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Essential Role of Nuclear Power for Implementation of Conclusions of Climate Conference 2015

Jozef Misak

Zagreb, Croatia, 16 March 2017

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Paper Elsevier Paper EPJ

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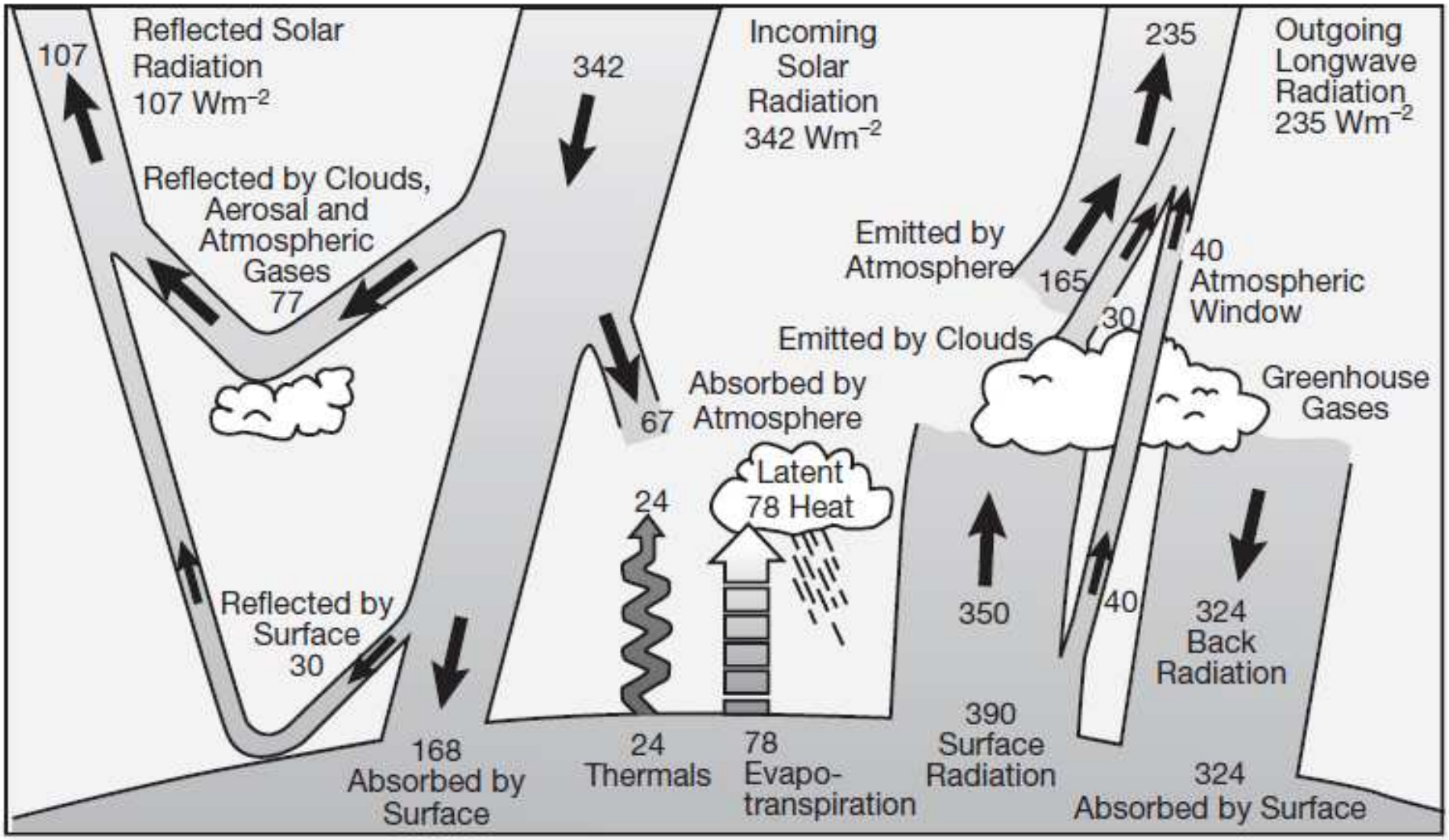
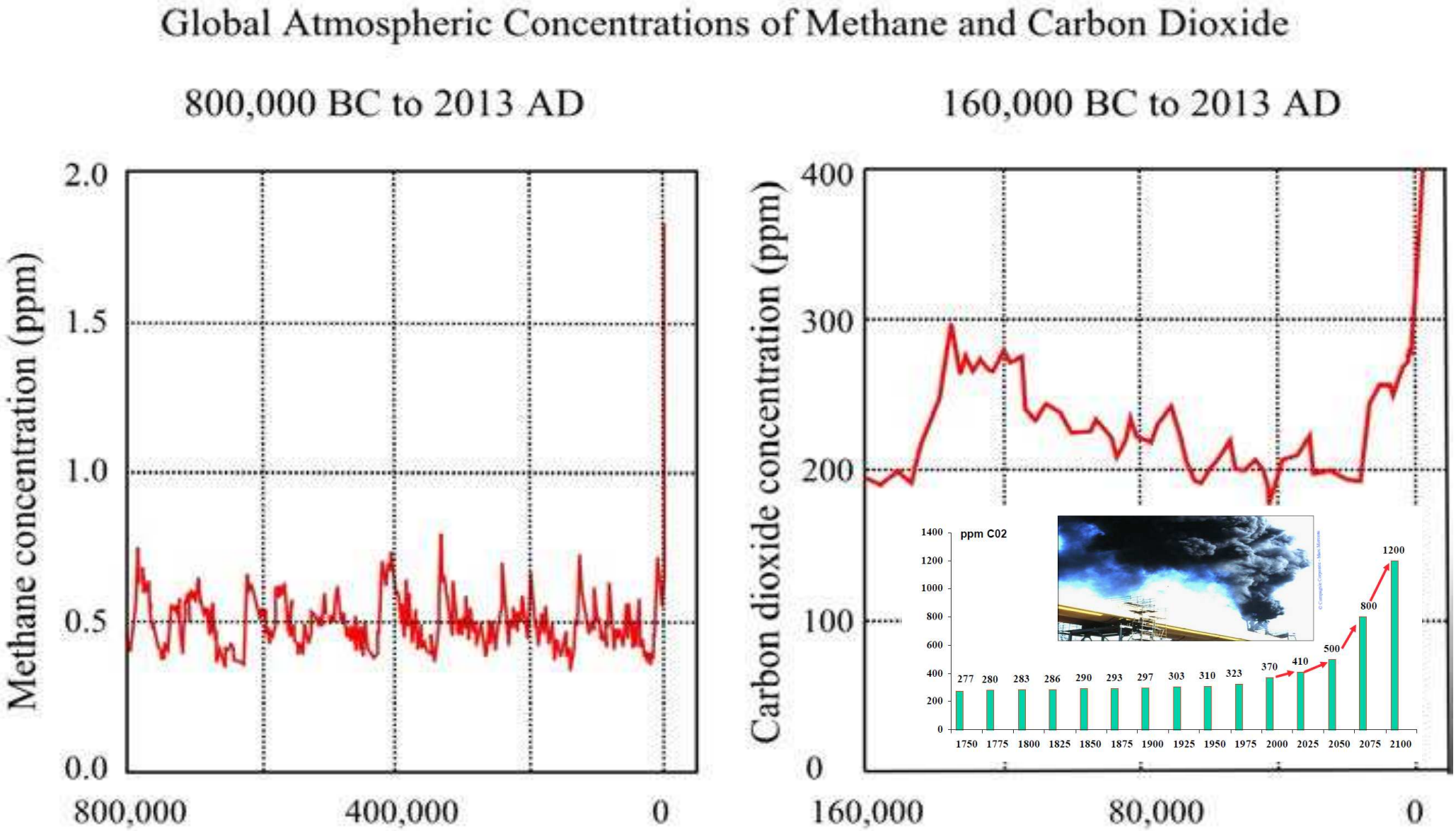
Energy balance between the incoming solar radiation to the earth and various processes that absorb or emit radiation

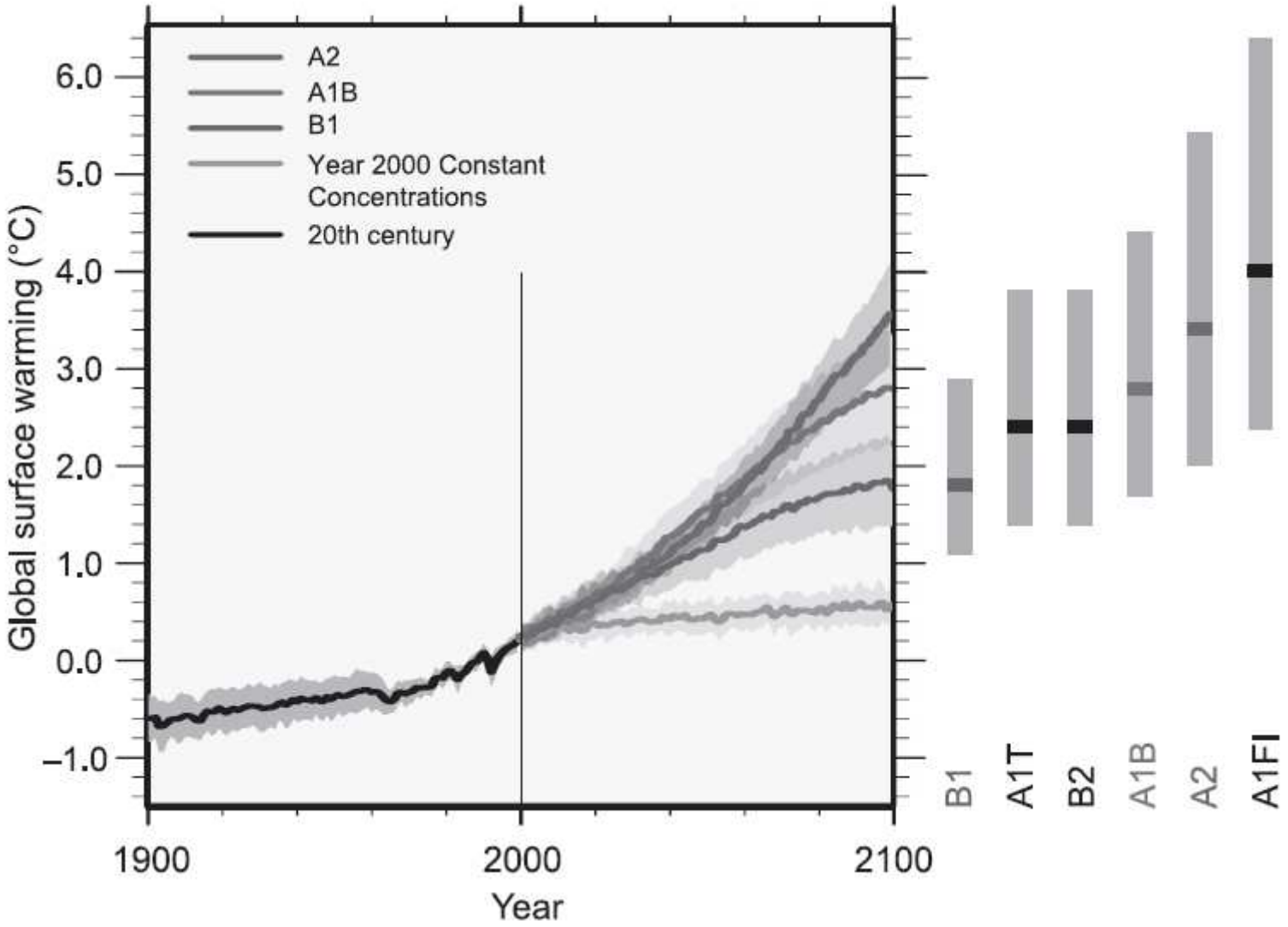
((M.H.Fox, Why We Need Nuclear Power, Oxford University Press 2014))



The Real Danger...



Estimated global warming for various development scenarios (M.H.Fox, Why We Need Nuclear Power, Oxford University Press 2014)



Selected articles from the Decision

- Recognizing that **climate change represents an urgent and potentially irreversible threat to human societies and the planet** and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions,
- **Emphasizing with serious concern the urgent need** to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways **consistent with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels,**
- Recognizing the urgent need to enhance the provision of finance, technology and capacity-building support by developed country Parties, in a predictable manner, to enable enhanced pre-2020 action by developing country Parties,
- Emphasizing the enduring benefits of ambitious and early action, including major reductions in the cost of future mitigation and adaptation efforts,
- Agreeing to uphold and promote regional and international cooperation in order to mobilize stronger and more ambitious climate action by all Parties and non-Party stakeholders, including civil society, the private sector, financial institutions, cities and other subnational authorities, local communities and indigenous peoples,

21st Session of Conference of Parties to UN Framework Convention on Climate Change (COP 21) – Dec 2015

- **The Agreement and a companion Decision were the key outcomes of the conference, culminating a four-year negotiating period**
- Recognizing that **climate change represents an urgent and potentially irreversible threat to human societies and the planet**
- **Emphasizing with serious concern the urgent need to hold the increase in the global average temperature well below 2 °C and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels**
- In the Agreement, the word **“renewable” appeared only once , ”nuclear” not mentioned** at all
- Acknowledging the need to promote universal access to sustainable energy in developing countries, in particular in Africa, through the enhanced deployment of renewable energy”
- Renewable energy sources are often presented as the only solution to control global warming
- **However, based on available technologies, the objectives of the Decision and Agreement can hardly be achieved without nuclear power**

The Concept of Sustainability

1. ***Sustainability: Meeting the needs of the present without compromising the ability of future generations to meet their own needs"***

(1987, Brundtland Report)

2. In the context of energy options, 'sustainable' implies: *The ability to provide energy on a very large-civilization-spanning-time scale without depriving future generations and in a way that is environmentally friendly, economically viable, safe and reliable*

What are real advantages of renewable sources?

"Sustainable" is more important attribute of power sources than "renewable"!

Questions to be answered in this presentation

- Is it possible to replace all or most fossil-derived energy with renewables and, if so, would this be sustainable?

- Is nuclear energy sustainable and what should its role in the energy mix be?

General issues associated with implementation of wind and solar power sources

- **Following are the main issues (with many implications):**
  - Location and transmission (production far from consumption)
  - Intermittency
  - Footprint (low density)
  - Environmental impact
  - Cost
  - Quality - to some extent

- **Some of the issues will be further illustrated**
- **For the above listed issues the wind and solar power sources are renewable but are not sustainable**

The Myths of “Renewable” Energy Sources: 1

- **Claim 1: All “Renewables” are sustainable.**
- **Truth: Grid-connected intermittent “renewables” are in general <u>not</u> sustainable because they require back-up power** for when the wind does not blow or when the sun does not shine. In most cases this back-up is provided by gas-fired generating stations because it has to be fast-acting and flexible. Averaged over a year, wind turbines deliver between **25% and 40% (very optimistic numbers!)** of their name-plate capacity. This means that the back-up power plants have to deliver between 75% and 60% of the energy delivered to the grid. Only if the back-up energy is provided by hydro-electric stations or supplied from energy-storage facilities could “renewables” be considered sustainable. However, hydro-electric energy is limited and energy from storage is in most cases not technically and economically viable for base-load applications.

