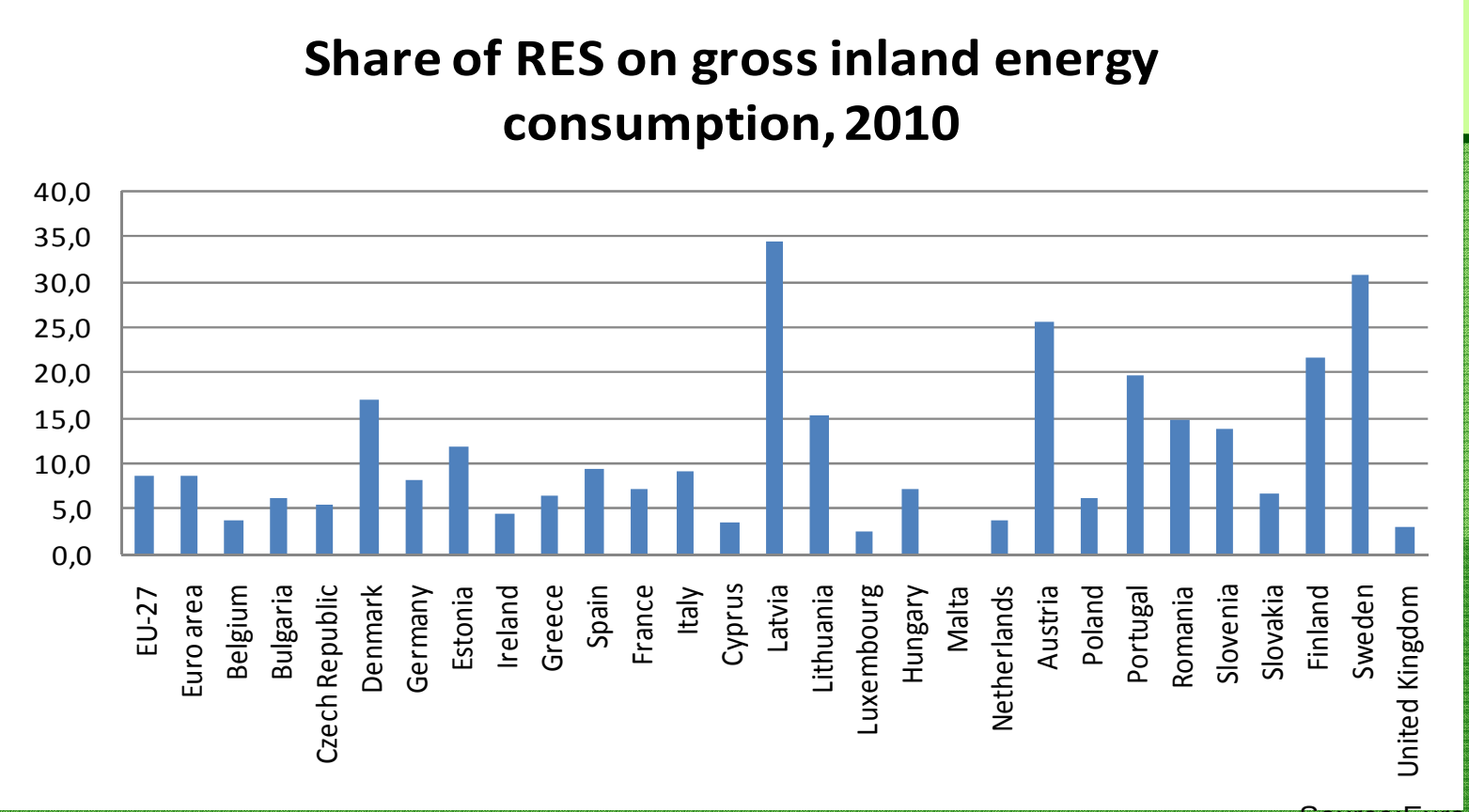
EU 27 RES statistics RES as the primary energy



Source:Eurostat

Biomass plays and is expected to play the decisive role

Current RES importance, EU

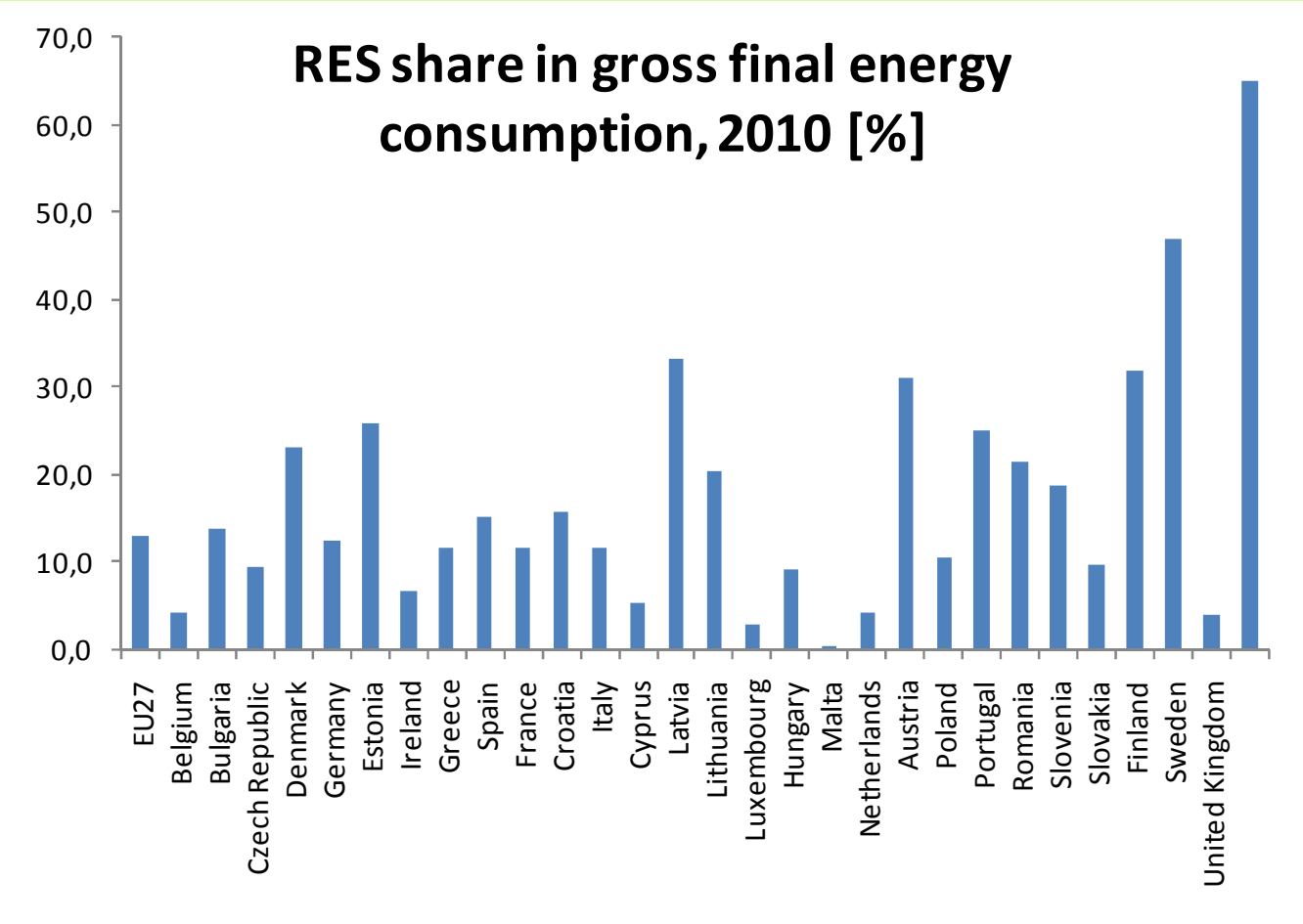


Source:Eurostat

Each country is unique (natural conditions, history, structure of economy and its power, ….)