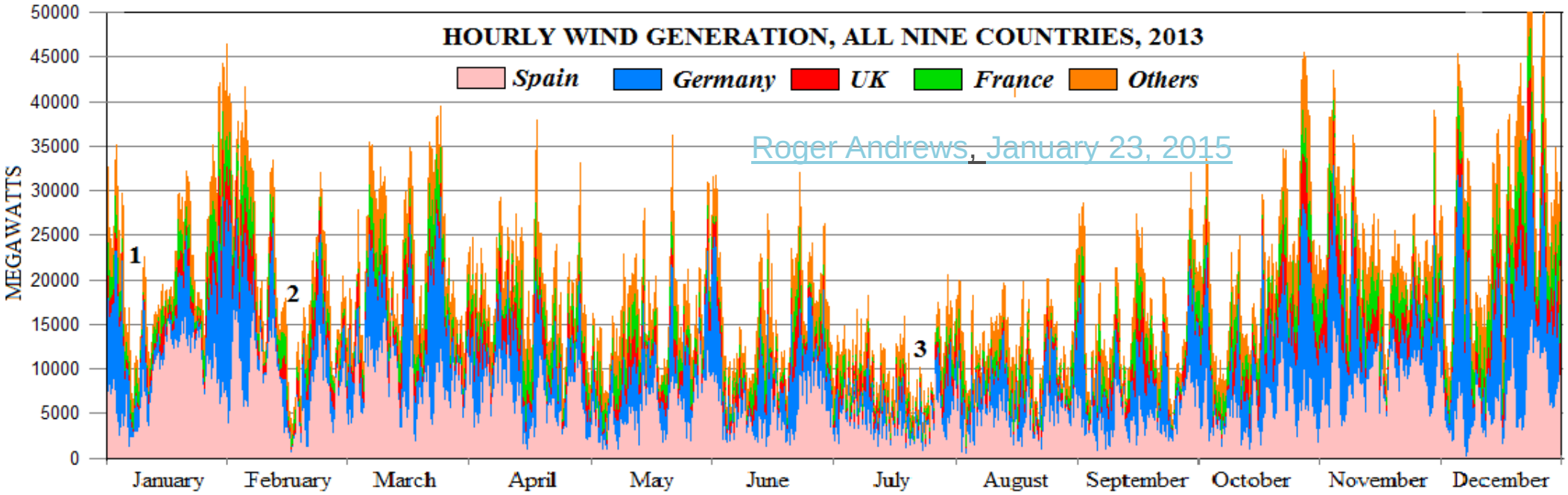
Solutions to intermittency
(for a large supply of electricity)

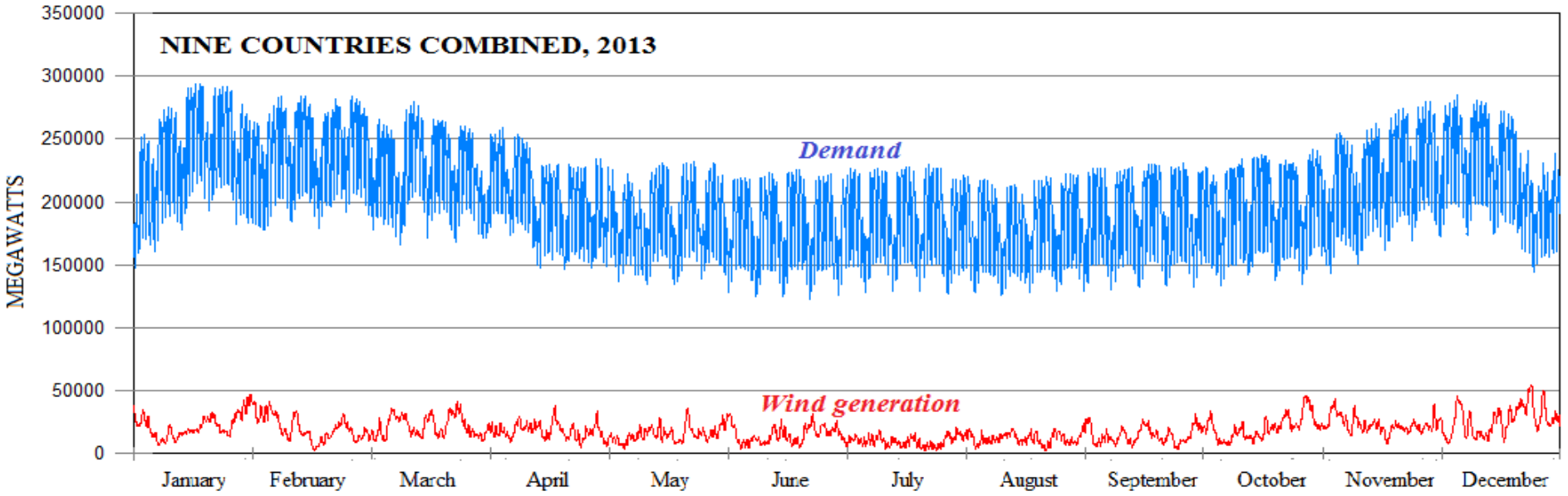
- **Connect renewable generators to «intelligent» grids:**
  - Technology not yet developed for large scale applications
  - Intelligent grids are very costly
  - Intermittency only partially addressed, as illustrated above
- **Create a balanced renewable energy generation-electricity storing-distribution system:**
  - Reversible pumped-hydro power stations have siting, technical and economic limitations
  - Even hydro stations can store energy for hours, but not for days
  - Batteries with sufficiently large capacity not available and can hardly be available
- **Provide back-up to renewable generators by gas-fired stations**
  - Large environmental impact due to production of carbon dioxide and methane releases as discussed further

Comparison of different sources

- NPP Temelin 1,2 (2x 1000 MWe WWER) occupies a surface of less than 1,3 km^2
- Solar equivalent of 2000 MWe would cover a surface of 3,300 km^2
- Wind onshore equivalent of 2000 MWe would cover a surface of 6 300 km^2
- Surface of the CZR = 78 866 km^2
- Replacement of 4000 MWe by solar would lead to a surface of 6 600 km^2 (8,4%) and replacement by wind onshore would lead to a surface of 12 600 km^2 (15%)

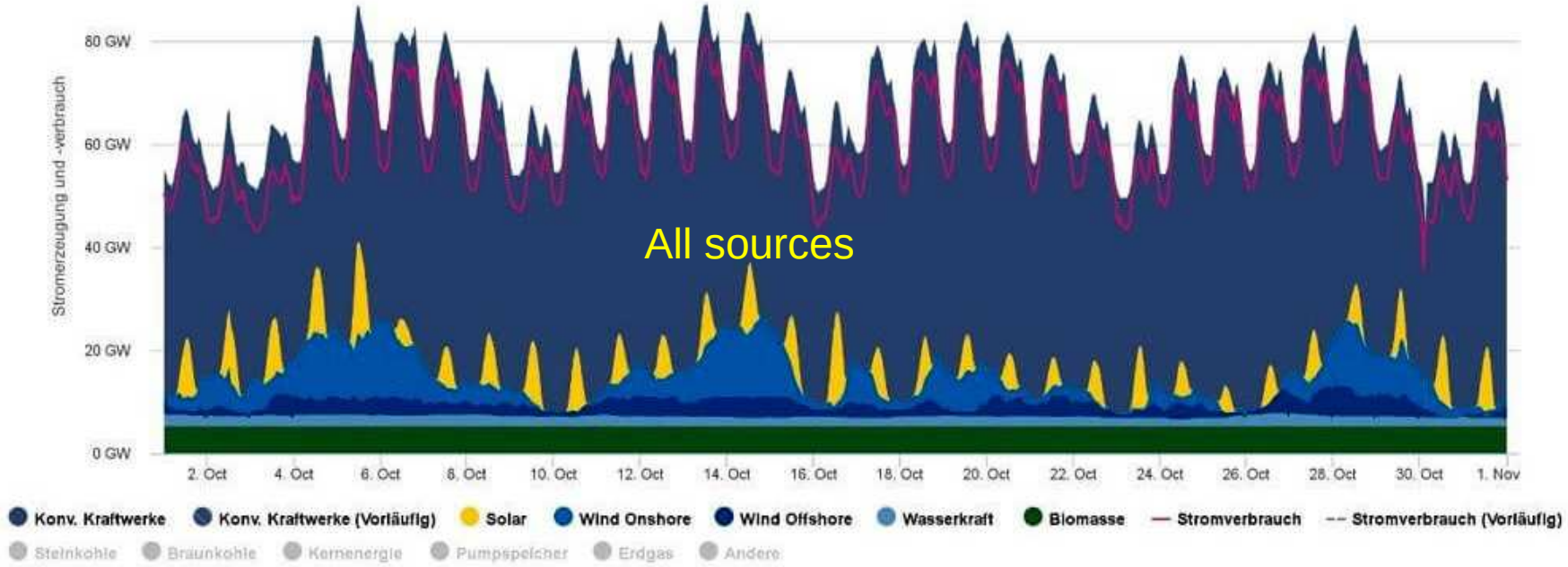
“If the wind stops blowing somewhere – it is always blowing somewhere else” – is it true?

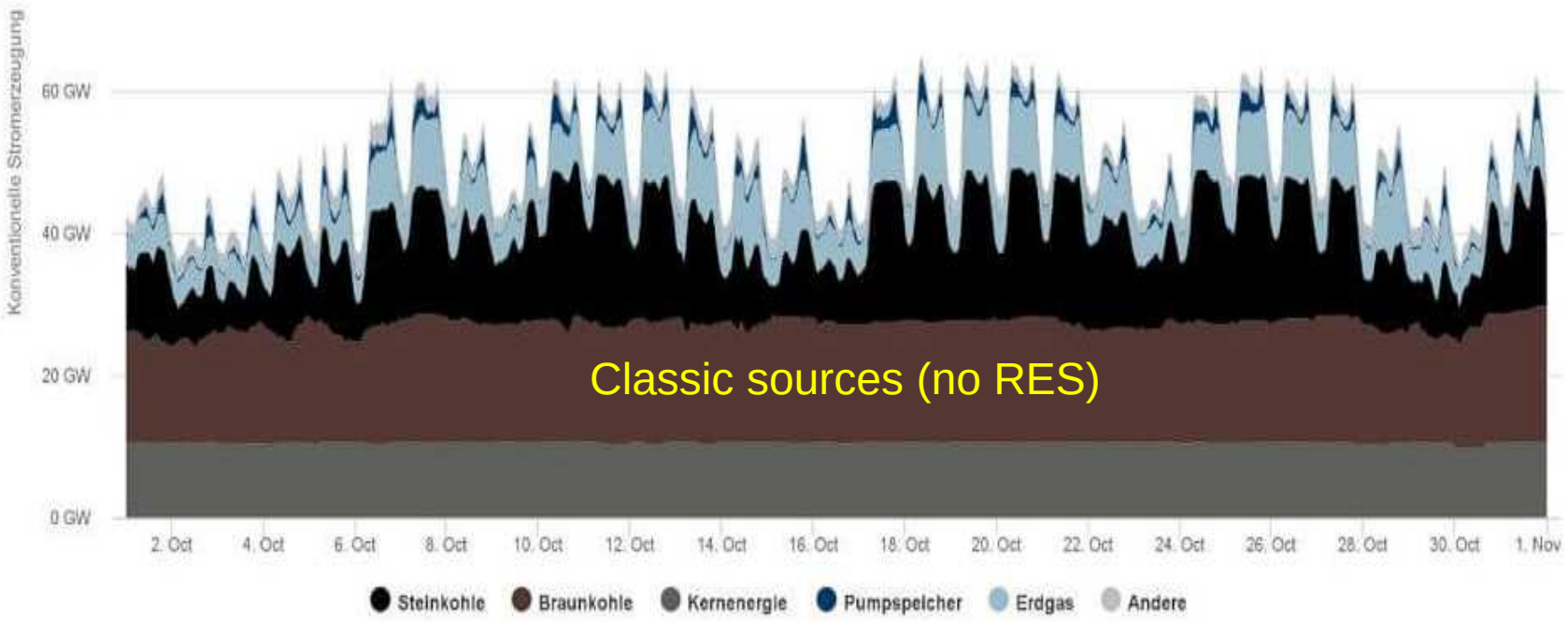




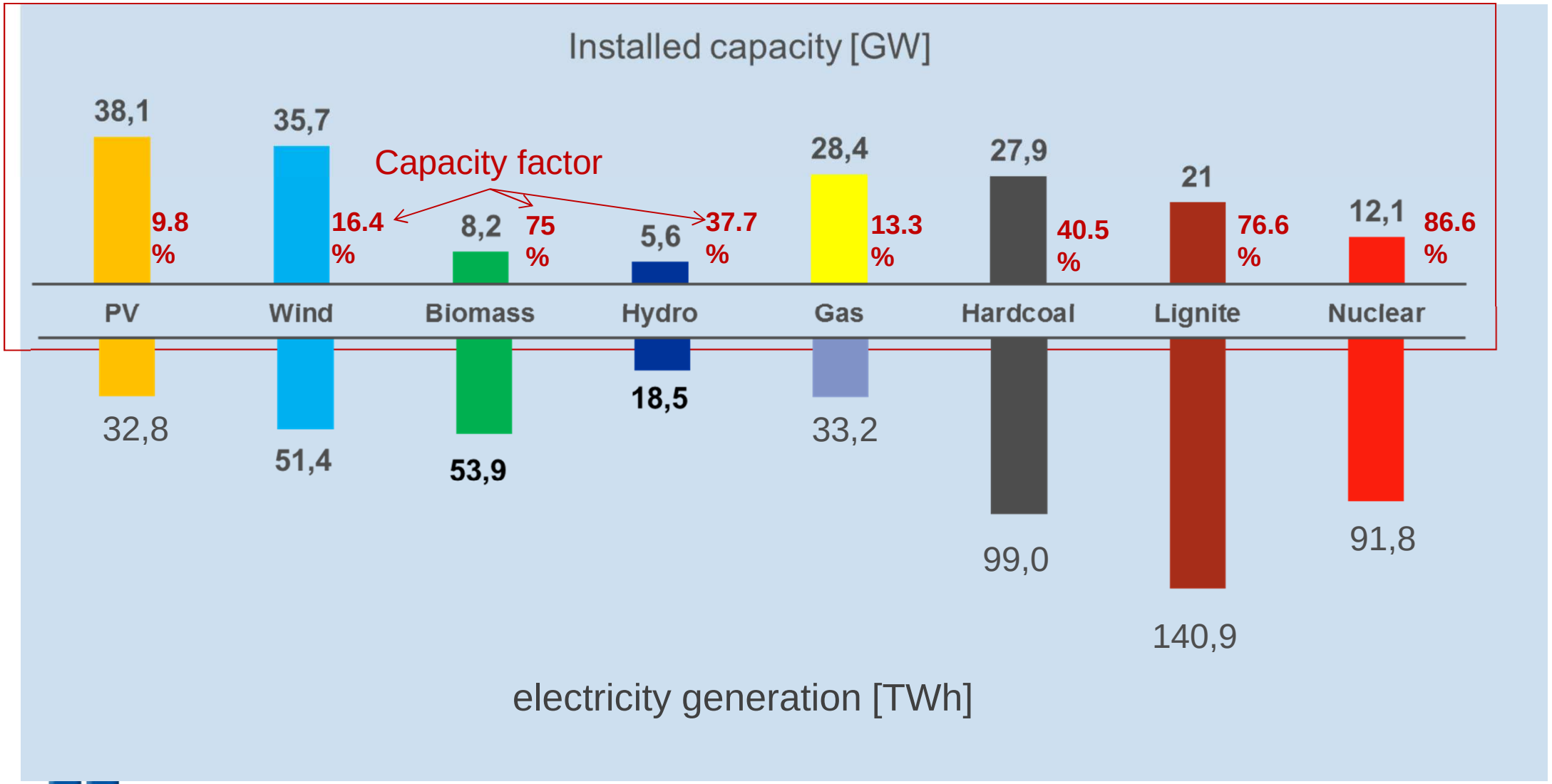
Generation does not follow the demand: Intermittency until now does not cause big problem only because its share is low

Production of electricity in Germany from various sources in October 2016

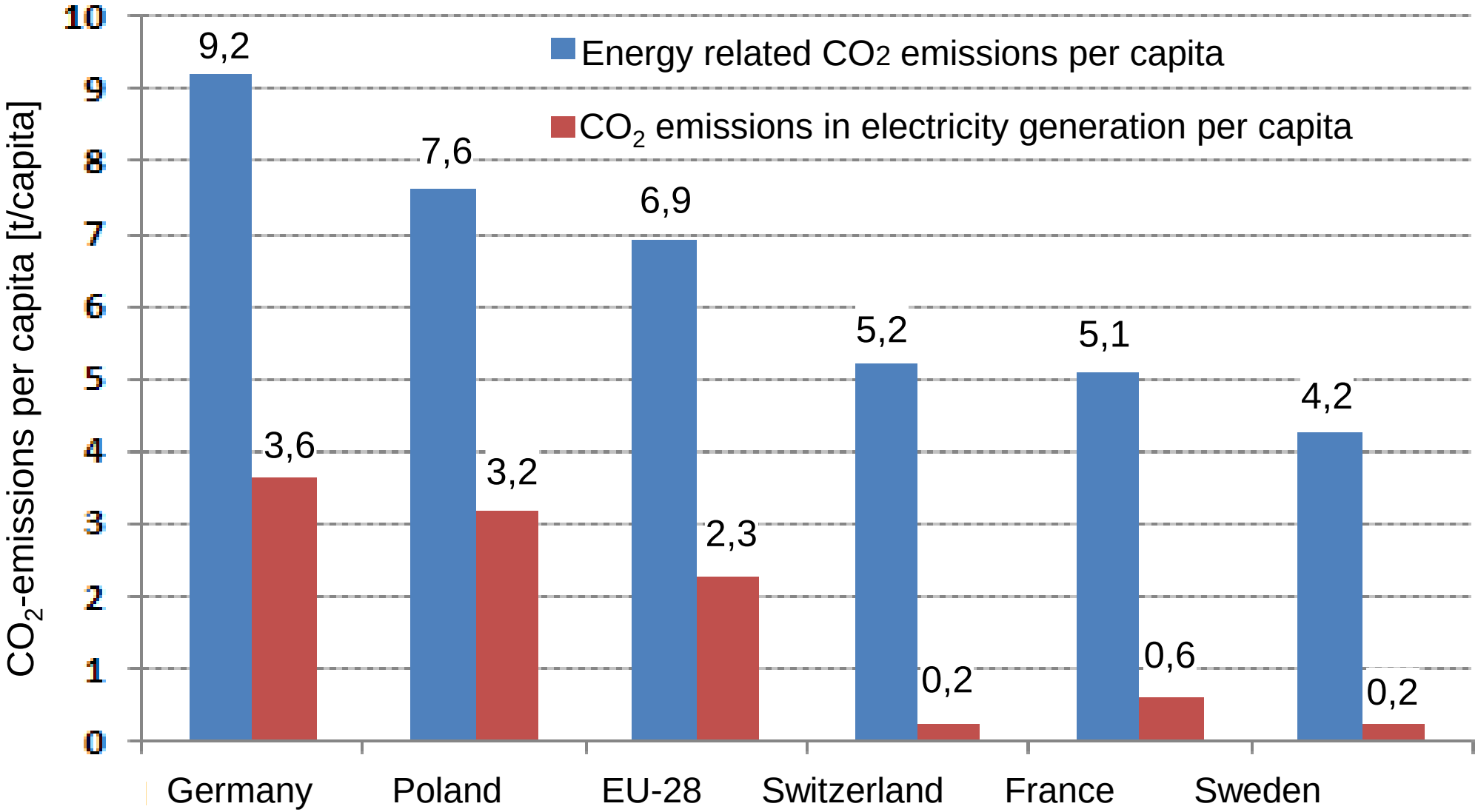




The German power system 2014



CO_2 emissions in Europe: selected countries (2012)



Cumulated Energy Consumption without Fuel

** Crystalline Silicon Solar Cells*

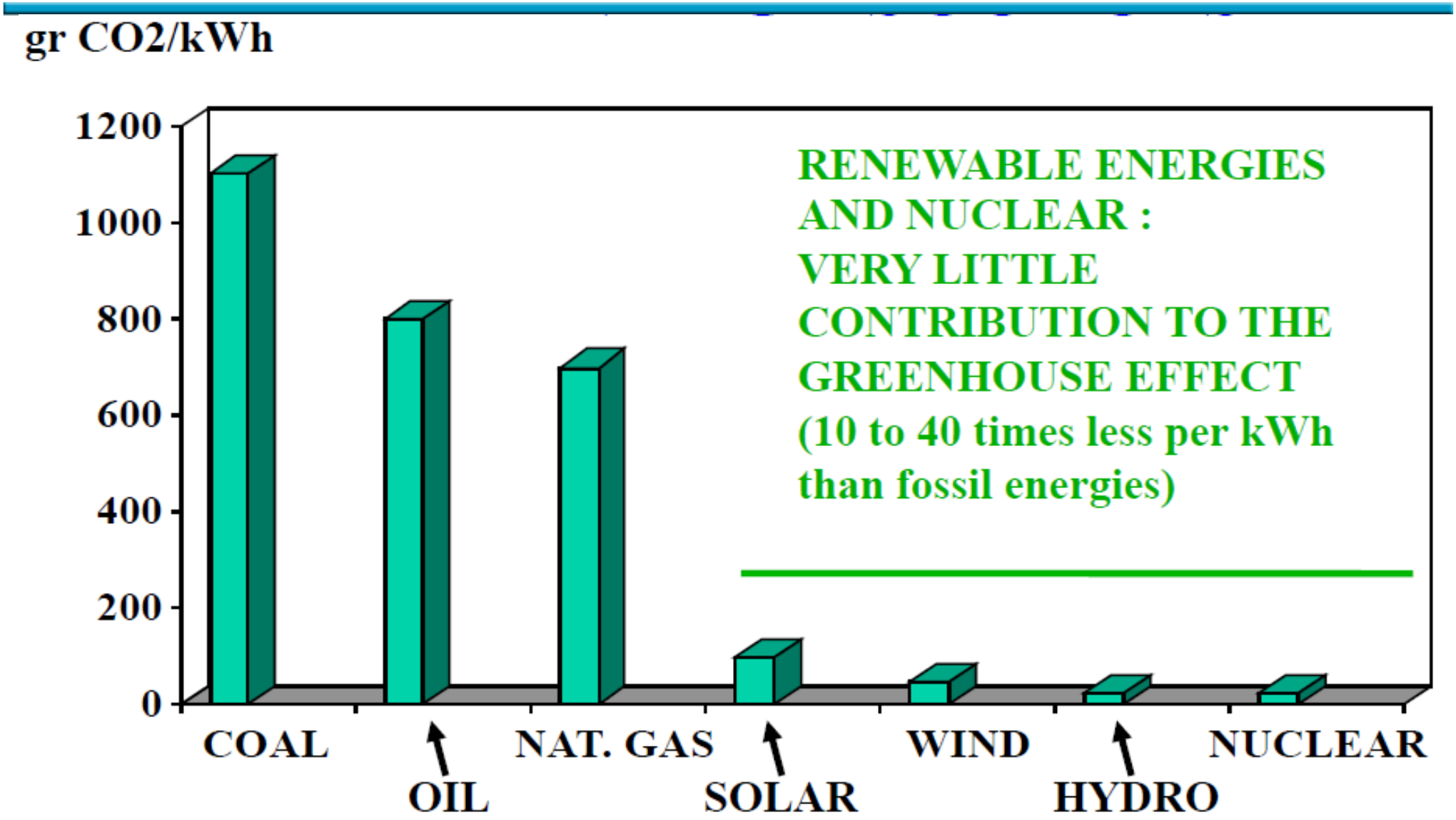
Source: University of Stuttgart, Institute of Energy Economics and Rational Use of Energy, November 2005, updated July 2007.

	Build and decommissioning/disposal of PP kWh_{Prim}/kWh_{el}	Use without fuel kWh_{Prim}/kWh_{el}	Total without fuel kWh_{Prim}/kWh_{el}
Coal	0.0176	0.2519	0.2695
Lignite	0.019	0.1415	0.1606
Natural Gas	0.0044	0.1655	0.1699
Nuclear	0.0151	0.0578	0.073
Wood	0.0827	0.0003	0.083
PV*	0.574	0.035	0.609
Wind 1500 kW (5.5)	0.054	0.004	0.058
Wind 1500 kW (4.5)	0.0784	0.0065	0.0849
Hydro 3.1 MW	0.0401	0.0045	0.0445

The Myths of “Renewable” Energy Sources: 2

- **Claim 2: Grid-connected “renewables” reduce anthropogenic greenhouse gas (AGHG) emissions.**
- **Truth: Grid-connected “renewables” will in many cases not reduce AGHG emissions if they are backed up with gas-fired stations.** In that case, one has to take into account not only the CO_2 emissions but also the leakage of natural gas into the atmosphere during its production at the well and during its processing, transportation and usage. The main component of natural gas is methane (CH_4) having a Global Warming Potential (GWP) that is about 120 times higher than that of CO_2. **Only a relatively small leakage rate of natural gas (2% - 4%) will make it questionable that the combined plant (i.e., wind/solar plant together with its back-up power), will reduce GHG emissions. Leakage rates as high as 10%.have been reported in the literature.**
- An additional reason militating against a reduction in GHG emissions, is that the gas-fired back-up power plants will operate below normal efficiency (possibly by some 20%), having to constantly follow the varying output of the “renewables”. This will increase the CO_2 emission rate.

Greenhouse gas emissions of various sources (for wind and solar without back-up sources)



B. Comby, President of Environmentalists for Nuclear Energy, 8th International School on Nuclear Power, 28 October, 2015 Warsaw

Comparison of total emissions (including construction, decommissioning and fuel cycle)

	CO_2 [g/kWh]	SO_2 [g/kWh]	NO_x [g/kWh]
Coal	793.7	800	865.5
Lignite	977.1	740.2	739.7
Natural Gas	413	71	385.9
Nuclear	15.7	34	35.8
Wood	40.5	156.1	1137.7
PV	156.1	341.6	272.5
Wind 1500 kW	16	40.1	33.4
Hydro 3.1 MW	12.5	24.8	41.5

Source: University of Stuttgart, Institute of Energy Economics and Rational Use of Energy, November 2005, updated July 2007.

Compared to coal, burning natural gas reduces production of CO_2 about 2-times, but incomplete burning and leakages of methane are very significant sources of GHGs

Effects of methane on global warming

- In addition to CO_2, methane CH_4 is the second most significant GHG contributing to global warming
- **Molecule of methane is ~120-times more powerful in heating the atmosphere than a molecule of CO_2**
- The methane contents in the atmosphere started to grow since 1750, the year considered as the start of the industrial revolution; until 2011 an average increase was plus 138 %.
- This value is compared with the same temporal increment of carbon dioxide in the atmosphere with an average increase 36 %.
- **The increase in the climatic relevance of methane has been 40 times larger than that for carbon dioxide**
- **The cause of the increase are most likely direct atmospheric releases of natural gas** during its geological extraction, purification, flaring and venting, liquefaction and transport, as well as storage and manipulation and use of the gas in electricity generating station and from poor gas combustion. **The mass fraction of natural gas leakages from all these operations are quoted from 2% to 10% of natural gas delivery.**

Effects of methane on global warming

- CO_2 emissions from burning methane are 50% less than coal, which is a substantial improvement, but it's still contributing to global warming.
- When natural gas is used instead of coal or to back up the intermittency and variability of wind/ solar photovoltaic systems for load based electricity generation, the expected climatic effect from the **natural gas directly released to atmosphere has to be added to the corresponding release of carbon dioxide** from the natural gas combustion process.
- It is not easy to estimate accurately the global warming effect of both gases (they are released to the atmosphere and they decay with half time for methane ~11 years, for CO2 ~100 years), since their effect depend on release rates and on time horizon considered
- **When comparing a wind farm that is backed up by a gas-fired station with a coal-fired station,** one finds that the wind farm plus gas-fired backup will, (for a time horizon of 20 years) **have a larger effective GHG emission if the leakage to the atmosphere of the natural gas exceeds 2.7 % and 4.1 %, respectively for annualized availability values of the wind farm of 25% and 50%**.

The Myths of “Renewable” Energy Sources: 3

- **Claim 3: “Renewables” are environmentally friendly**.

- **Truth: Wind and solar installations are <u>not</u> environmentally friendly.** The residents in the area with wind turbines are subjected to **noise and visual disturbance** caused by the rotating turbine blades that also **kill birds and bats.** “Renewables” are “low-density” sources, requiring **very large areas** for the energy to be harvested. Typically in order to generate 1 GWy of wind energy with land-based turbines, one needs about 1000 wind turbines with name-plate capacity of 4 MWe each. Because of the wind-shadow effect, these turbines have to be widely spaced, thus requiring an area of about 1000 km^2. Also, the high turbine towers cause ugly **“horizon pollution” in the landscape**. Similar considerations apply to large solar energy installations which blanket the affected area.

Renewable sources are environmentally friendly?

Renewable sources are environmentally friendly?

- **“Wind and solar plants are gas plants”** (M. Conley&T.Maloney, 17 April 2015, Preparation for the book “Power to the Planet”)
- Wind and solar plants need for the same average power about 1 500 – 3000 times more space than nuclear
- Environmental effects of huge infrastructures and hydro energy storages not to be counted? *(500 MWh needs to pump roughly 1 800 000 tonnes of water 100 m high)*
- Wind turbines kill between 140,000 and 328,000 birds in the U.S. every year (2013 study of Smithsonian Conservation Biology Institute)
- More than 2,000 wild birds were burned flying through an area of intense heat between the mirrors and the power towers at the US Ivanpah solar plant between March and August of 2015, according to estimates that biologists hired by the plant owners
- Germany's CO2 emission per KWh in 2015 was a factor 12.6 higher than that of France

Some numbers for US conditions

M. Conley&T.Maloney, 17 April 2015, Preparation for the book “Power to the Planet”

- **Comparison of renewables with nuclear power for producing 500 MWe average**

Option	500 MW_{avg} baseload wind farm (43 %) with Pumped-Hydro Energy Storage	500 MW baseload 33%with Concentrated Solar Power (much more efficient than PV-15 %, much more land)	500 MW_{avg} Gen 3+ Light Water Reactor (90 %)
Steel mass	219,618 t	787,315 t	28,818 t
Concrete mass	627,480 t	2.52 Million t	46,208 t
CO_2 mass (from material production and transport)	2.17 Million t	4.44 Million t	107,322 t
Land area	119 km^2	63 km^2	0.04 km^2
Death-print (casualties from power production)	0.15 deaths/TWh	0.44 deaths/TWh	0.04 deaths/TWh
Carbon karma (achieving CO_2 break-even) – no GHG considered during operation	181 days	370 days	9 days
Construction cost	$26.7 Billion	$12.3 Billion	$4.03 Billion

The Myths of “Renewable” Energy Sources: 4

- **Claim 4: “Renewables” are (or will become) competitive for base-load delivery of electrical energy.**
- **Truth: “Renewables” are not competitive and will remain forever be dependent on (direct and indirect) subsidies and on favorable legislation.** It is necessary to distinguish clearly between the ‘bare’ cost of a kWh that is generated and consumed locally and the cost of a kWh delivered to the electrical grid. In the latter case, it is necessary to account for the investments in the backup power and transmission capacity. **The cost per kWh delivered to the grid is in most cases several hundred percent higher than the `bare´ cost. The primary reasons for this are: (a) the need for investment in redundant under-utilized generating capacity and (b) the need for extra under-utilized transmission capacity.**
- Furthermore, **“renewables” deleteriously affect grid reliability,** particularly if the installed capacity of the intermittent sources becomes a high percentage of the grid’s total capacity. Such unreliability of the electrical grid can have serious economic and social consequences as has been observed when long-lasting blackouts occurred in large urban areas. To date, in most grids, “renewables” have only reached a relatively low market penetration and so have been able to rely mostly on existing marginal capacity. However, problems will arise when the percentage of “renewables” exceeds the existing marginal capacity. It then becomes necessary for the base-load plants to function as back-up plants making them less efficient and uncompetitive.