Significance of individual RES kinds

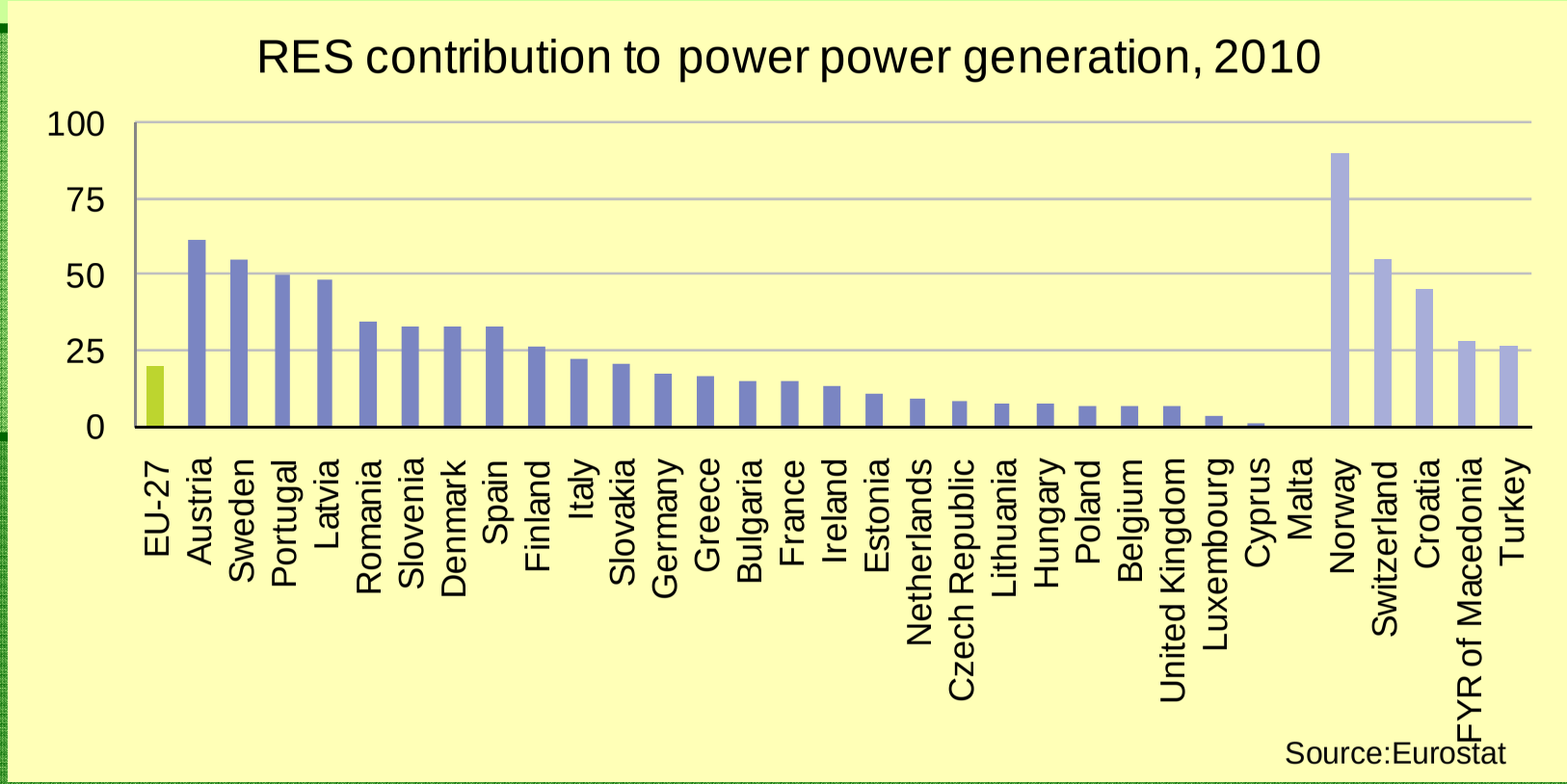
Share of RES on gross final consumption of energy, 2010