Consumption of specific materials

(SWOT Analysis of Energy Technologies, ENEF Subgroup on the Competitiveness of Nuclear Power, May 2008)

Specific Resources and Material Consumption			
	Iron [kg/Gwh$_{el}$]	Copper [kg/Gwh$_{el}$]	Bauxite [kg/Gwh$_{el}$]
Coal	1700	8	30
Lignite	2134	8	19
Natural Gas	1239	1	2
Nuclear	457	6	27
Wood	934	4	18
PV*	4969	281	2189
Wind 1500 kW (5.5)	3066	52	35
Wind 1500 kW (4.5)	4471	75	51
Hydro 3.1 MW	2057	5	7

* *Crystalline Silicon Solar Cells*

Source: University of Stuttgart, Institute of Energy Economics and Rational Use of Energy, November 2005, updated July 2007.

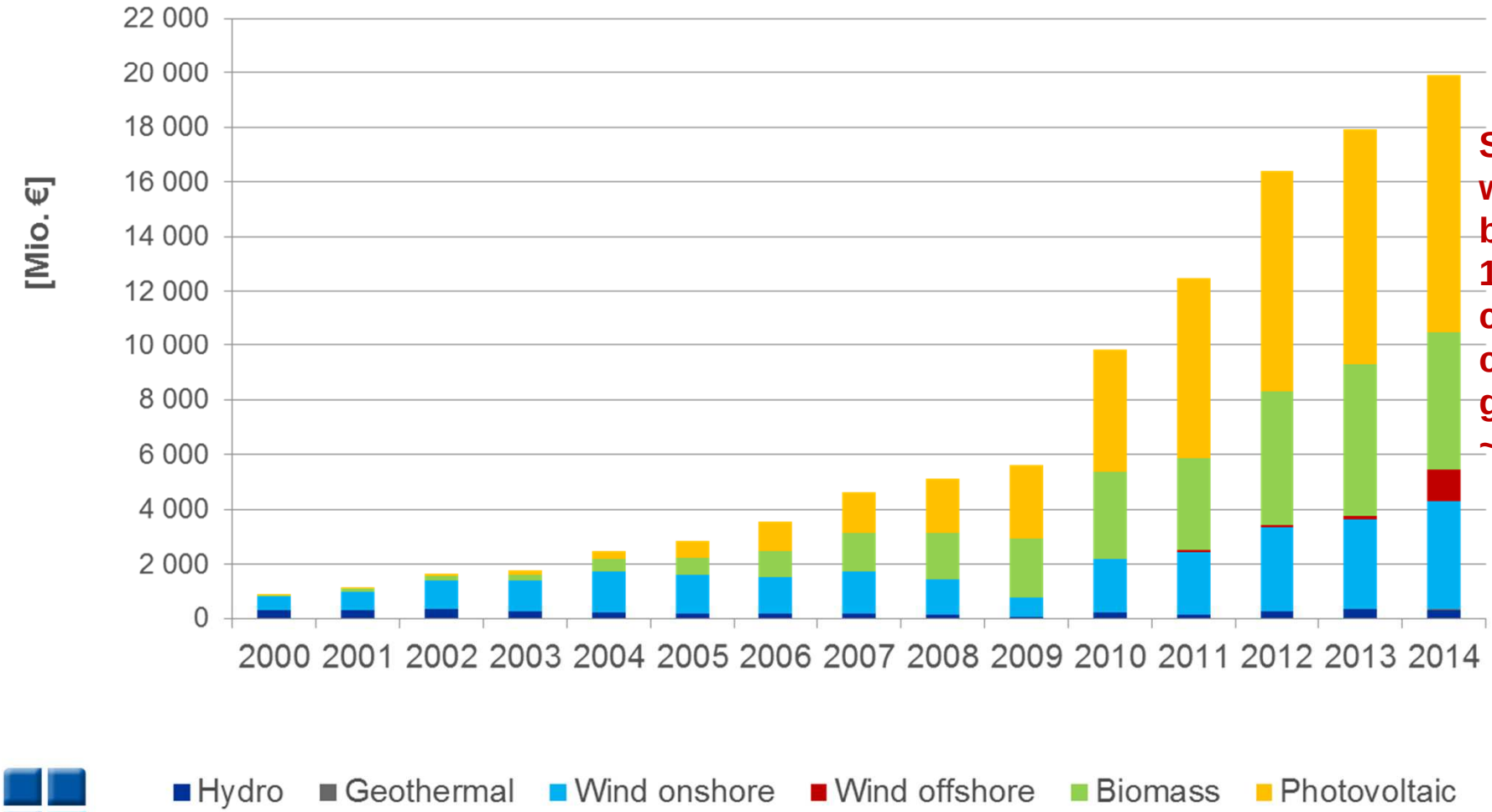
Expected effects of large penetration of RES on electricity prices (Joint MIT-Japan White Paper: Compatibility of Nuclear and Renewables with Grid Stability, Economics and Deregulation)

- Renewable sources (RES) are high-capital-cost low-operating-cost power sources, similarly as NPPs
- In opposite, fossil plants are low-capital- cost high-operating-cost power sources
- If share of RES will become high, at sunny days all solar plants would like to deliver to the grid and prices of electricity will be low (if not subsidized) and fossil plant are not needed
- At the time with low solar output other sources will be required to operate, but due to low capacity factor not economically, unless price of electricity will become very high
- Use of NPPs at low solar output would be a solution, but at present they do not have needed load follow capability
- If RES are not subsidized, price collapse at the time of high solar output will limit the use of RES due to revenue collapse

Financial support (subsidies) to renewable electricity production under the Renewable Energy Source Act (EEG)

Support until 2014: ~ 106 billion €

Future funding of existing capacities: ~ 300 billion €

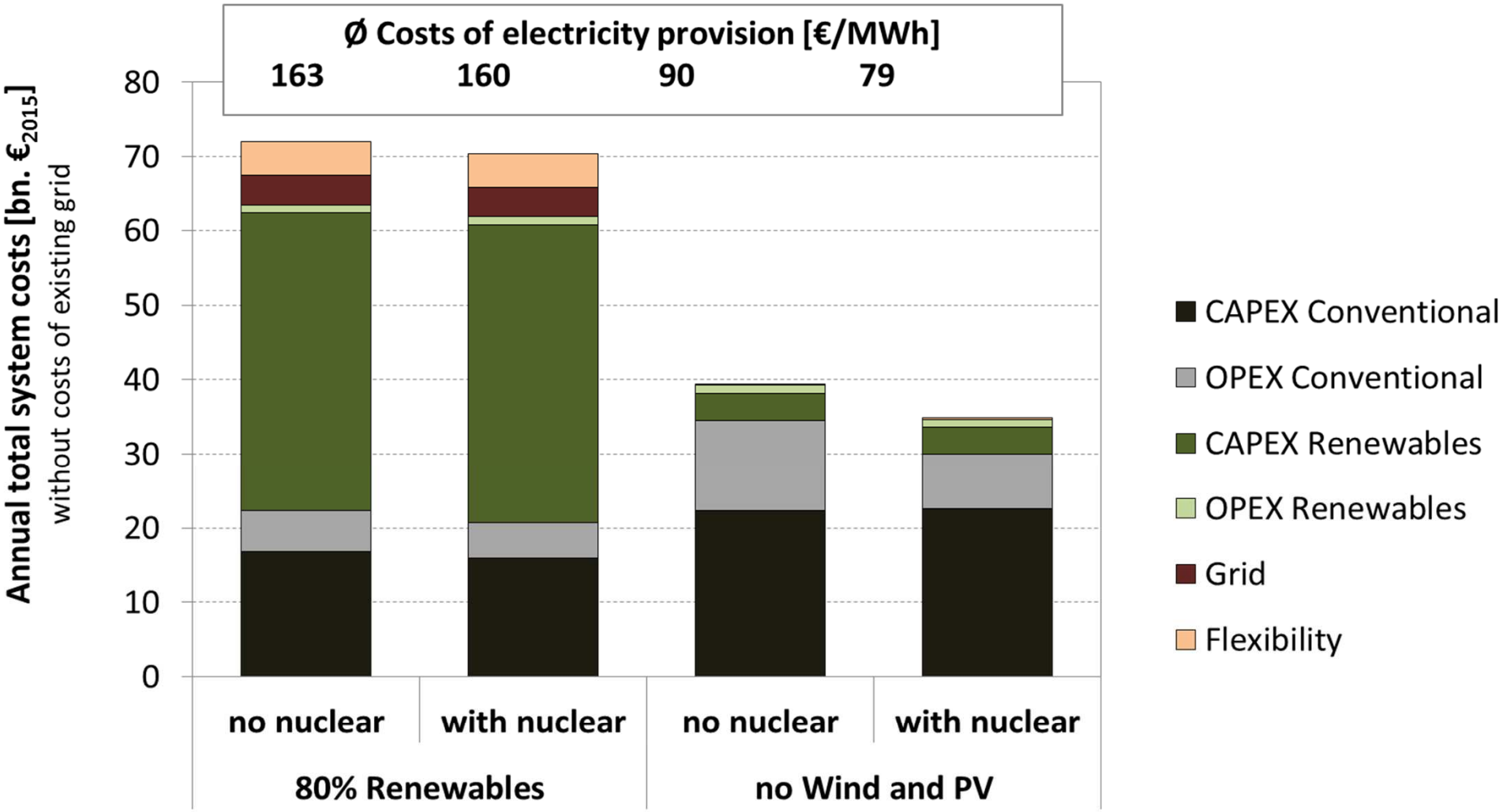


Subsidies to PV, wind and biomass in 2014~ 145 €/MWh compared to current generation price ~25€/MWh

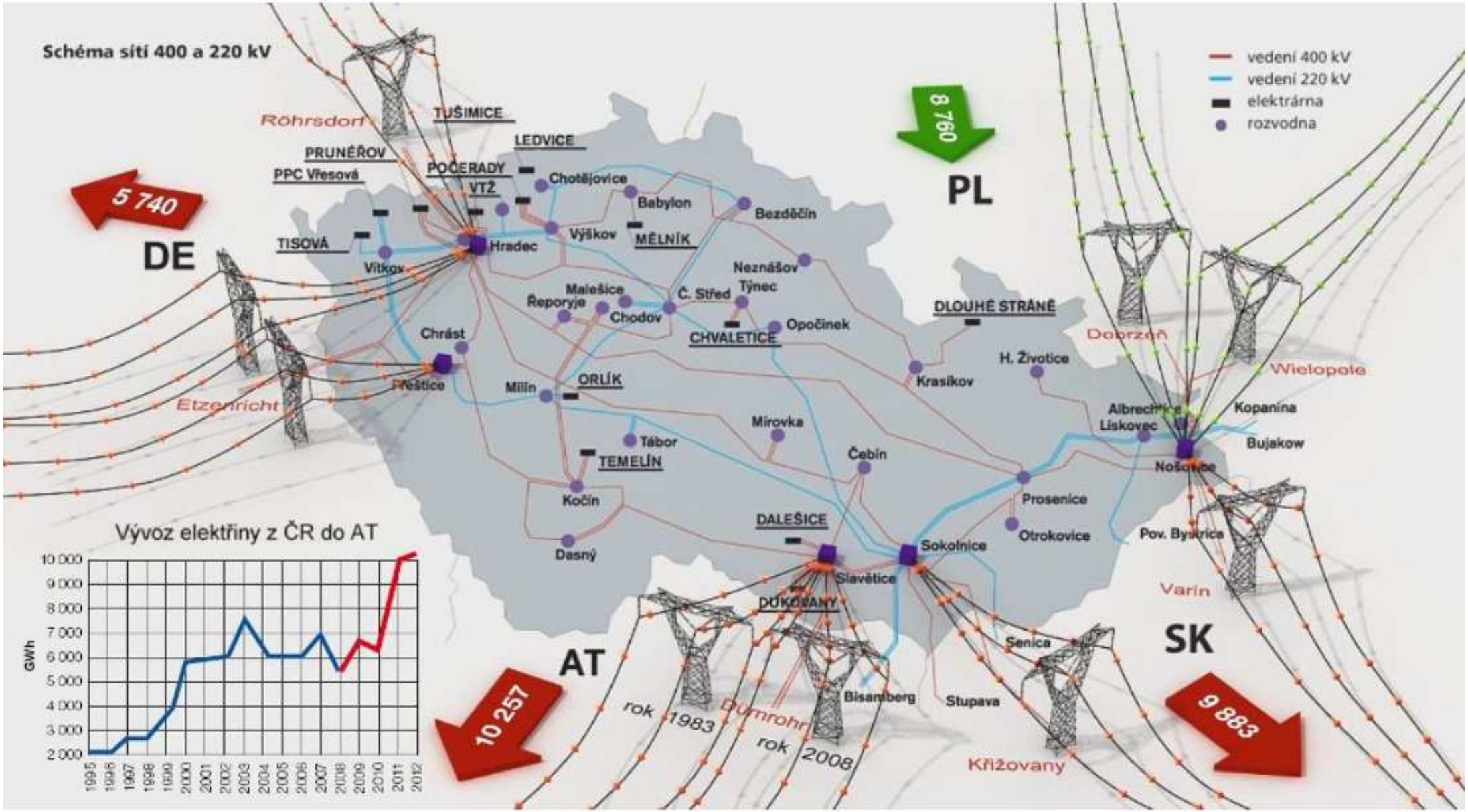
System Effects and System Costs

- All power technologies cause system effects and have system (integration) costs
- System (Integration) costs are the costs above plant-level to supply electricity at a given load and given level of security of supply
- For variable renewables the system (integration) costs are higher than for dispatchable technologies, due to their:
  - intermittent production profile
  - low capacity credit
- Due to the high auto-correlated production of wind or PV system (integration) costs increase with the share of their production (penetration level)
- System (integration) costs are technology as well as system specific

Total system costs of electricity provision



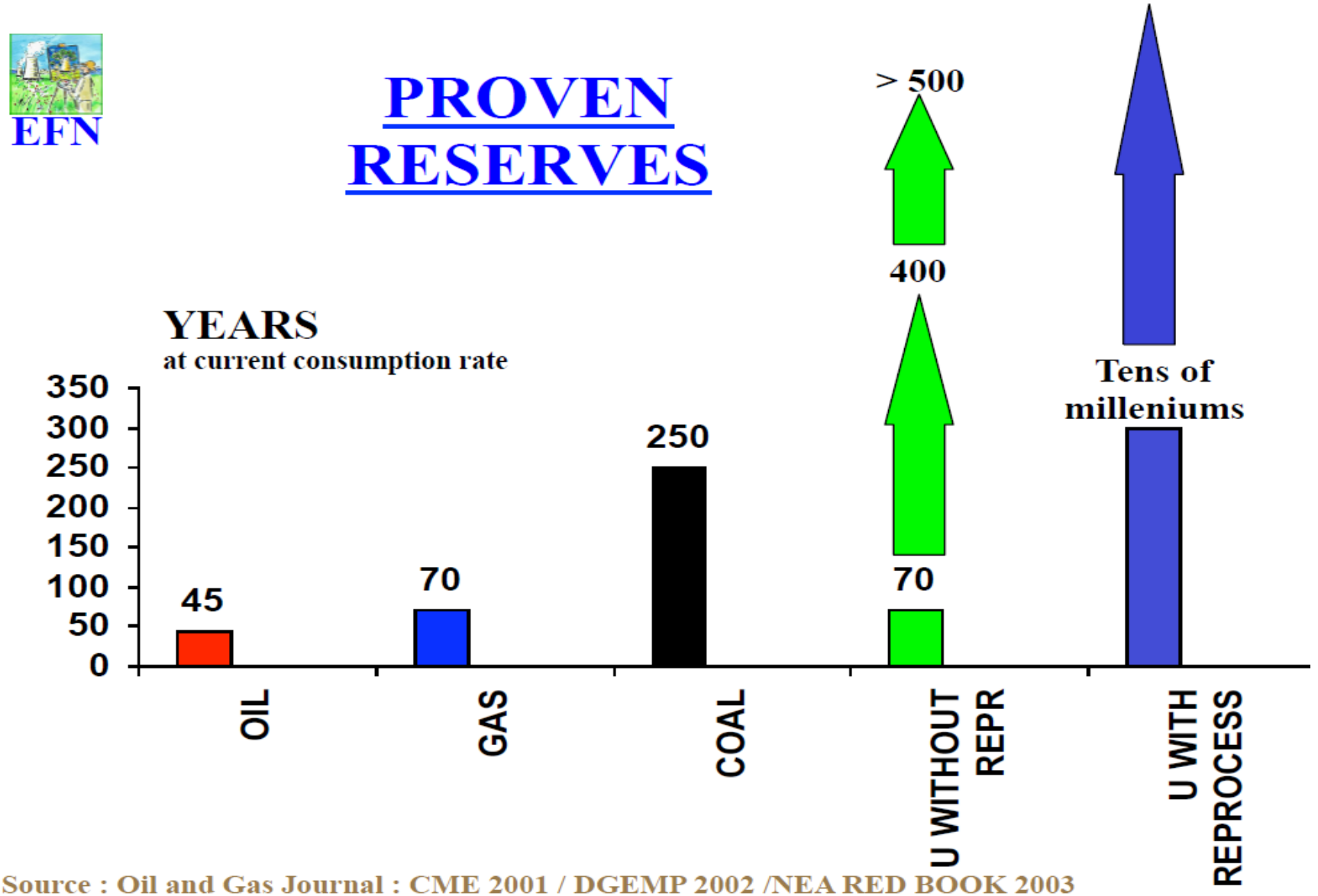
GERMAN WIND POWER PLANTS ARE CAUSING PROBLEMS ALL AROUND CENTRAL EUROPE



The Myths of “Renewable” Energy Sources: 5

- **Claim 5: Energy derived from nuclear fission is not sustainable and not environmentally friendly.**
- **Truth: Nuclear fission is a low AGHG-emission energy source that is reliable and clean.** It meets all requirements for sustainability as regards both the fuel supply and the availability of necessary structural and other materials. Nuclear fission is an energy source that is already widely deployed for the generation of electrical energy. Annually, the 435 operating nuclear power plants prevent the emission of more than 2 billion tons of CO_2. Notwithstanding these facts, the UN-FCCC adopted in 2001 during COP-6 the position that nuclear energy is not a clean development mechanism (CDM). This is difficult to understand if one considers that nuclear fission is already now the main contributor towards reducing AGHGs.

Sustainability of nuclear power (availability of fuel for long time period)



Source : Oil and Gas Journal : CME 2001 / DGEMP 2002 /NEA RED BOOK 2003

Sustainability of nuclear power - Utilisation of U238– breeding reactors and advanced fuel cycles

Yearly fuel consumption of 1000 MWe NPP with FBR and closed fuel cycle

Depleted U and U from reprocessing 0,98 t

Production of fuel for fast reactor

Fuel 10,765 t HM

FAST REACTOR

Produced electricity 28 806 TJ

Heat to environment 55 420 TJ

Spent fuel 9,785 t HM 0,98 t FP

HM from reprocessing 1,000 t Pu+MA 8,785 t U

Reprocessing of fuel from FBR

RA waste 0,98 t FP

Initial fuel load yearly (first 5-10 years):
Depleted uranium and U from reprocessing 9,765 t U
Pu from reprocessing 1,00 t Pu

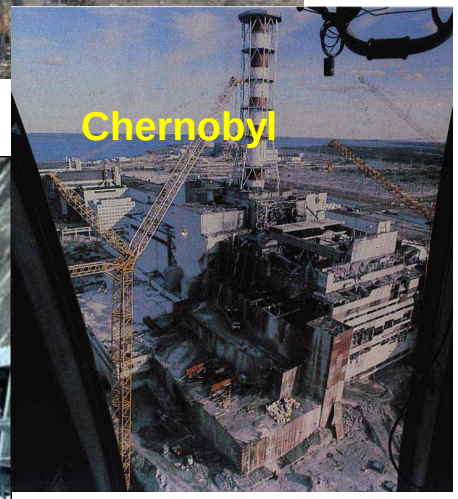
Time Sustainability of Nuclear Energy

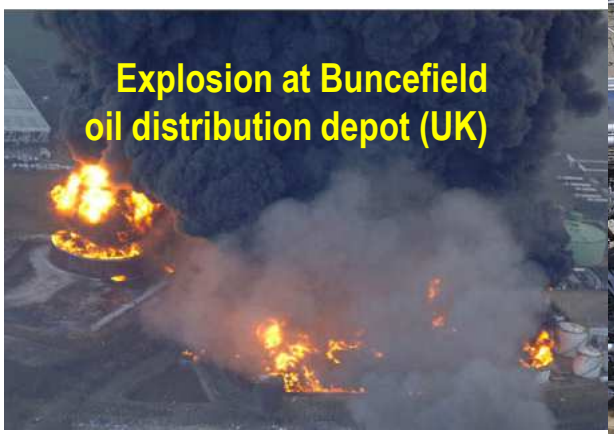
- Deployment of fast-neutron fission reactors will harvest up to one hundred times more energy from the same amount of mined uranium
- Mining of small quantities of uranium in future centuries, including extracting uranium from lower-grade ores and from seawater, could satisfy global energy needs economically for as long as human civilization will endure.

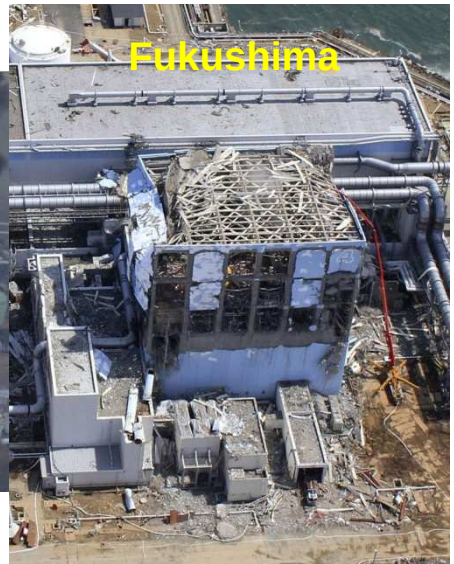
Results of simplified calculation of energy accumulated in the spent fuel In Slovakia

Electricity produced in Slovak NPPs till 2050	5 496,56 PJ
Mass of minor actinides in spent fuel	4,1 t
Mass of plutonium in the spent fuel	41,0 t
Mass of fission products in the spent fuel	187,7 t
Thermal energy stored in the spent fuel	**327 921,2 PJ**
Potential for electricity produced in a FBR (assuming 45 % efficiency)	40 990,15 TWh
Current annual electricity consumption in Slovakia	30 TWh
Coverage of current consumption	**1 366 years**

Energy Infrastructure Accidents - Technological





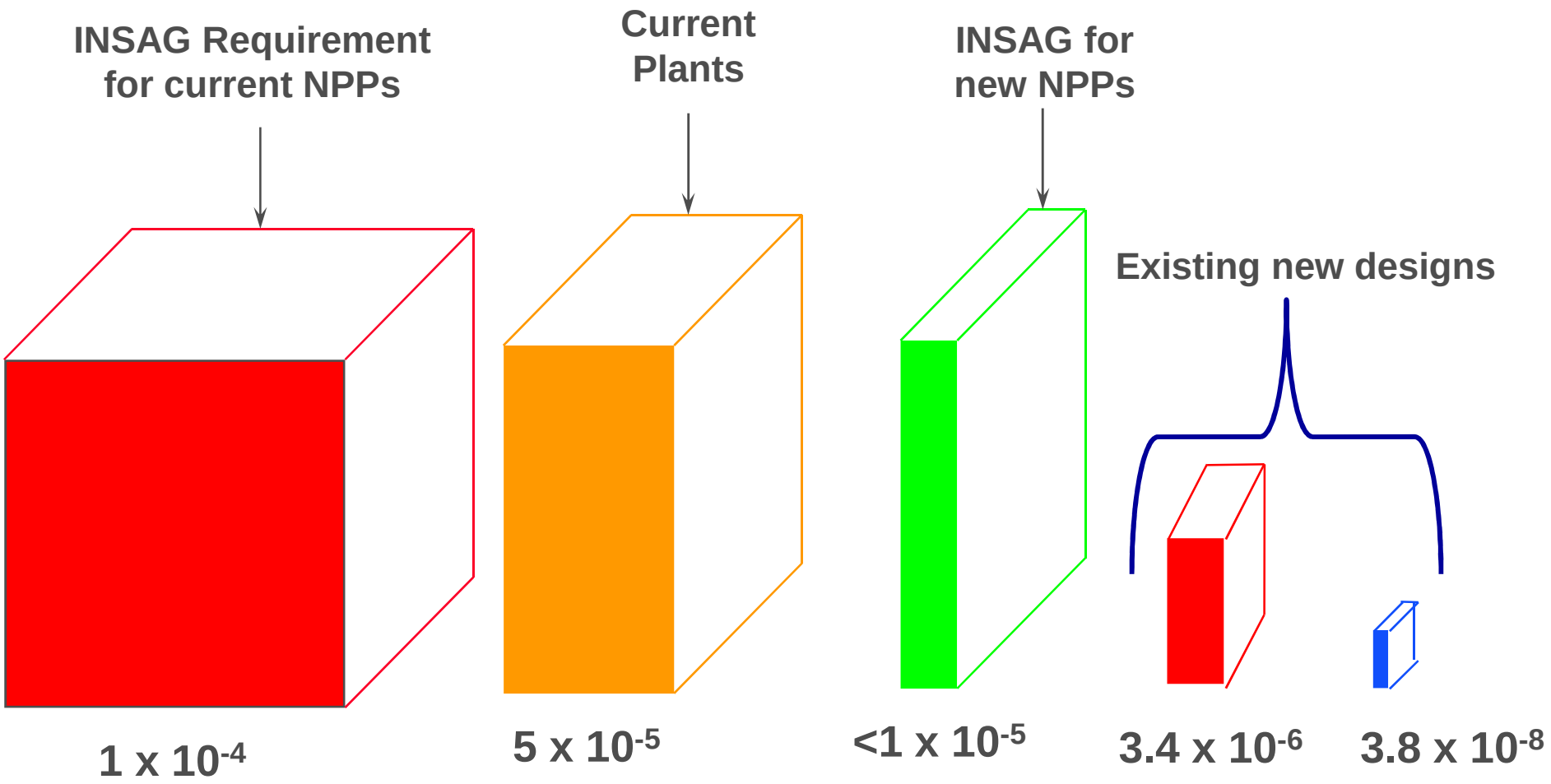


Source: Hirschberg et al., 2008

Mortality Rates (deaths per TWh) from Energy Sources (Updated data from World Health Organization)

Coal global average	100	50% global electricity
Coal China	160	75% China's electricity
Coal U.S.A.	15	44% U.S. electricity
Oil	36	36% global/8% electricity,
Natural gas	4	20% of global electricity
Biofuel/biomass	24	21% global energy
Solar (rooftop)	0.44	< 1% global electricity
Wind	0.15	~ 1% global electricity
Hydro global average	1.4	15% global electricity,
Nuclear global average	0.04	17% global electricity

Core Damage Frequency



Range of quantified safety for new NPPs:

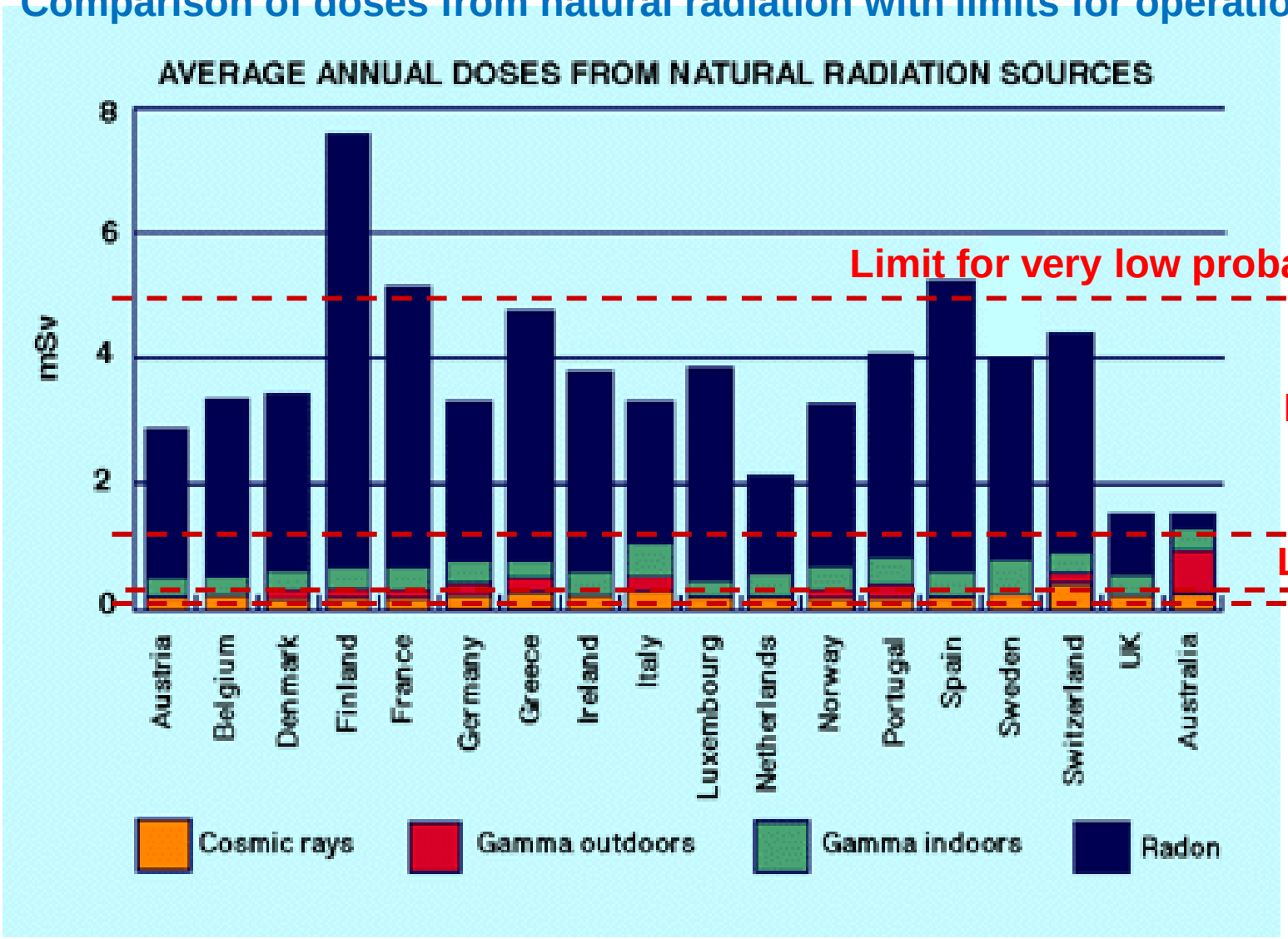
CDF= 3.8E-8 – 3.39E-6/year

LRF= 3.67E-9 – 6.3E-8/year

Age of universe 5.E+9 years

Radiological impact of normal operation and design basis accidents on plant surroundings