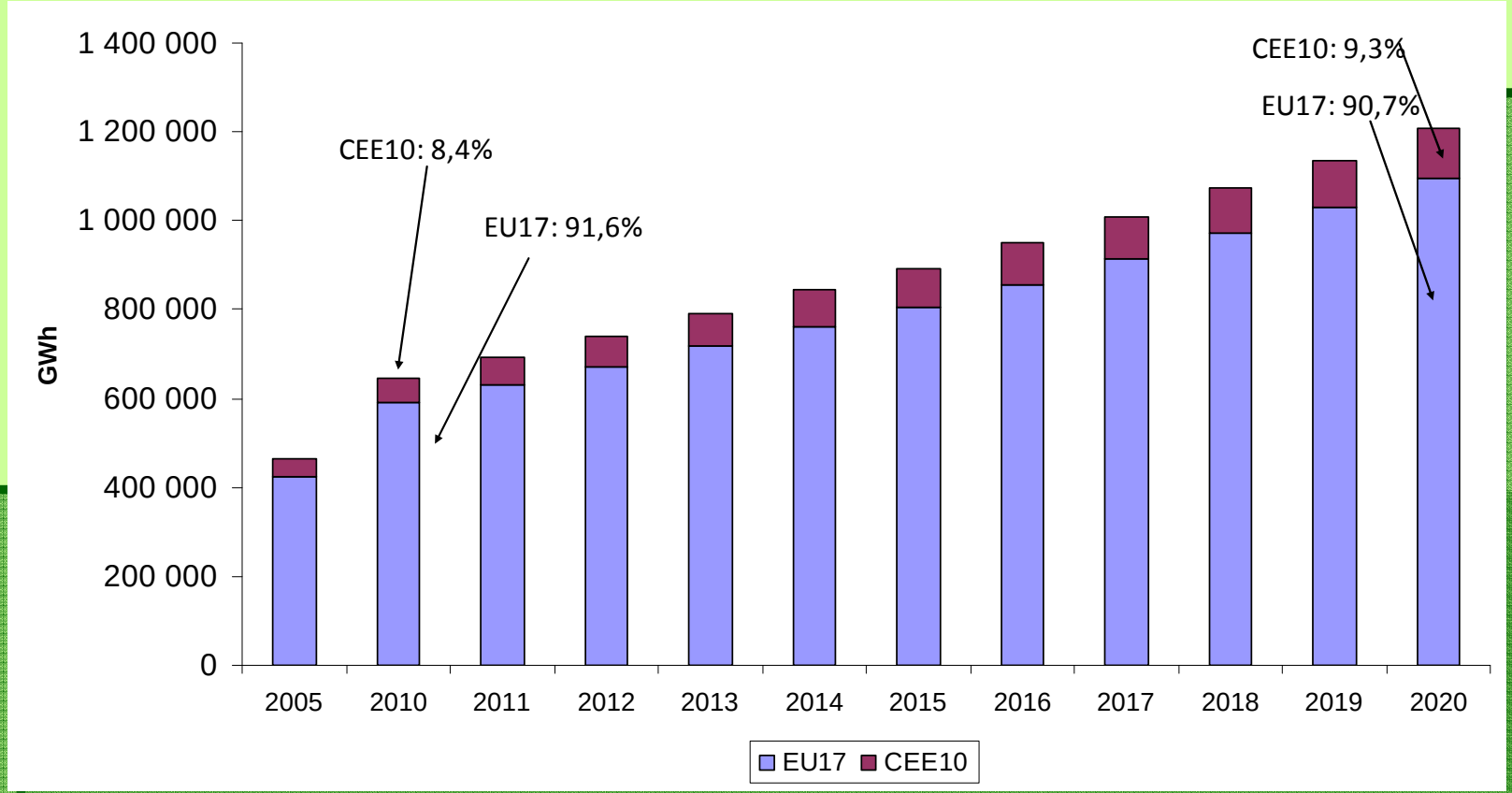
Source:Eurostat

Current RES importance

Power generation

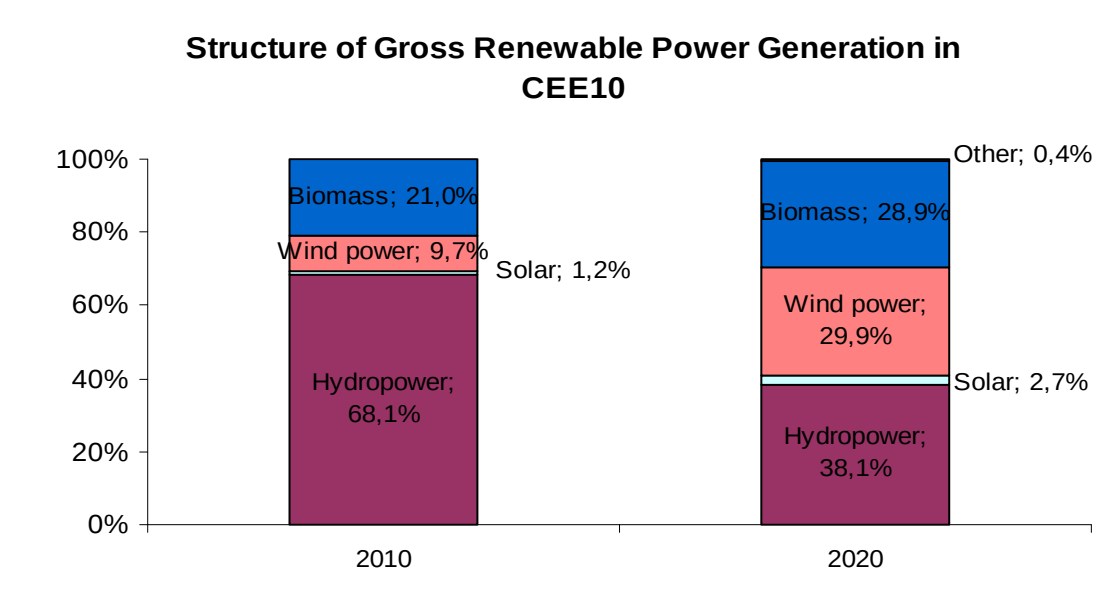


Estimation of gross renewable power generation according to group of countries

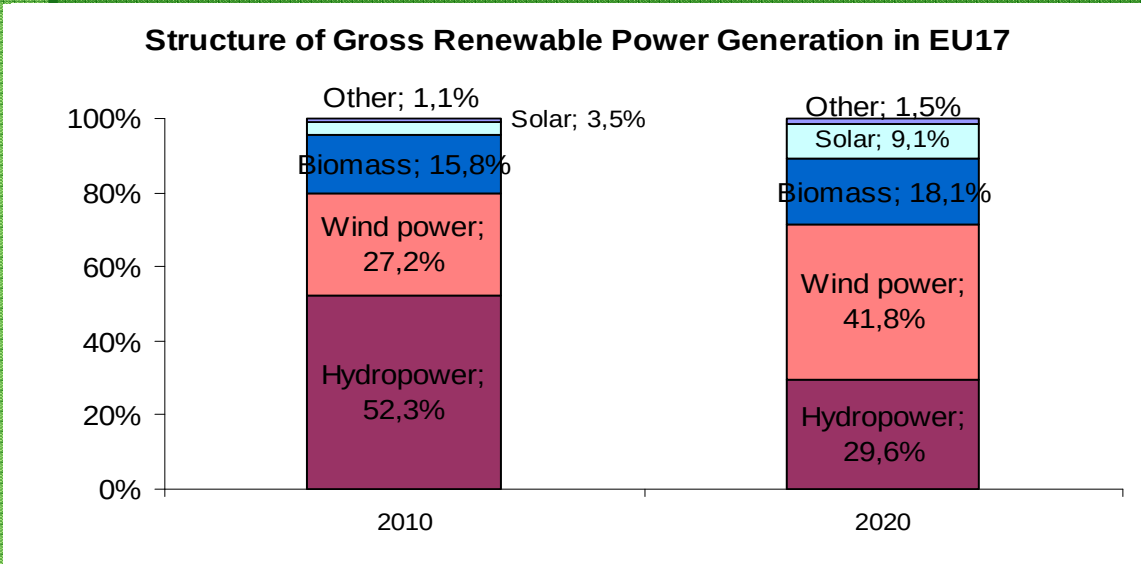


CEE10: 2010 to 2020 growth: 109%, **EU17:** 2010 to 2020 growth: 85%

Current RES importance



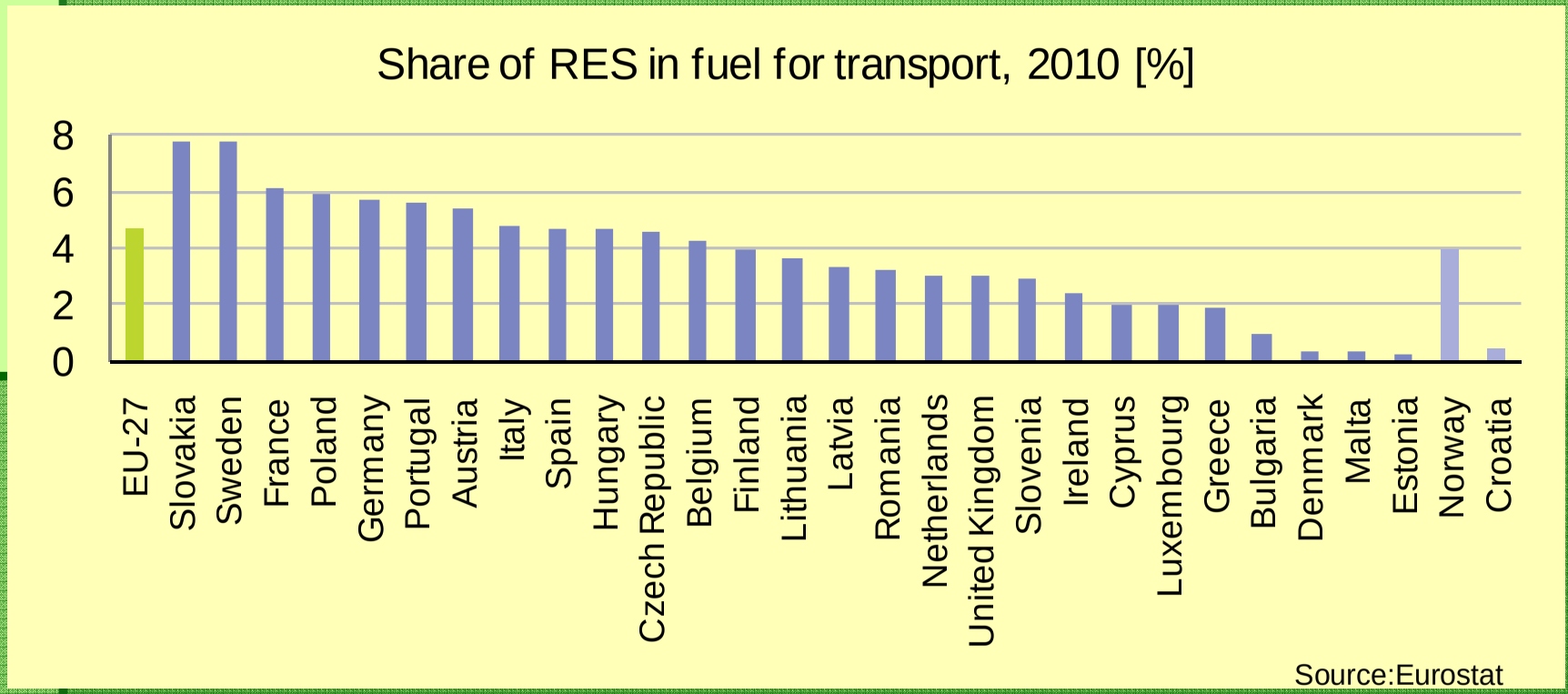
CEE10: depend more on biomass



EU17: depend more on PV and wind

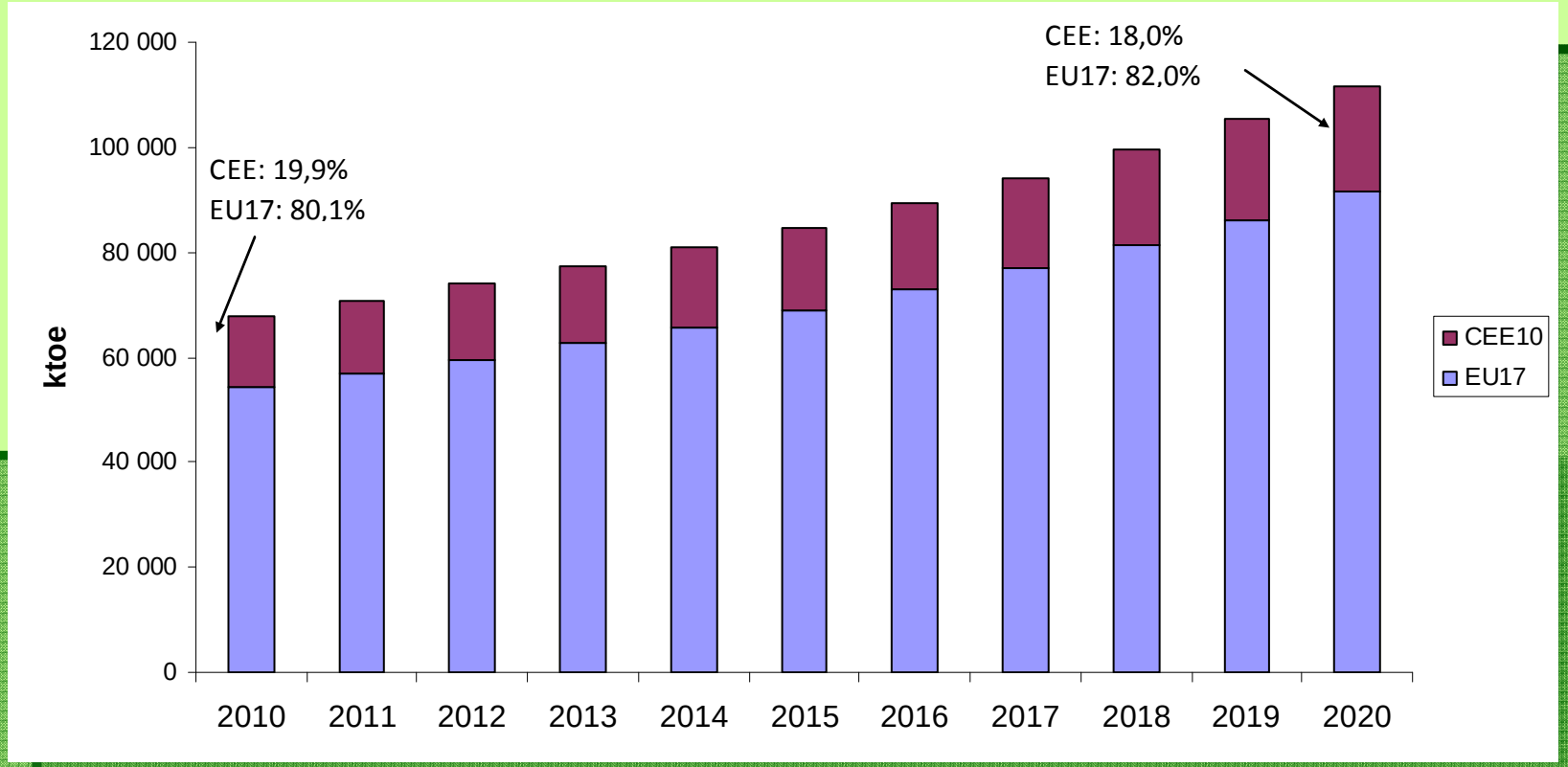
Current RES importance

Transportation



Current RES importance

Heating and cooling

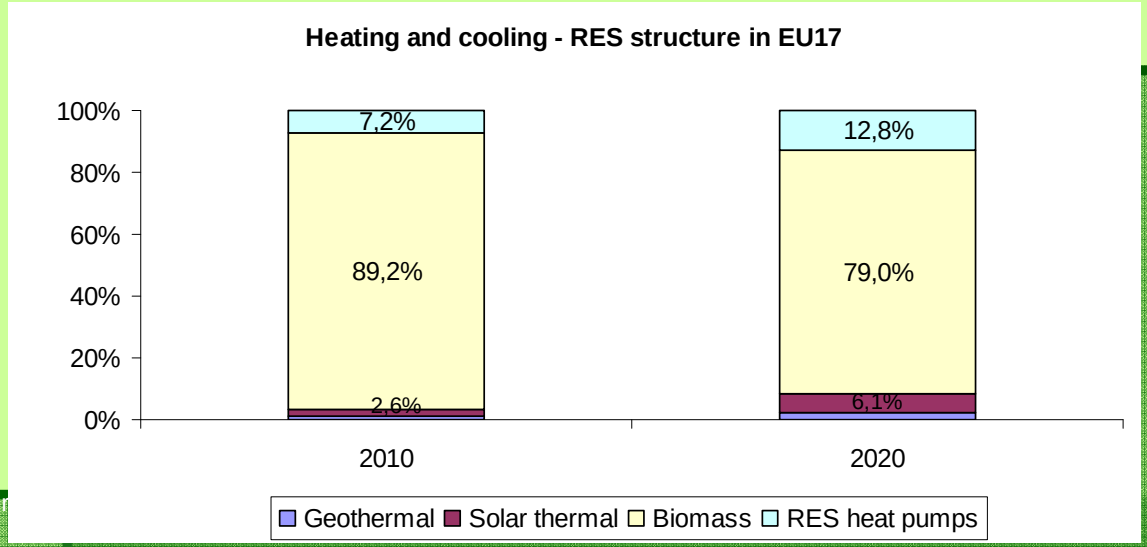


Source: NREAPs

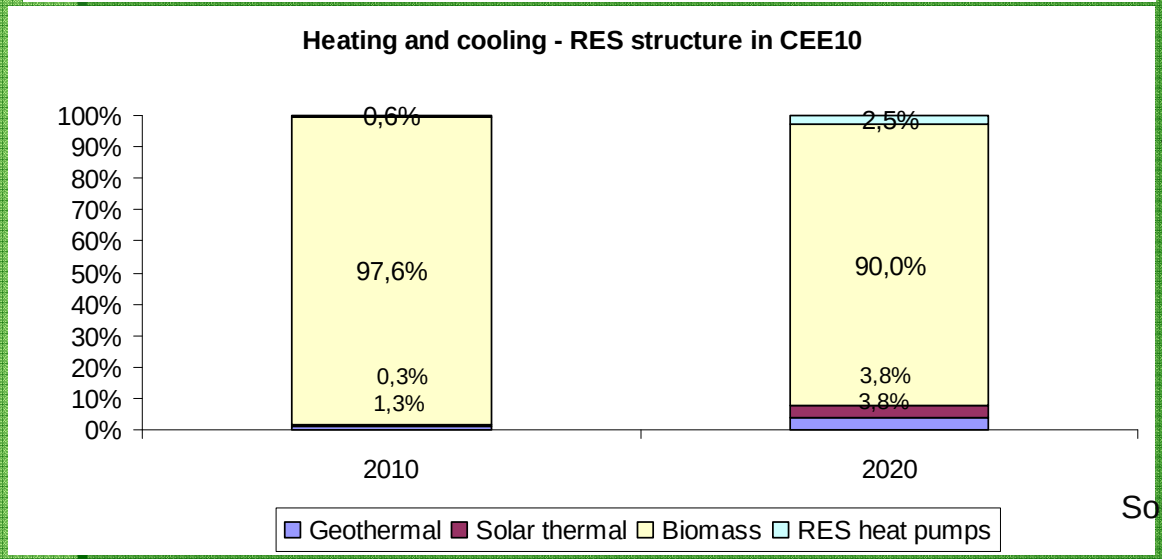
CEE10: 2010 to 2020 growth: 48%

EU17: 2010 to 2020 growth: 68%

Current RES importance



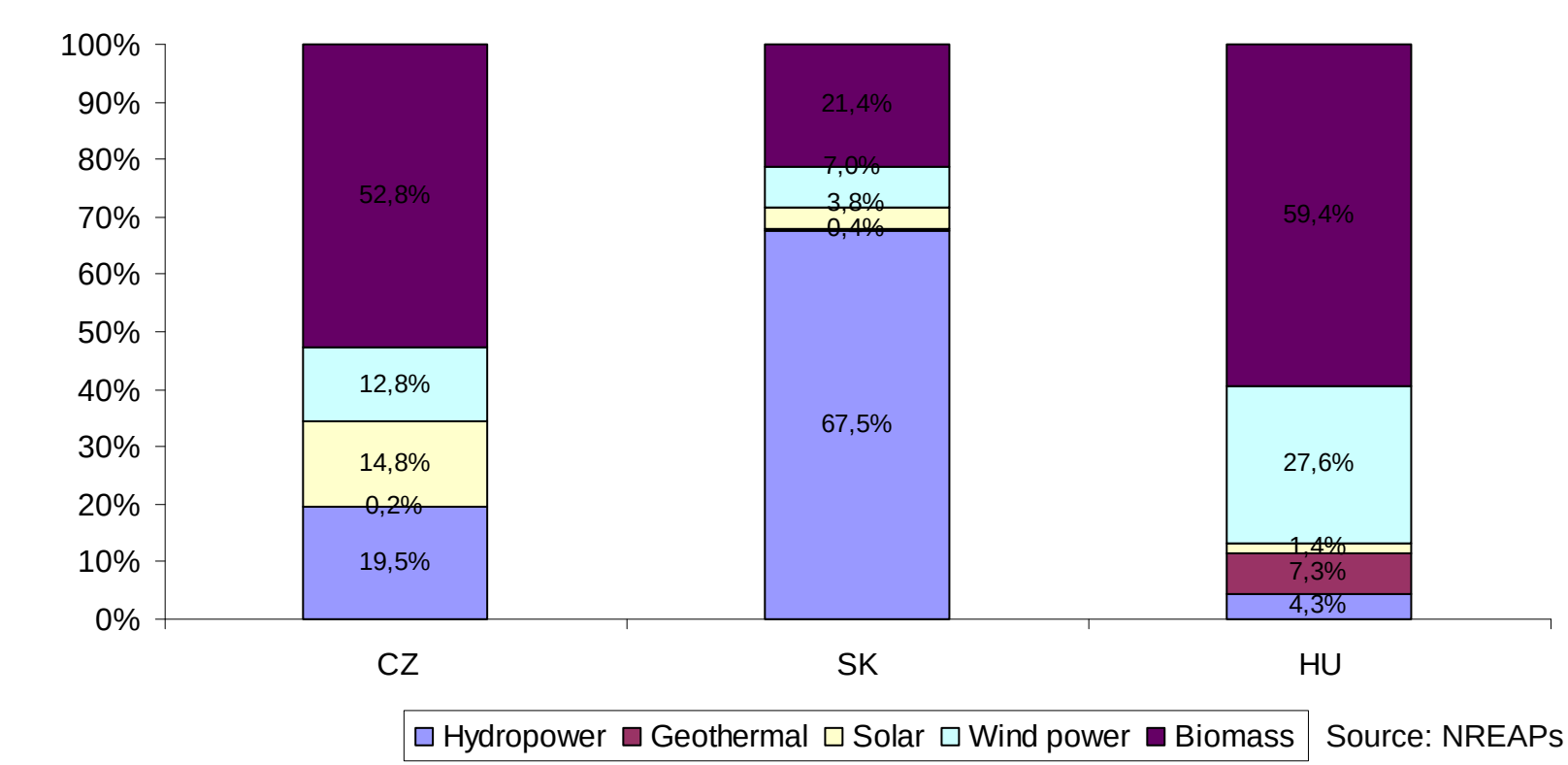
EU17: increasing share of solar thermal and heat pumps



CEE10: biomass still play the key role

Source: NREAPs

Example of differences between states Power generation, NREAPs, 2020



Regions **CEE10** and **EU17** differ significantly, but much higher differences between MS in both regions can be found – see example for CZ, SK, HU

Details on RES sources and technologies

Wind power

- wind turbines, propellers, uplift (aerodynamic principle)
- on shore, off shore
- wind power – proport. to v^3
- load factor: depends on location, CZ app. 2000 h
- quick fluctuation of the output

Wind mills, wind water pums

Details on RES sources and technologies

Solar power

- solar thermal collector (hot water, hybrid systems)
- solar power plants with heat cycle

Solar towers

Solar farms

Details on RES sources and technologies

Solar power

PV technology

- boom since the end of last decade (PV boom in some countries - Czech Rep., Spain, Germany)
- significant fall of technology cost
- load factor in CE conditions: 900-1000 hours
- grid on and grid off applications, accumulation of energy

Details on RES sources and technologies

Small hydro/Large hydro

SH < 10 MW

- standard technology (more than one century)
- only limited potential for the development
- load factor depends on location, app. 3000-5000 h
- no quick fluctuation of power, seasonal curve
- currently most expensive technology (investment cost)