Comparison of doses from natural radiation with limits for operation



EUR limits

Limit for very low probability accidents

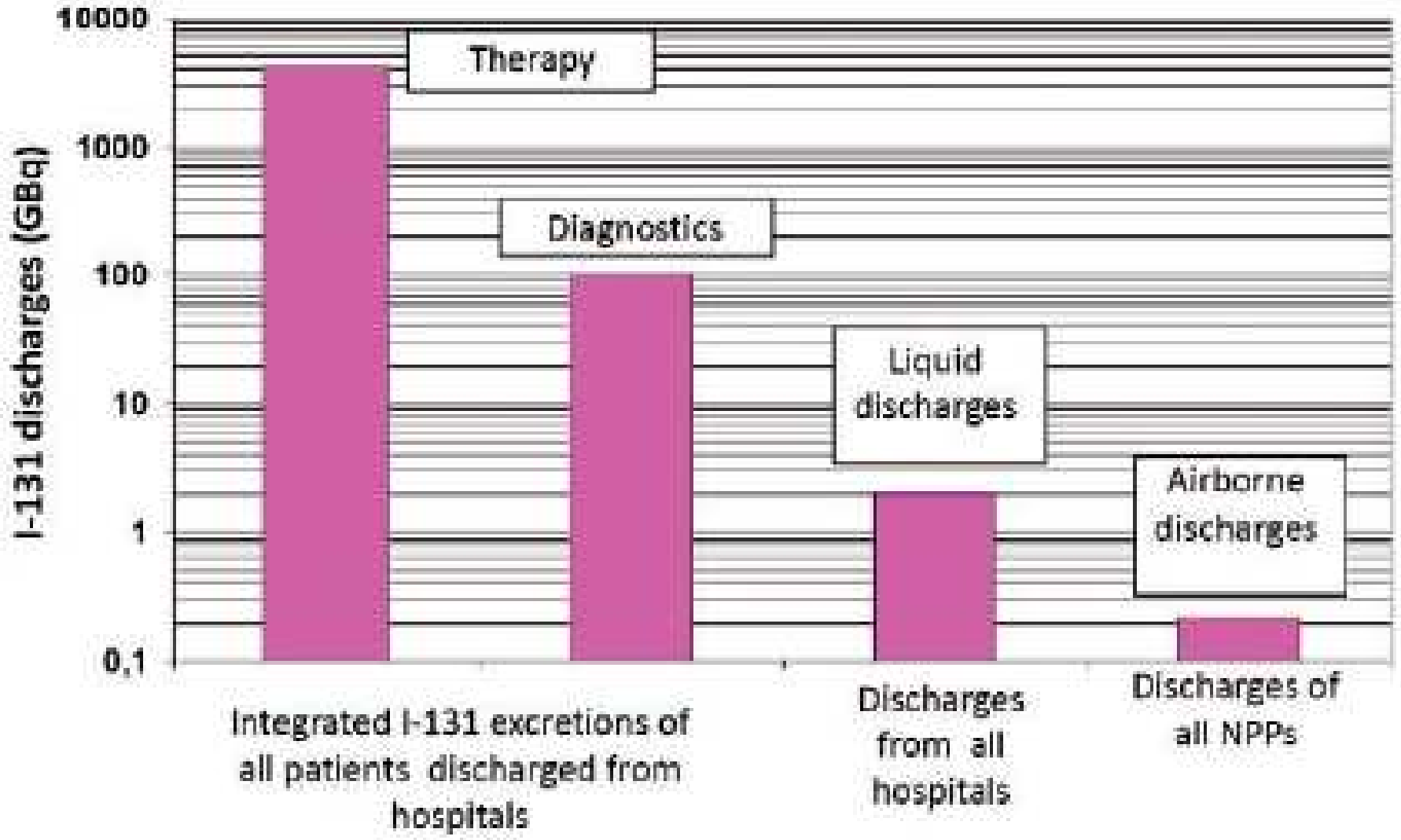
Limit for low probability accidents

Limit for incidents

Limit for normal operation

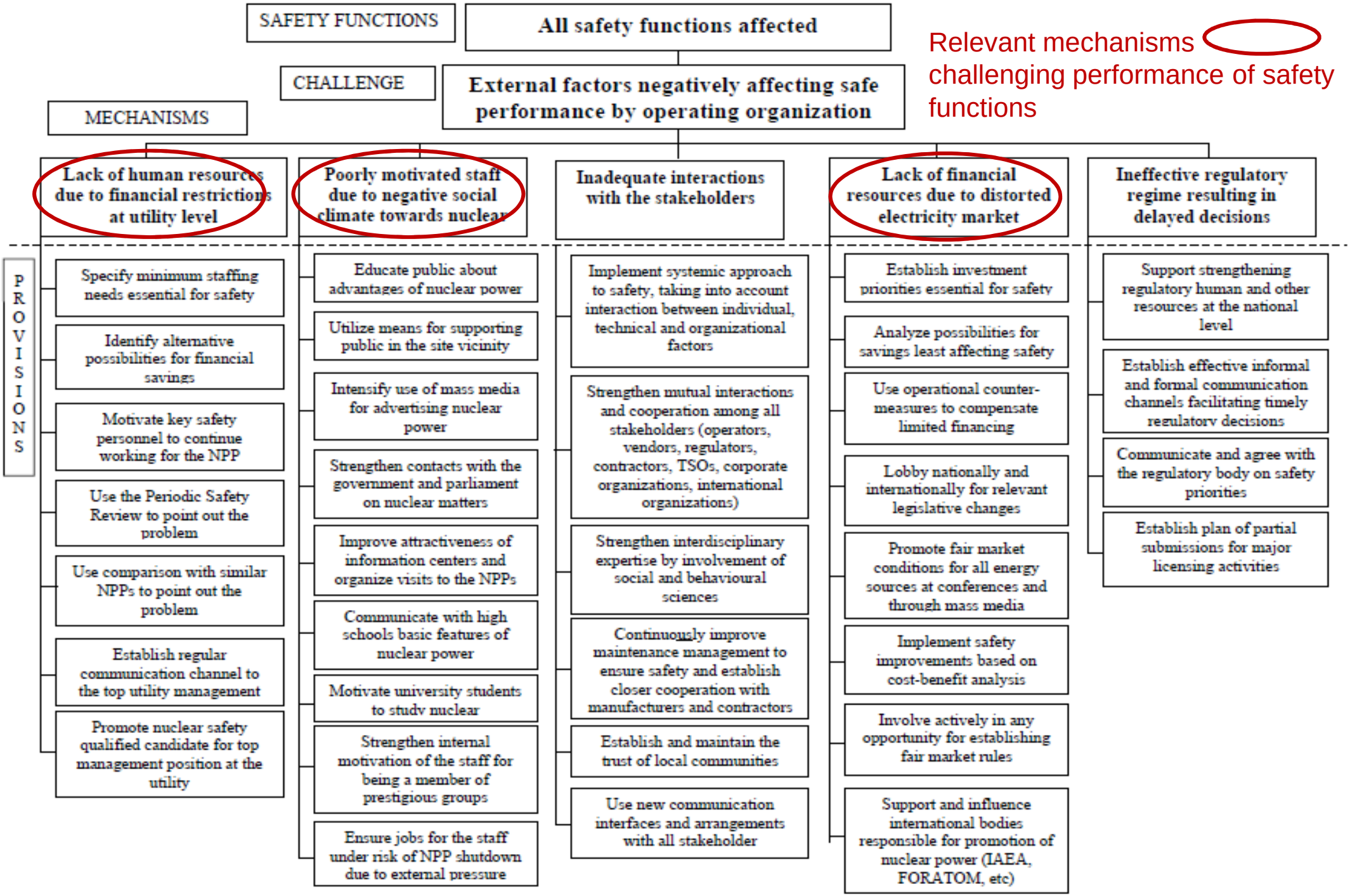
Source: European data from NRPB*, Australian from ARPANSA**.
* Since 2005 the NRPB has been replaced by Health Protection Agency (UK)
** ARPANSA - Australian Radiation Protection and Nuclear Safety Agency

Comparison of iodine-131 discharges in 2000 to the environment from several sources in Germany (IAEA SR No. 64)



In Germany, in 2000 the releases of I-131 from medical treatment were 20 000-times higher than discharges from all NPPs (before closing some of them)

Impact of external factors including subsidies of renewable sources on capability of operating organization for safety performance



Selected news from the press (October 2016 –March 2017)

Source: http://oenergetice.cz, Top 10 events during the week

9 October 2016

- The operator of the world's first commercially operated **battery storage** in Europe, the German company WEMAG, will extend their battery storage in northern Germany. ... After the expansion, to be completed in June next year, **will increase output of 10 MW and a storage capacity of 14.5 MWh**.
- An **extensive blackout in South Australia**, will be examined by the independent investigation. Major failure of electricity supply for nearly 24 hours led to a debate over the safety of a large share of intermittent renewable energy sources into the electricity system.

6 November 2016

- **Germany lags behind its goal of newly installed photovoltaic power plants**. Newly installed capacity of solar photovoltaic plants achieved in the first nine months of this year is 0.8 GW while in 2015 it was 1.5 GW, which represented the lowest level since 2008. The target value of newly installed capacity is set in a range from 2.4 to 2.6 GW.

20 November 2016

- **Germany reduced its targets to greenhouse gas emissions for the industry**. The German government now requires industry to reduce greenhouse gas emissions by 2030 by 20% compared to the level of 2014 while the initial requirement was a reduction of 30%.
- This autumn is not so extreme, but steady weather since September shows one of the main problematic issues of Energiewende. It is **windless situation that has been going on for nearly three months, not only in Germany but in large parts of Europe.**

Selected news from the press (October 2016 –March 2017)

Source: http://oenergetice.cz, Top 10 events during the week

4 December 2016

- According to the statement of the Czech Ministry of Industry and Trade (MPO) **the operators of renewable sources will next year receive around 37 billion Czech crowns (1.4 billion EUR).**
- Before federal elections in Germany, which will take place in the autumn of 2017, the Christian Democrats consider **the rapid end of support for renewable energy sources** (RES). The wind, solar or biofuels plants had to "stand on their own feet".

18 December 2016

- On Wednesday came the German report "Climate Protection 2016", according to which **Germany seems to fail to meet its own climate goals proposed for 2020.**

9 January 2017

- **German wind power is safe, even after the fall of three turbi**nes, assures BWE. At the beginning of the week in the north of Germany there was the collapse of almost 100-meter wind turbine near Hamburg. The incident comes only a few weeks after falling 95 meters high turbine in Saxony and 70 meters turbines in Mecklenburg-Vorpommern in mid-December.
- This year's statistics for the production of electricity from wind power and solar power is not as pronounced as it was in the previous year. For both types of resources **despite the increase in installed capacity production fell by 1.2 TWh.**

Selected news from the press (October 2016 –March 2017)

Source: http://oenergetice.cz, Top 10 events during the week

- **23 January 2017**
- Former CEO of RWE: **No country does such Harakiri as Germany with Energiewende**. According to the decarbonisation plan the aim is to achieve a share of RES to 80% on electricity consumption. However the German households already pay the second highest price for electricity in Europe, in the case of industry it is the fourth highest. In 2017, moreover, **the fee for support of renewable sources was increased from 6.35 cent/kWh to 6.88 cent/kWh.**
- **6 February 2017**
- Survey: **German Energiewende** can serve as an inspiration, not the guidance. According to the latest survey of Weltenergierat Deutschland, the majority of surveyed experts believe that Energiewende cannot serve as a blueprint for the transformation of the energy sector in other countries. Nearly half of survey participants from more than 40 countries believe that the German plans will be delayed at least partially implemented**. The full implementation without delay believe only a tenth of the respondents.**
- Deutsche Bank: Energiewende hampering capital expenditures. One source of uncertainty for the industry is the future price of electricity. **Electricity prices in Germany are currently significantly higher than the EU average especially due to the EEG fee supporting the expansion of renewable energy sources.**

Selected news from the press (October 2016 –March 2017)

Source: http://oenergetice.cz, Top 10 events during the week

13 February 2017

- **January in Germany was the record for coal and natural gas**. German black coal power plant in January gave an average of 17.3 GW network performance being the highest in the last five years.
- Nearly 90% of newly installed capacity in the EU in 2016 were renewable energy, wind reigns. Of a total of 24.5 GW of newly installed capacity across the EU in 2016 was 21.1 GW, or 86%, built in wind, solar and hydro power or biomass power plants. In the renewable energy sector, however, is dominated by concerns over the lack of political support after 2020.

6 March 2017

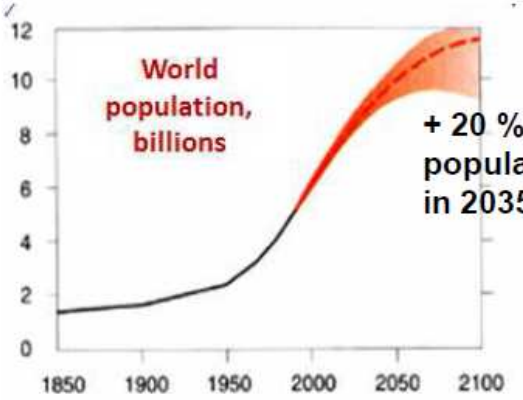
- **German Network operators are clamouring for gas power plants in the south of the country.** To be even after the conclusion of the last nuclear power plants in Germany ensure reliable electricity should be built in southern Germany, reserve power plants with an installed capacity of at least 2 GW.

13 March 2017

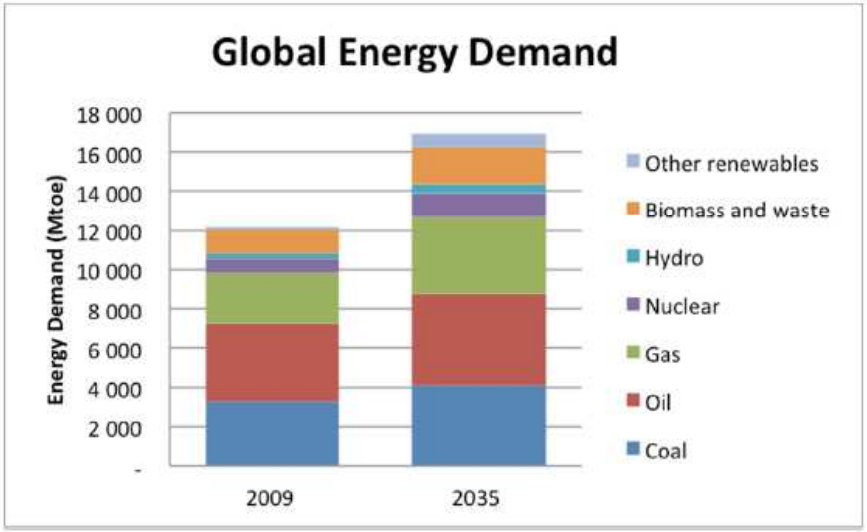
- **Will the German nuclear plants be followed in 2022 by windmills?** Without financial support some may doubt about the economic benefits of their continued operation.
- German energy company **E.ON recognized last year's net loss of over 12.4 billion euros (335 billion CZK) and cancelled 1000 to 1500 of its 43,000 jobs.**

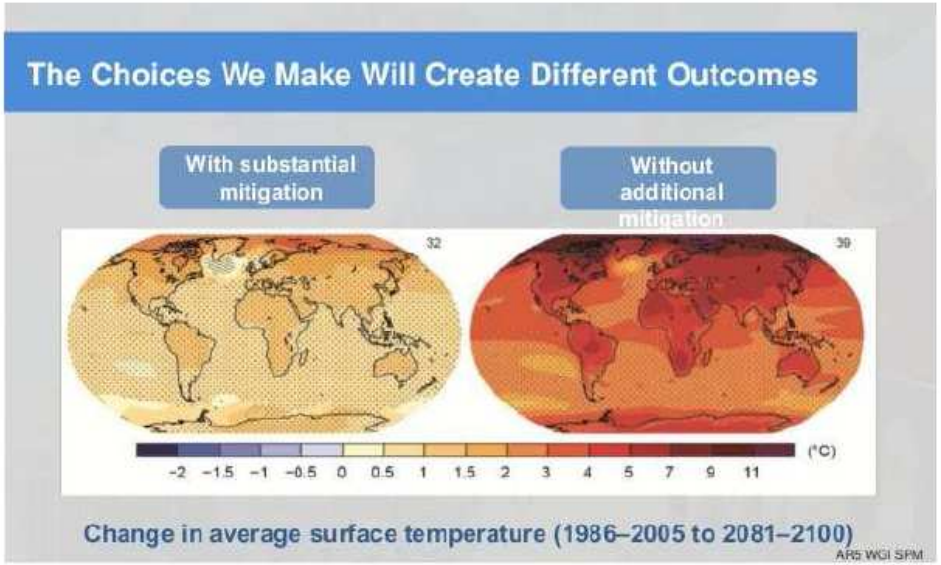
Global energy context

From presentation on Synergies between nuclear and renewable energy sources: French context and CEA experience, by Françoise Touboul, Hervé Bernard,, CEA France, *Golden, June 9th, 2016*