Details on RES sources and technologies

Biomass

- **residual biomass**
  - agriculture: straw, grass, manure, etc.
  - food industry (e.g. olive stones, oil from McDonalds)
  - forestry: residuals from forest harvesting, 12-15%
  - wood processing industry
  - biodegradable part of municipal and industrial waste (landfill gas, sewage gas)
- **Intentionally planted biomass**
  - firewood
  - SRC plantations
  - energy crop (Reed canary grass, miscathus, etc.)
  - maze (biogas), corn, sugar cane, sugar beet (bioethanol), rape seed (FAME - biodisel)

Details on RES sources and technologies

Biomass

- **power and heat generation**
  - direct burning of original matter (wood chips, straw, saw dust, etc.)
  - transformation into solid biofuels (pellets, briquettes)
  - co-firing (biomass is added into coal and burnt in coal fired PP, 5-20%, currently the cheapest RES technology)
- **Biogass stations**
  - transformation of biomass into biogas (fermentation)
  - high load factor (>7000 h)
  - usually uses combination of waste and plated biomass

Details on RES sources and technologies

Biomass

Agriculture land potentially is available for energy biomass in many of EU MS

POTENTIALS OF RES – FROM TECHNICAL TO ECONOMIC POTENTIAL

Understanding of different meaning

- **Technical potential** – done by source presence and by conditions of energy transformation (only theoretical meaning)
- **Exploitable (available) potential** – part of technical potential that can be used currently available technologies and limitations are done by legal, ecological and other limitations
- **Attainable potential** – part of exploitable potential that can be used for energy purposes
- **Economic potential** – part of available potential that can be used based on current economic condition influencing economic effectiveness of project for investors

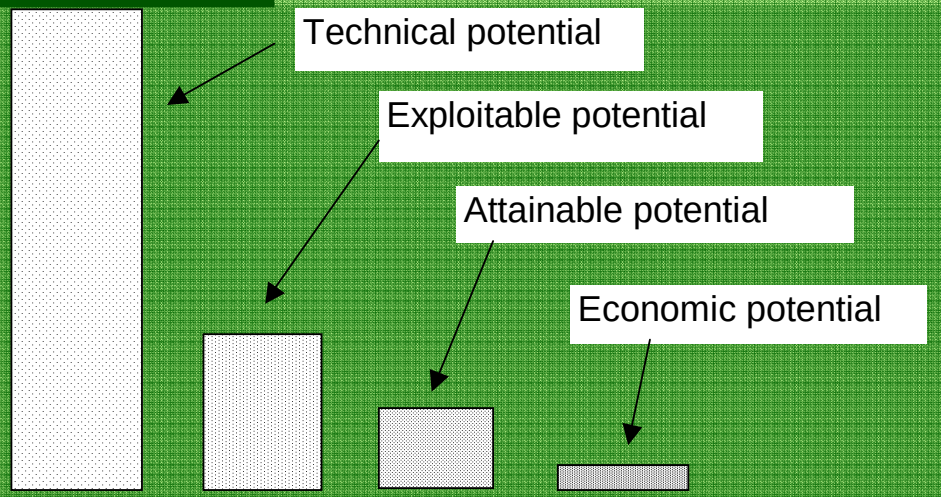
POTENTIALS OF RES – FROM TECHNICAL TO ECONOMIC POTENTIAL - 2

Understanding of different meaning

ČR example of potential relation – wind power:

- Technical potential: theoretical figure
- Exploitable potential: app. 3800 MW
- Attainable potential (year 2010): 460 MW
- Economic potential (year 2010): depends on value of feed-in tariff

Potentials depends on natural conditions, availability of tech-nologies, economic power and political strategy of given country !



HOW

⇨HOW ? ⇨RES effective support

PROMOTION SCHEMES FOR RES

What is the goal of RES support - the different points of view

- **Similar effects of different tools**
  - RES for electricity generation
  - RES for heat production and delivery (industrial, households)
  - Energy savings
  - Energy efficiency (e.g. cogeneration)

- **One cannot concentrate only at EU Directive 2001/77 targets !**

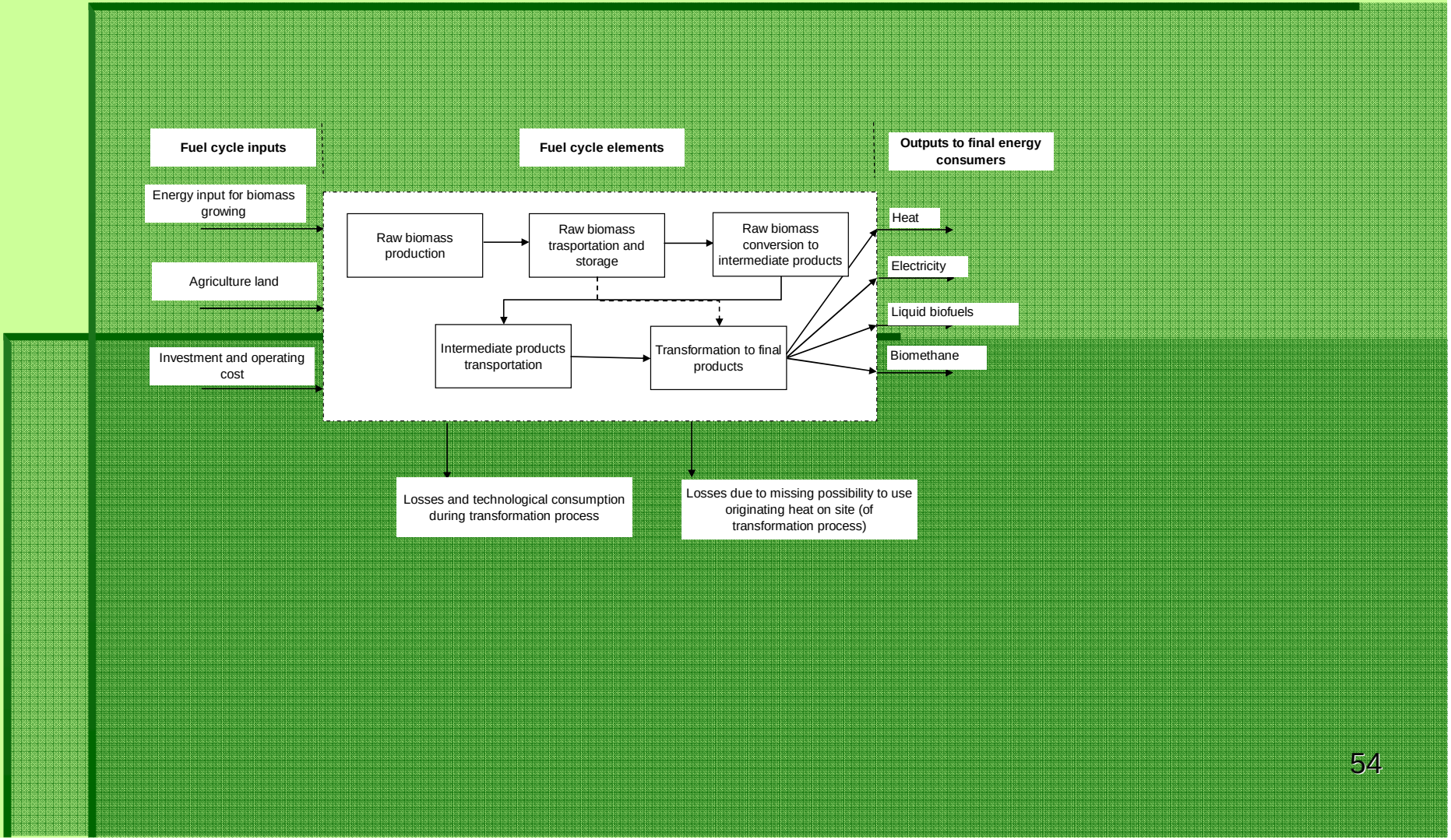
- What are the system goals ? Just RES support ?

- Economic rule about scarce resources – invest into fields with highest marginal effects !

- Is it rational to use biomass for electricity generation ?

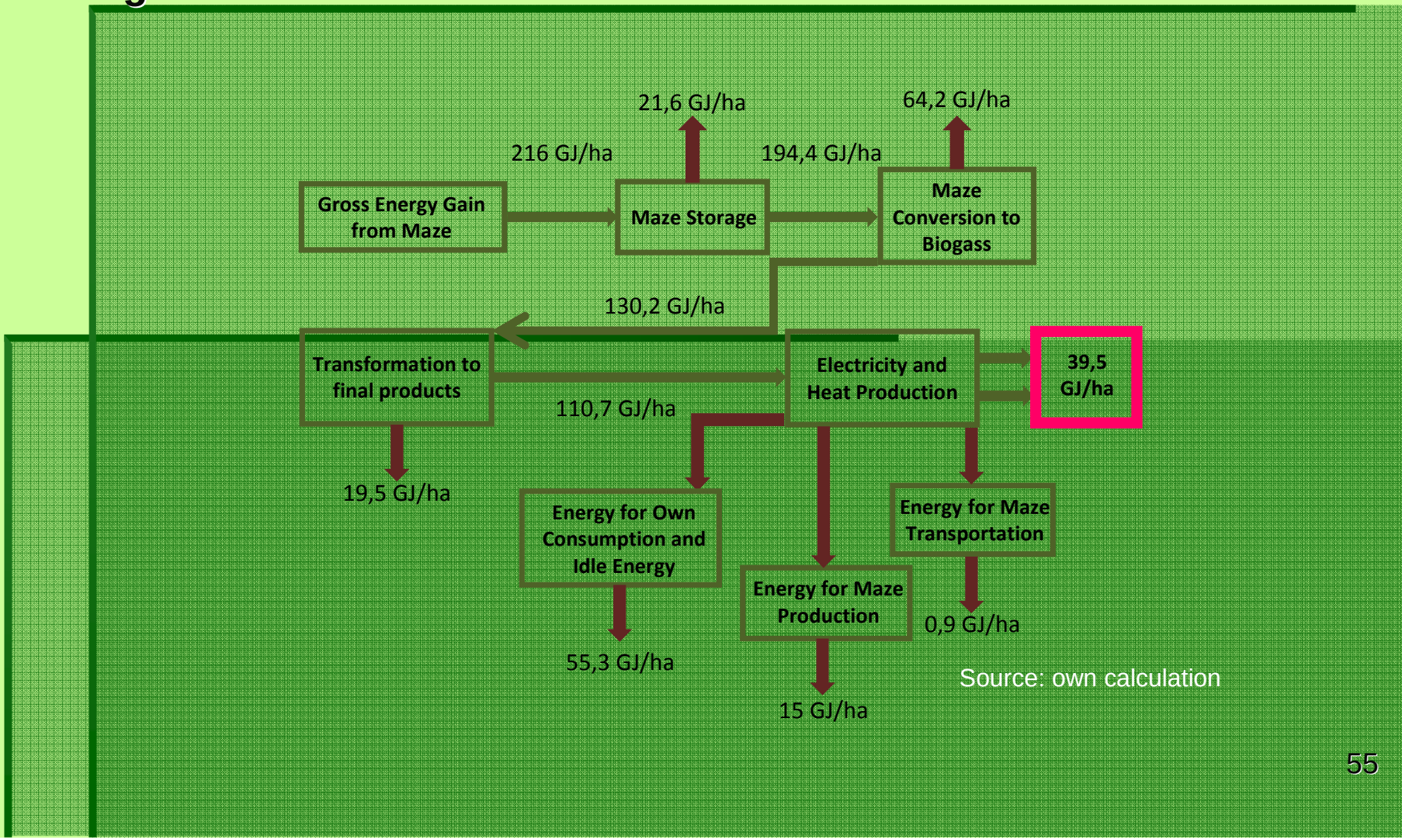
HEAT versus POWER versus TRANSPORT

Effectiveness of RES utilization – example of biomass fuel cycle



HEAT versus POWER versus TRANSPORT

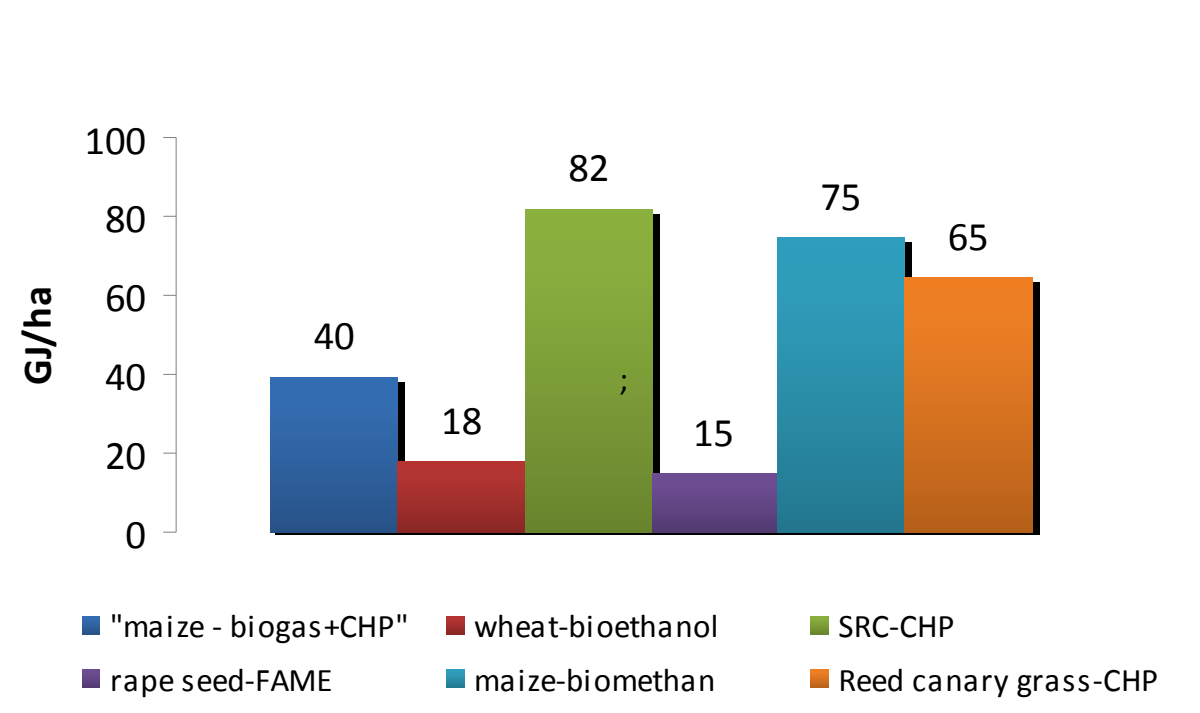
Effectiveness of RES utilization – example of energy balance for biogas station



Source: own calculation

HEAT versus POWER versus TRANSPORT

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



Source: own calculation

PRIVATE INVESTORS AND RATE OF RETURN

Rule of scare resources – money for investments are also scarce !

Why do investors invests ?

⇨ Profit ?

⇨ Rate of return ? (real money ?)

Rational investors compare initial investment with money generated by the project

⇨ Basis for decision are cash flows – results of project existence

Why do investors invest into RES (RES-E) projects?

BASICS ON ECONOMIC EFFECTIVENESS OF PROJECTS

- **Private investors run RES projects**

- Investors expects (fair, adequate, required) rate of return on capital invested – they need to sell at least for the minimum price cmin

$$NPV = \sum_{t=1}^{T_\xi} CF_t \cdot (1+r_n)^{-t} = 0 \qquad \sum_{t=1}^{T_\xi} c_{\min t} \cdot Q_t \cdot (1+r_n)^{-t} = \sum_{t=1}^{T_\xi} V_t \cdot (1+r_n)^{-t}$$

$$c_{\min 1} \cdot \sum_{t=1}^{T_h} (1+\inf)^t \cdot Q_t \cdot (1+r_r)^{-t} \cdot (1+\inf)^{-t} = \sum_{t=1}^{T_h} V_t \cdot (1+r_n)^{-t}$$

$$c_{\min 1} = \frac{\sum_{t=1}^{T_h} V_t \cdot (1+r_n)^{-t}}{\sum_{t=1}^{T_h} Q_t \cdot \left[\frac{(1+r_n)}{(1+\inf)}\right]^{-t}} = \frac{\sum_{t=1}^{T_h} V_t \cdot (1+r_n)^{-t}}{\sum_{t=1}^{T_h} Q_t \cdot (1+r_r)^{-t}}$$

- NPV=0 means that production is sold for c_{min} price and investor gains rate of return equal to discount rate !

BASICS ON ECONOMIC EFFECTIVENESS OF PROJECTS - 2

How c_{min} is calculated:

- ⇨ data of reference projects are necessary
- ⇨ decision on discount rate value

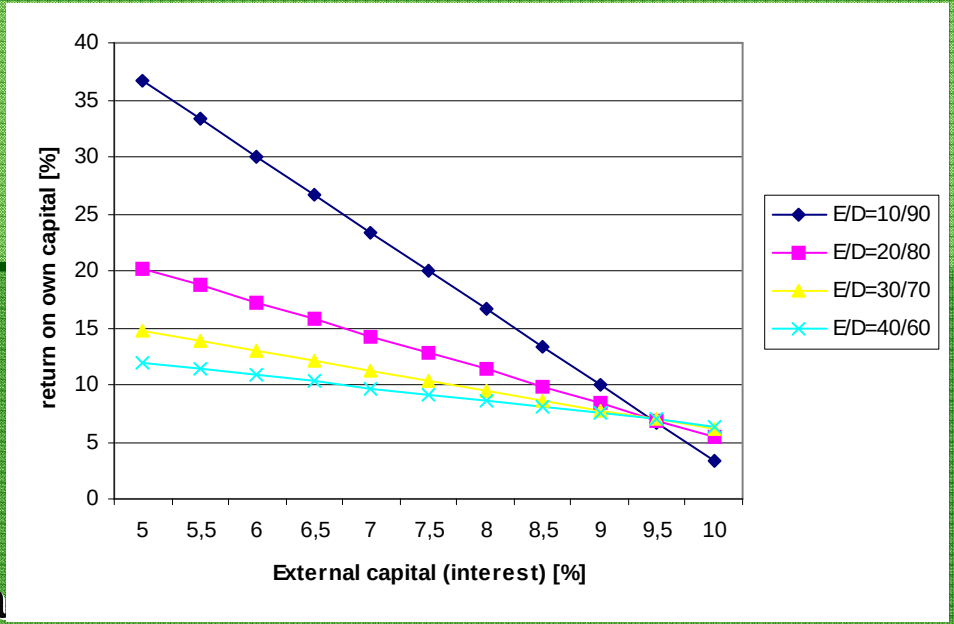
Meaning of discount – WACC

$$WACC = r_{ed} * \frac{E}{E+D} + i * (1-d) * \frac{D}{E+D}$$

E ... equity (own capital)
D ... debt (external capital)
i ... cost of external capital
d ... tax rate
red ... return on own capital

What is the "fair" return on capita

Higher risk - higher return,
lower risk – lower return !