- Even when promoting « green economy » and « energy savings », **energy needs will continue to grow**
- 2.5 toe / year as a minimum need for everybody would represent: **+ 40 % energy demand in 2035**





GIEC WG1 2015 report

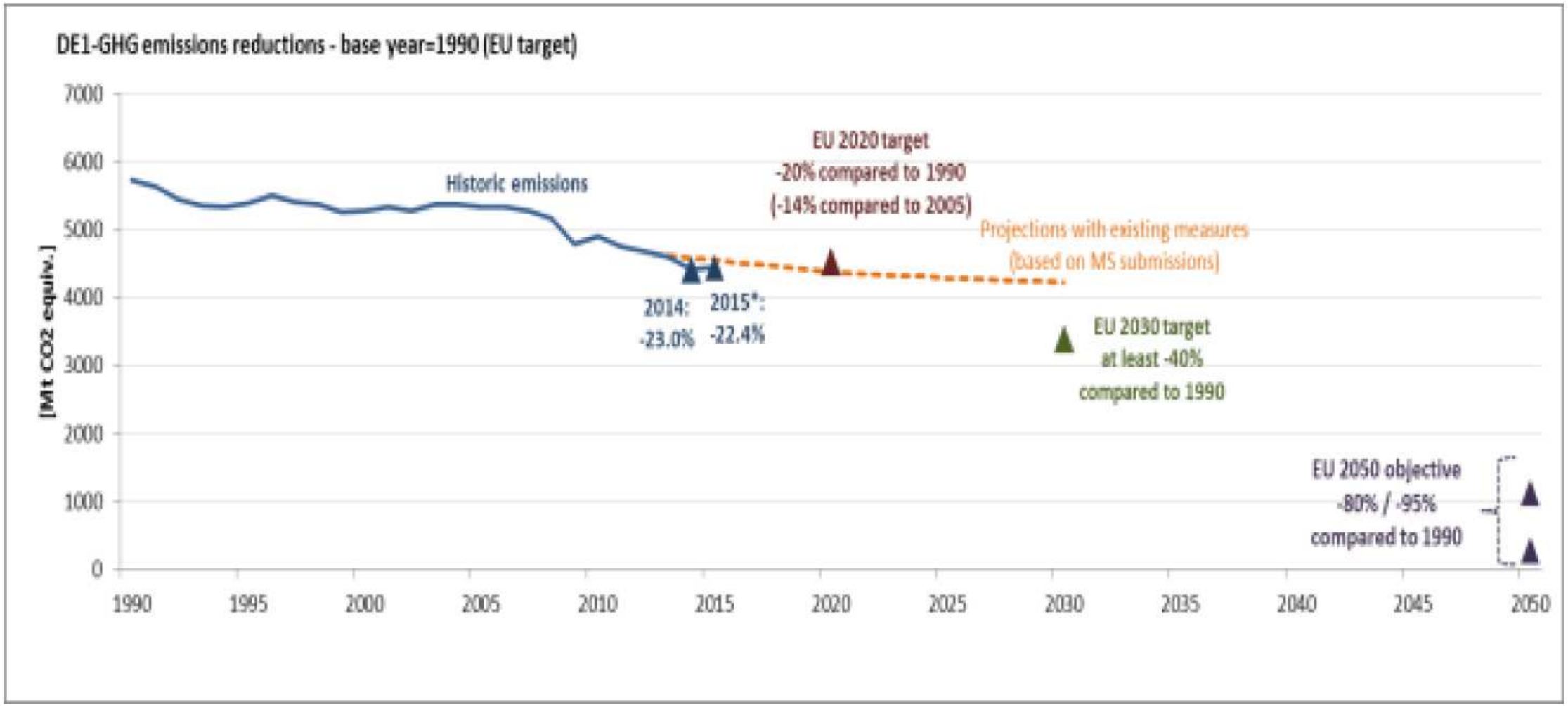
ipcc climate change

Global warming:

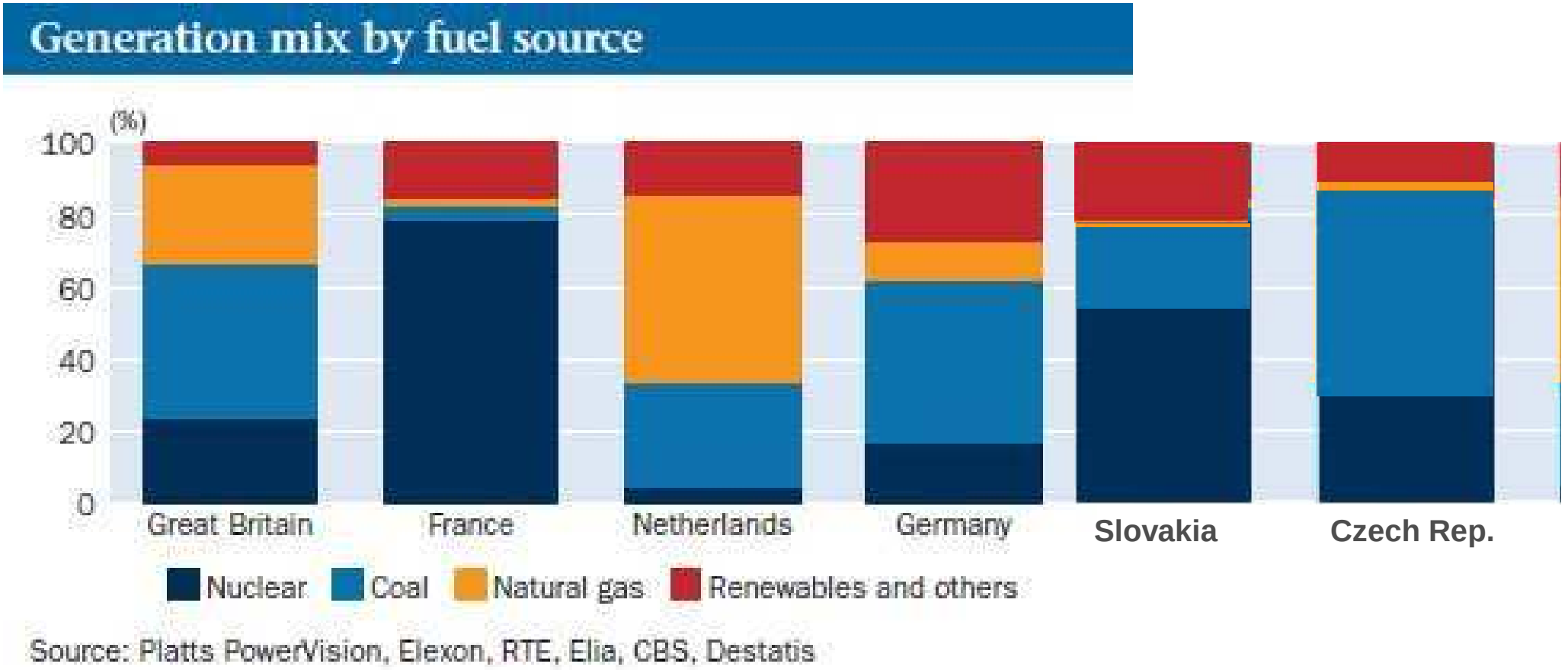
- a drastic reduction of **GHG** is necessary
- a drastic reduction of **fossile energy** is necessary

GHG emissions reduction

EC, SWD(2017)32 Final Second Report on the State of the Energy Union

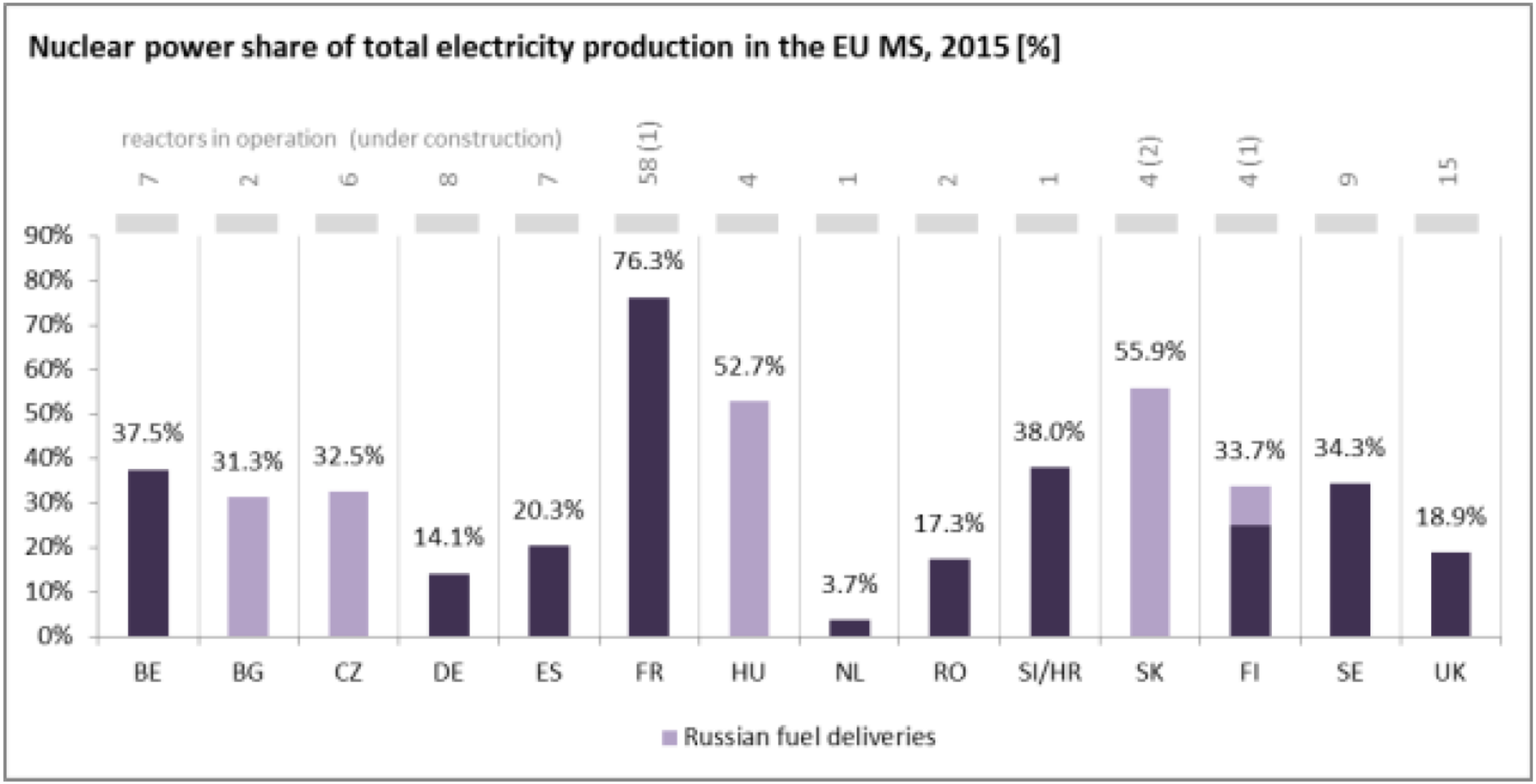


Electricity generation mix by fuel source



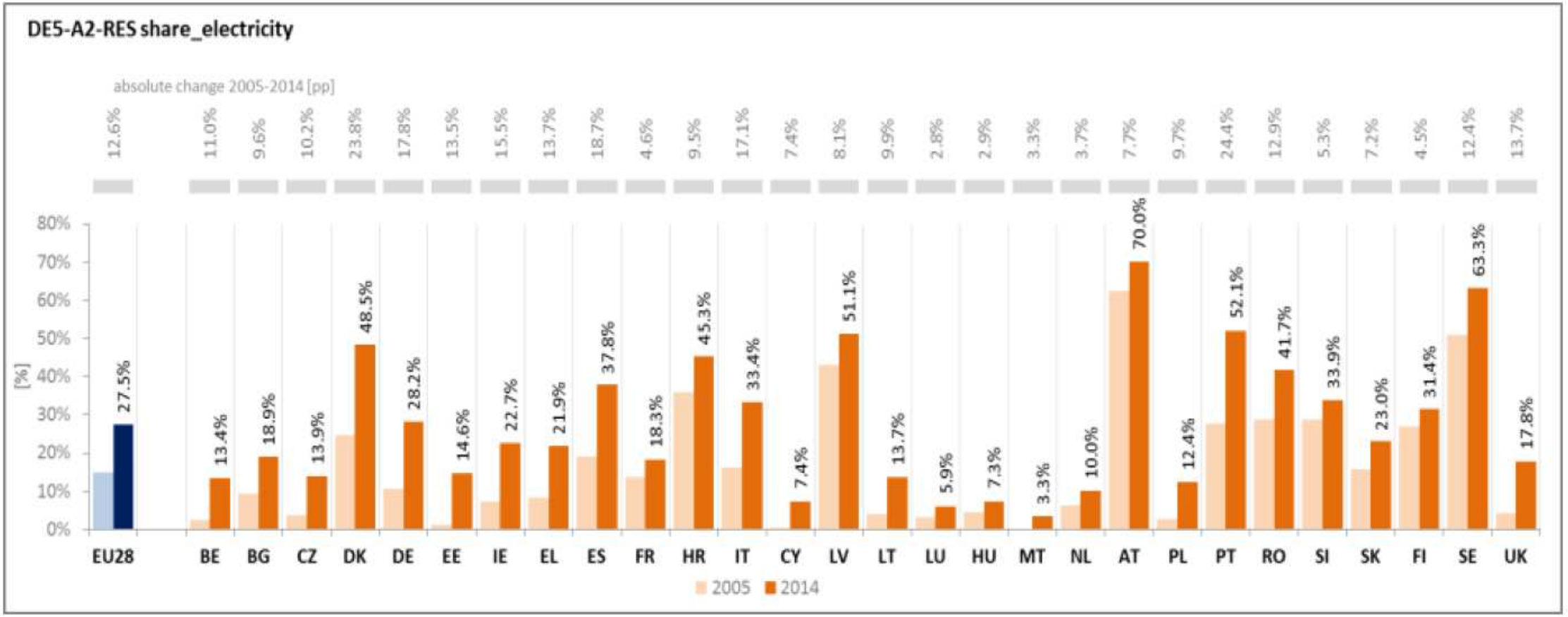
Nuclear power share of electricity production in EU (2015

EC, SWD(2017)32 Final Second Report on the State of the Energy Union



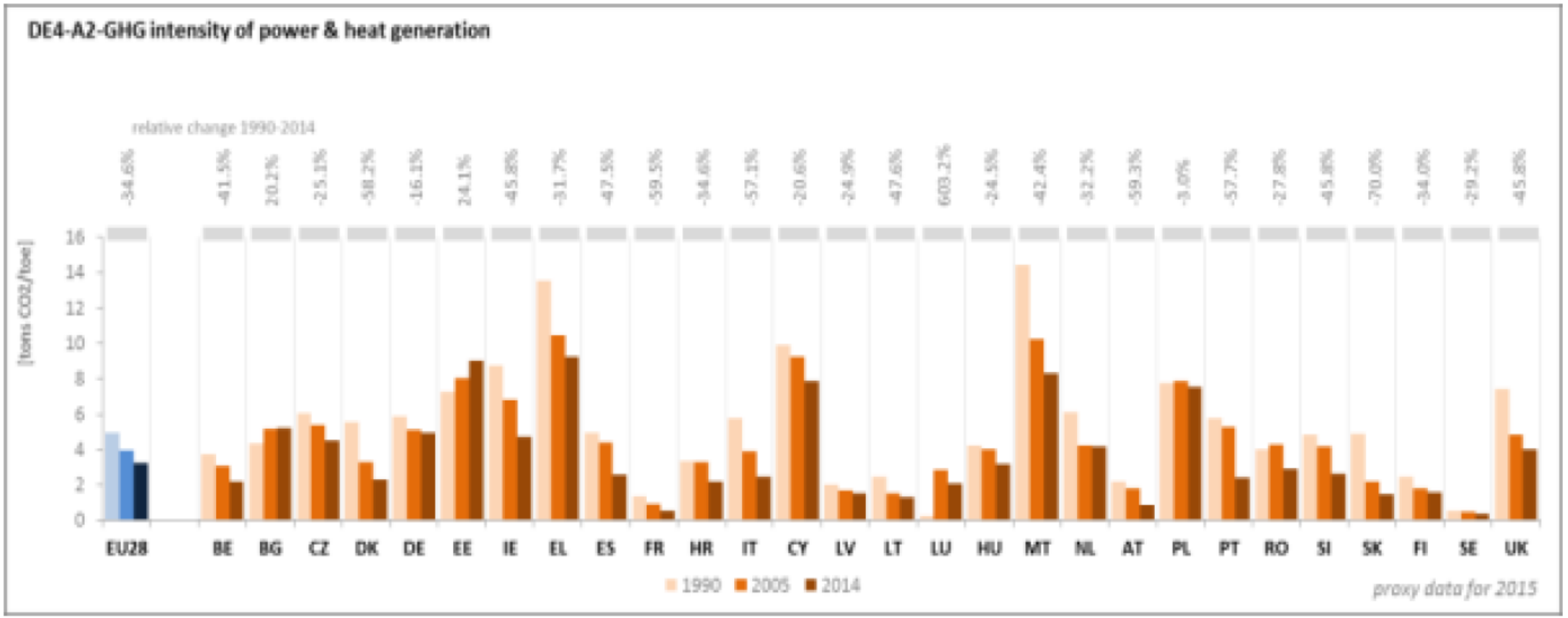
Share of renewable sources in electricity production

EC, SWD(2017)32 Final Second Report on the State of the Energy Union



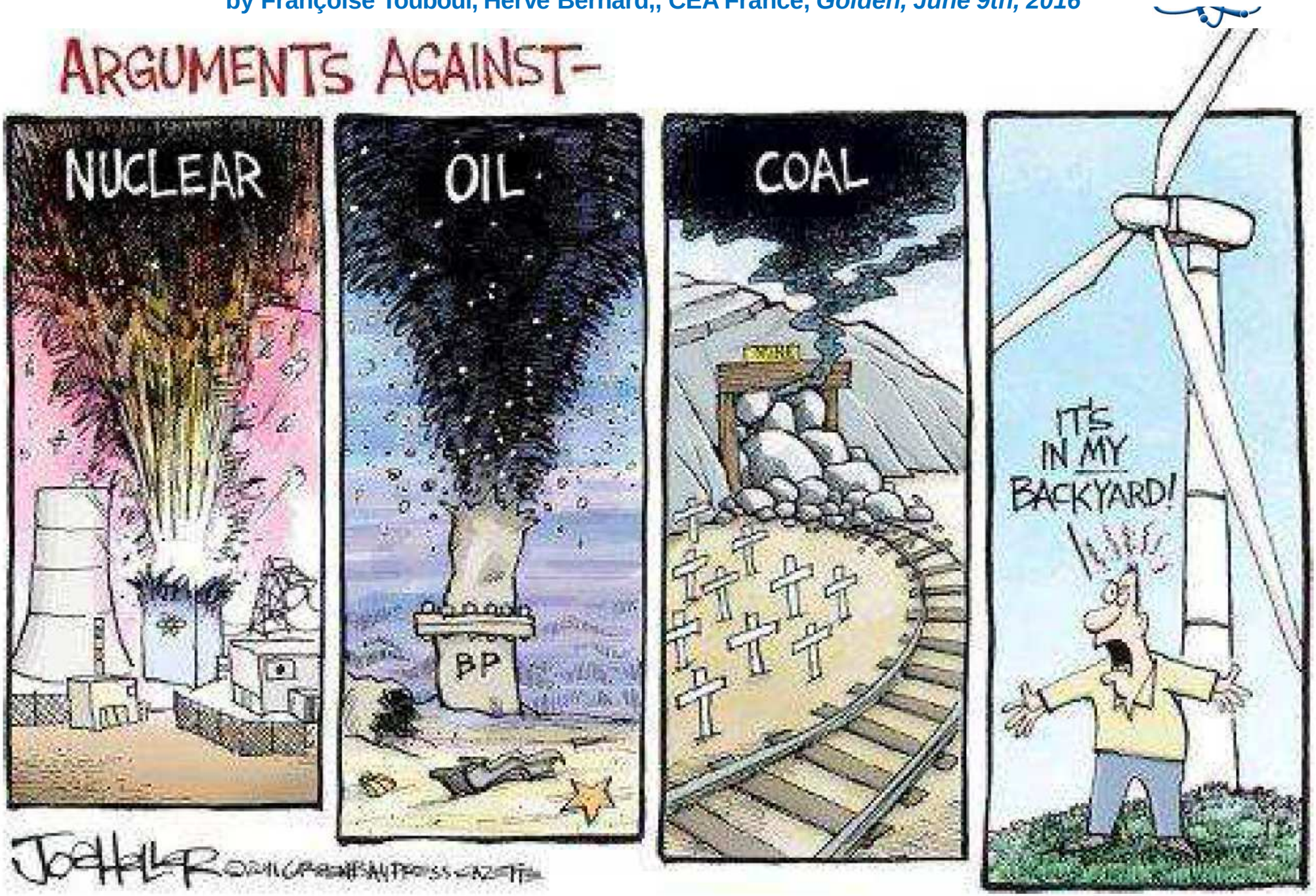
GHG intensity of power and heat generation

EC, SWD(2017)32 Final Second Report on the State of the Energy Union



Energy is a controversial issue

From presentation on Synergies between nuclear and renewable energy sources: French context and CEA experience, by Françoise Touboul, Hervé Bernard,, CEA France, *Golden, June 9th, 2016*



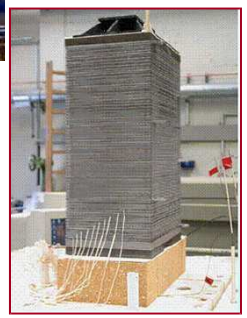
The final confrontation with the Environmental Anti Fire Party, 125,000 BC, perhaps

Innovative applications of nuclear energy: Hydrogen

From presentation on Synergies between nuclear and renewable energy sources: French context and CEA experience, by Françoise Touboul, Hervé Bernard,, CEA France, *Golden, June 9th, 2016*

alkaline electrolysis

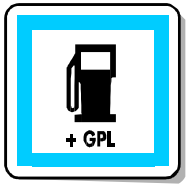
H_2



High température electolysis

BIOMASS + HYDROGEN · BIOFUEL

$C_6H_9O_4$ + water + 5.5 H_2 · 6 -CH_2- & CO



2e génération biofuels

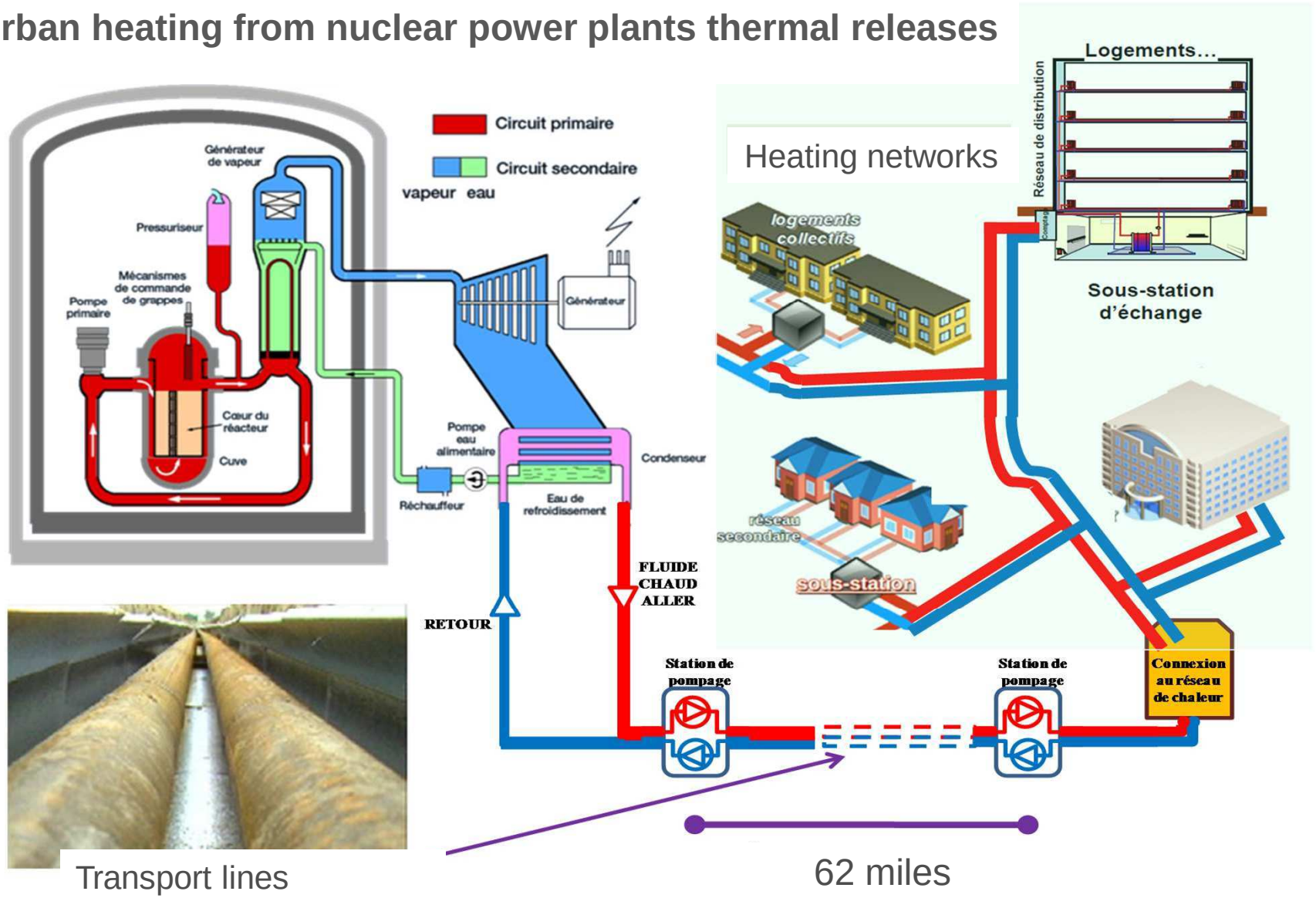
Industrial Applications (NH_3, refining, chemicals…)

Transports

Nuclear cogeneration

From presentation on Synergies between nuclear and renewable energy sources: French context and CEA experience, by Françoise Touboul, Hervé Bernard,, CEA France, *Golden, June 9th, 2016*

Urban heating from nuclear power plants thermal releases



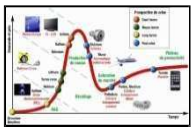
CEA R&D support to decarbonization of energy mix

From presentation on Synergies between nuclear and renewable energy sources: French context and CEA experience, by Françoise Touboul, Hervé Bernard,, CEA France, *Golden, June 9th, 2016*

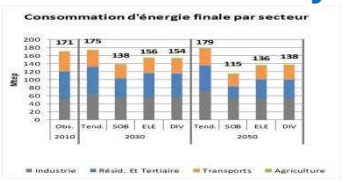
Control the impact on environment

Climate

Strategic raw material resources



Technico-economy



Technology by 2020-2030

Electricity production

Centralised nuclear production

Localised PV and CSP production

Demand/response Adaptation

2G Batteries

Indirect storage

Electrolysis
Hydrogen
2G biofuels

Smart grids

Demand/ response Management

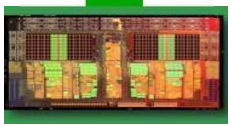
Building, cities, regions, country

New applications

Electric and hybride vehicle

Industry

Building



Green IT

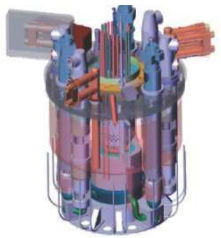
Efficiency/sobriety

Unused energy

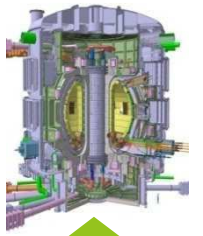
> 2040- 2050

Energy storage

4th Generation



Nuclear fusion



Responses to the Questions

1. Because of their uncontrollable intermittence, it will not be sustainable and economically viable to replace, fully or in a great part, the current fossil-derived with renewable energy sources

2. Nuclear energy is long term time sustainable, climate friendly, safe, reliable and economically viable and it should be a major component in the world electricity generation mix

Additional comments

- Distorting the electricity market with subsidies and by legislation to attract intermittent energy technologies into applications is costly, economically wasteful and counterproductive.

- Countries exploiting their natural gas resources and those that depend on imported natural gas should carry full responsibility for their part of the global consequences of the associated atmospheric leakage of methane.

Summary

- The Paris COP21 Agreement on Climate Change, 12 December 2015, emphasized the need to limit the increase in the global average temperature to well below 2°C above preindustrial levels
- Sustainable energy supply is a major challenge for all countries
- Sustainable is more important attribute of energy sources than renewable; absolute preference currently given to renewable sources is not justified at the present stage of technology
- Nuclear power accounts for 27% of EU's electricity production and provides nearly half of the EU's low-carbon electricity, being in terms of life-cycle greenhouse gas (GHG) emissions similar to onshore wind
- Nuclear power plants provide stable base-load capacity for up to 60 years or even more
- Nuclear can be an important contributor to the EUs goal of decarbonising its economy by 80-95% by 2050
- Nuclear power plants are capable of sustainably and reliably supplying the large quantities of clean and economical energy needed to run industrial societies with minimal emission of greenhouse gases.

Summary

- The most effective way to reduce AGHG emissions is to replace fossil-fuel-based electrical energy generating stations by nuclear power plants. Industrial nations should take the lead in this, thus allowing developing countries more time to reduce their use of fossil fuels.
- “Renewables”, backed up with gas-fired stations, will in most cases not be able to make a worthwhile contribution towards reducing the rate of AGHG emissions, even for relatively low atmospheric leakage rates of natural gas. In some case, there may be an increase in AGHGs.
- A solution with low carbon sources could be a combination of intermittent renewable sources with a NPP with a capability to accumulate part of energy quickly convertible into electricity (e.g. producing hydrogen)
- Countries that depend on imported natural gas should be aware that they carry responsibility for their part of the associated atmospheric leakage of methane, including for the leakage occurring outside their borders
- Large portion of intermittent renewable sources in the grid is possible only with major subsidies both for renewable as well as for conventional back-up sources

Summary

- Distorting the electricity market with subsidies and by favorable legislation for the purpose of steering intermittent energy technologies into applications for which they are not well suited, is costly, economically wasteful and counterproductive
- In addition, distorting the electricity market with subsidies of renewable power sources has negative effects of safety performance of operating organizations and therefore on nuclear safety
- The world's industrial nations should take the lead in transforming the major part of their electrical energy generating capacity from fossil-fuel based to nuclear-fission based
- Wind/solar photovoltaic systems with gas-fired backup power stations will not be able to reduce the rate of greenhouse-gas emission, even for relatively low atmospheric gas leakage rates.
- Only in specific cases and for some isolated locations without access to an electric grid, may the use of intermittent energy sources for electrical energy generation be economically viable.

Key questions to be addressed

- What are our alternatives?
- What are the criteria we take into account (the actual price is the only criterion to be taken into account)?
- We know how to calculate the social value of the security of electricity supply?
- Will we be able to buy electricity economically, if we do not have our own sources in the country?
- How will be the energy sector of the country look like in 2035 without investing in new energy sources?
- What is the price of a complete failure of electricity supply (black-out)? How real is the risk?
- What is socially tolerable price for electricity and what is in fact the current price?
- Will not the postponement of today's decision to build a new source result in problems that will be difficult or impossible to handle in the future (can the current government to postpone the decision for future governments)?