DISCOUNT AND RISK

Discount:

- ⇨ Time value of money – opportunity cost
- ⇨ Required rate of return by the investor
- ⇨ Nominal discount: risk free return, risk premium, inflation

$$(1+\text{inf})\cdot(1+r_f)\cdot(1+r_{pr})=(1+r_n)$$

Higher risk means higher discount

- ⇨ Higher risk - higher return, lower risk – lower return !

Types of risk:

- ⇨ Technology
- ⇨ Fluctuation of weather conditions, natural effects
- ⇨ Business risk
- ⇨ Political risk

What is the "fair" return on capital in RES-E projects ?
What is the risk in RES-E project ?

TWO POINTS OF VIEW ON ELECTRICITY PRICE

Supply side (investor's point of view):

- Rate on return from invested capital
  - minimum price of production – C_{min}
  - NPV = 0 → rate of return on capital invested equals to applied discount rate

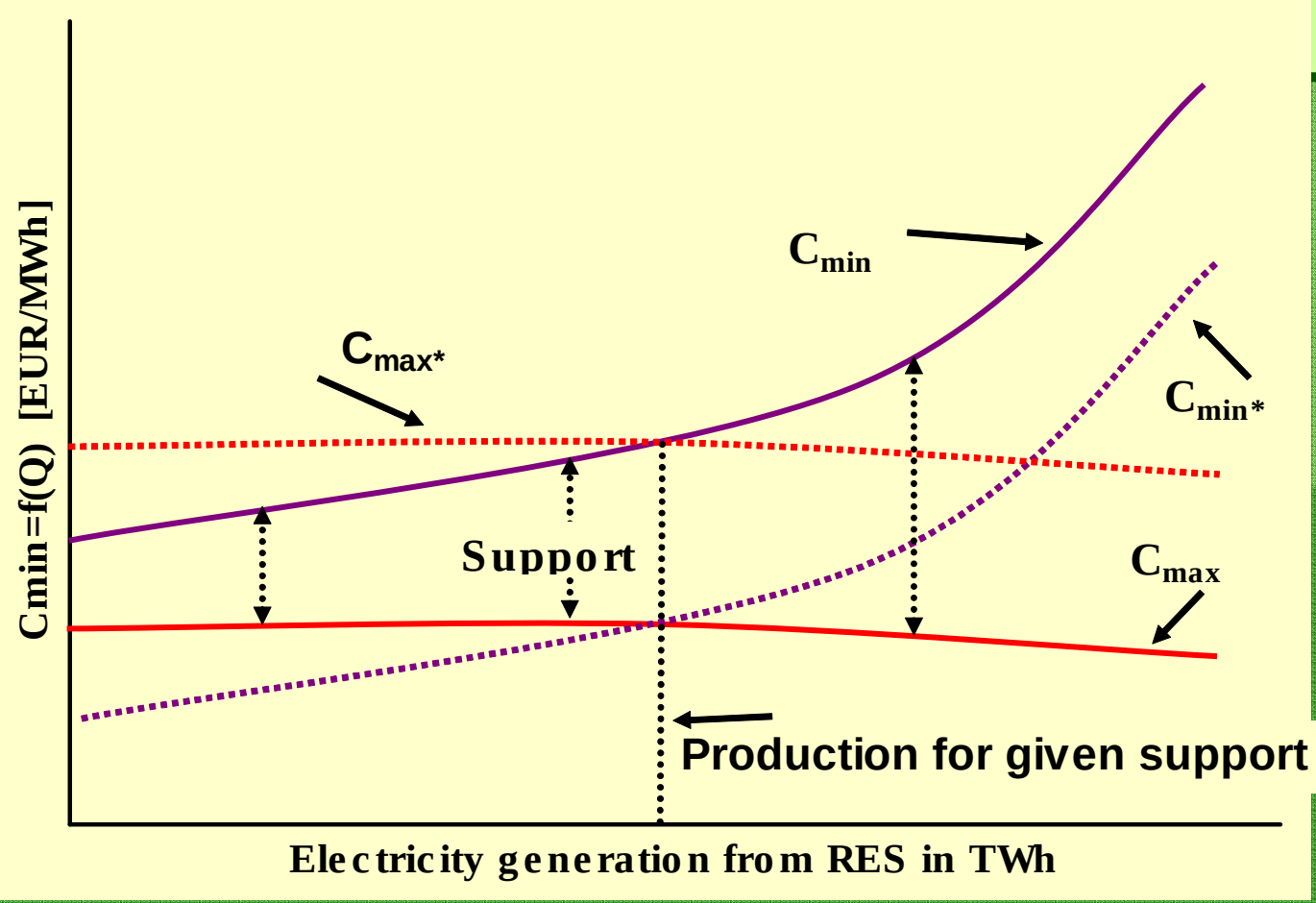
Demand side (purchaser):

- Alternatives for electricity purchase on market with electricity – C_{max}
  - Should respect market rules and technical features of generated electricity

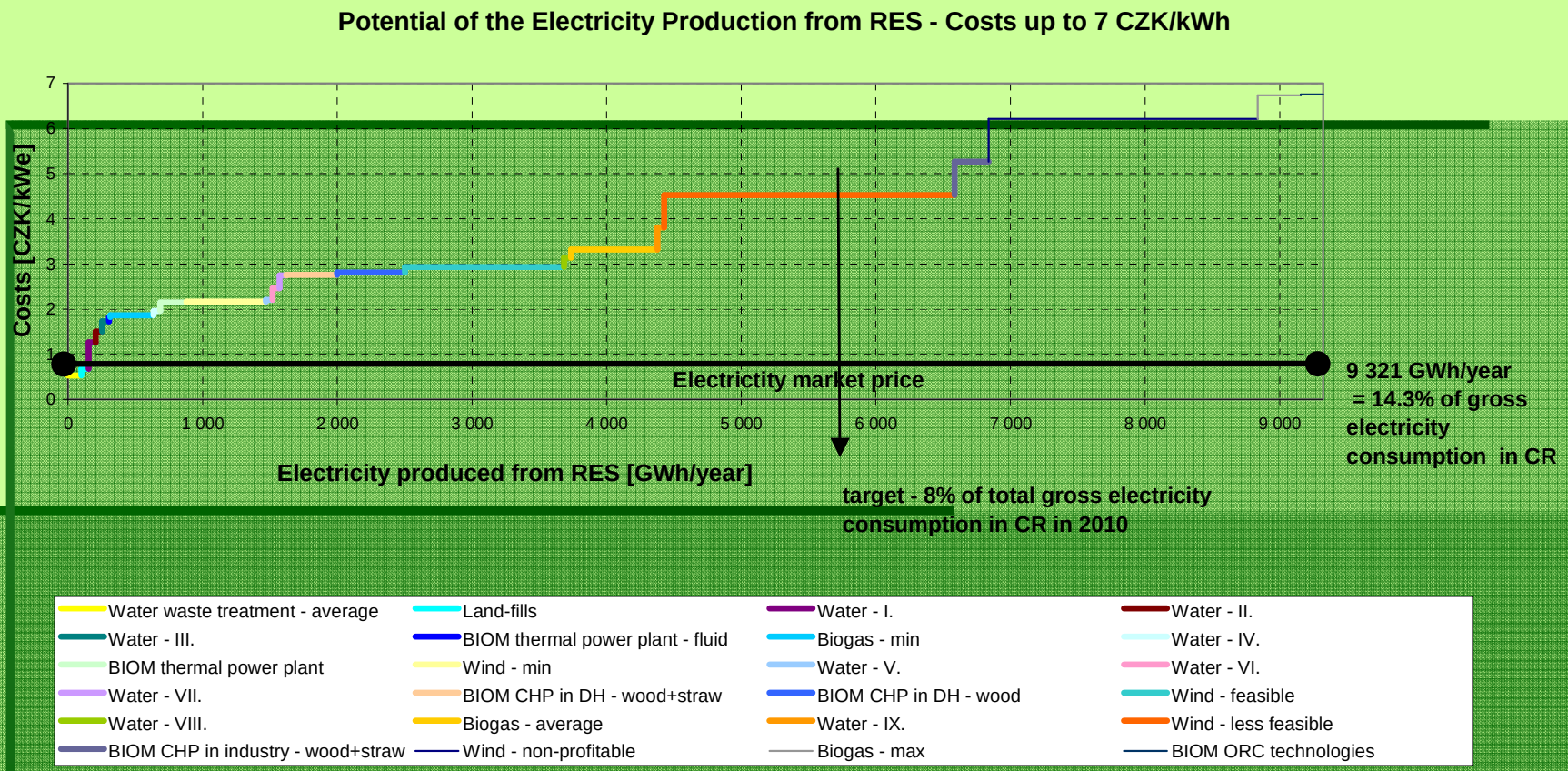
$C_{min} \leq C_{max}$
investor will invest

$C_{min} > C_{max}$
investor will not invest

SUPPLY AND DEMAND CURVES



SUPPLY SIDE – CZ EXAMPLE



DEMAND SIDE

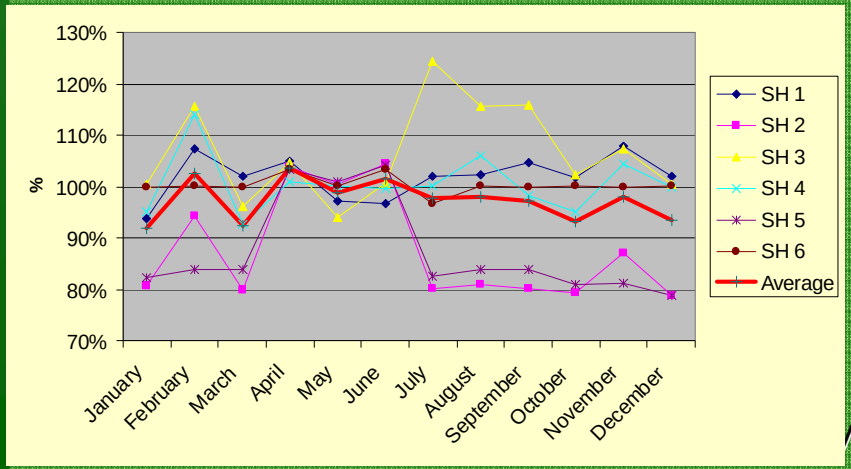
Demand curve – point of view of consumers

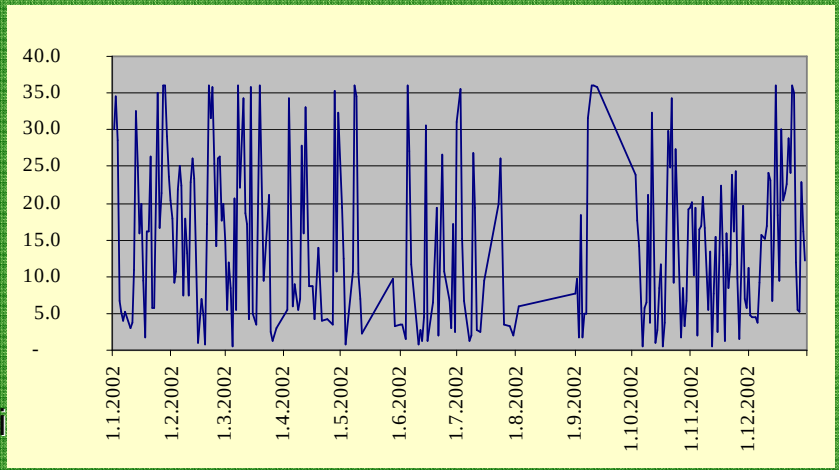
Technical features of production are taken into account

- ⇨ Reliability
- ⇨ Diagram of delivery
- ⇨ Possibility of regulation
- ⇨ Electricity: power and system services

Role of electricity market

Who will pay for system services? Back-up capacity ?





MEASURES FOR CHANGING POSITION OF SUPPLY AND DEMAND CURVES

How support renewables – case example of electricity generation

⇨ **affection of supply or demand curves**

Moving supply curve down

⇨ investment subsidy

⇨ operational subsidy related to power generation – green bonus

⇨ reduction of investors risk – investment to R&D, good conditions for investors

⇨ reduction of cost of financing – preferential loans (zero or reduced interest)

⇨ tax exemptions (income tax holidays, real estate tax)

⇨ green certificates – sale of emission reduction

⇨ combination of quota system and sale of certificates

MEASURES FOR CHANGING POSITION OF SUPPLY AND DEMAND CURVES - 2

Moving demand curve up

- ⇨ feed-in tariff and obligation of purchase
- ⇨ quota system
- ⇨ information campaigns (voluntary purchase of green electricity for higher price)
- ⇨ ecological taxation imposed to classical electricity generation (carbon tax)
- ⇨ emission allowances

Feed-in tariffs – widely used instrument

- ⇨ but can significantly differ in methodology of calculation

FEED-IN TARIFFS VALUES

Basic decision what RES sources to support

- all
- selected ?
- limit for some kind of RES ?

FEED-IN TARIFFS VALUES

- decision
- calculation
  - assured period
  - degressive
  - constant

FEED-IN TARIFFS CALCULATION

REFERENCE PROJECTS APPROACH

How to define reference projects ?

- it should be representative well prepared projects, market technologies, good locations
- where to find data for reference projects ?
  - statistical analysis of already realized projects ? Do they reflect future state ?
  - to manage lobbyists ?
  - how to reduce extra return for some investors ?
    - time matrix ?
    - individual FT ?
- What is the adequate rate of return on capital invested ?

FEED-IN TARIFFS CALCULATION 2

REFERENCE PROJECTS

⇨ investment cost

⇨ operational cost (typically as % of investment)

⇨ fuel cost (biomass, biogas)

⇨ long term average inflation

⇨ tax depreciation of the investment

⇨ tax rate and tax holidays

⇨ (other support if applicable)

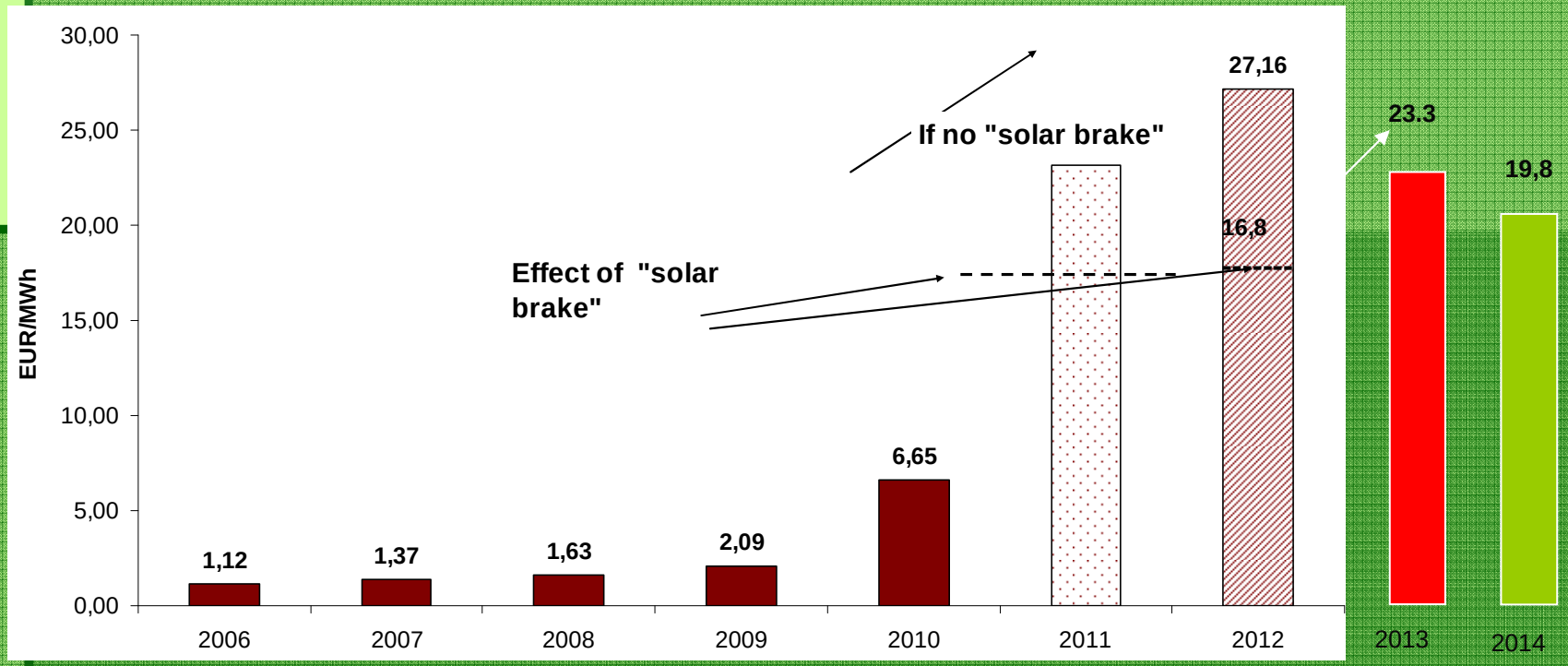
⇨ discount rate that defines rate of return on capital invested

FT is price in first project year assuring NPV=0

Who bears the RES support cost

Taxpayers, electricity consumers, combination of both

RES resulted in many countries in quick increase of electricity prices (see RES fee in Czech Rep.)



1 EUR=25 CZK

Problems connected with the RES-E penetration into grid

- Significant increase of electricity prices in some countries (Germany, Czech rep., etc.)
- Power prices increase has significant negative impact to industry and other branches competitiveness
  - Some countries reduces fees for energy intensive and globalised industries – even impact to the companies in different MS
- RES electricity (thanks to the logic of support) has (almost) marginal cost of production equal to zero
  - This reduces load factor of classic PP (grid cannot be operated without them), many of PP become uncompetitive (e.g. NG PP)
  - Fall of power prices (2008: 80 EUR/MWh, 2013: 37 EUR/MWh)
  - Investors are postponing investments – big threat for the future

Thank you for attention