Energy Policies in Europe:

Going green at what cost?

William D'haeseleer
K.U.Leuven Energy Institute

What will be the **cost**

of a full transition to low-CO_2 economy?

The honest answer is:

…I do not quite know… ☹

Too many uncertainties, and
depends on boundary conditions & assumptions

Some reflections on transition to a CO_2-free 2050

William D’haeseleer

5-th South East Europe Energy Dialogue
Thessaloniki June 2-3 2011

image AERIAL VIEW OF A WINDPARK OFF THE COAST OF DENMARK.

For comparison, the overall investment for the NorNed project, a classical HVDC cable connecting Norway and the Netherlands with a capacity of 700 MW, was 600 million Euros. During its first two months of operation, this interconnector has generated revenues of 50 million Euros, which is more than 800,000 Euros per day.

By extending the HVDC grid connections of offshore wind farms to other power market regions, wind power can offer transmission capacity for commercial use at much lower investment costs than for a single interconnector while providing similar benefits to the market.

figure 3: offshore grid topology proposal and offshore wind power installed capacity scenario

Wind energy is booming in the EU. In 2007 alone, no less than 8,550MW of wind turbines were installed in the EU, which is 40% of all newly installed capacity. By 2020-2030, offshore wind energy in the North Sea could grow to 68,000MW and supply 13 per cent of all current electricity production of seven North Sea countries. In order to integrate the electricity from the offshore wind farms, an offshore grid will be required. Greenpeace demands that the governments of these seven countries and the European Commission cooperate to make this happen.

INSTALLED AND PLANNED CAPACITY (MW)

	[MW]	[TWh]
BELGIUM	3,850	13.1
DENMARK	1,580	5.6
FRANCE	1,000	3.4
GERMANY	26,420	97.5
UNITED KINGDOM	22,240	80.8
NETHERLANDS	12,040	41.7
NORWAY	1,290	4.9
TOTAL	68,420	247

LEGEND

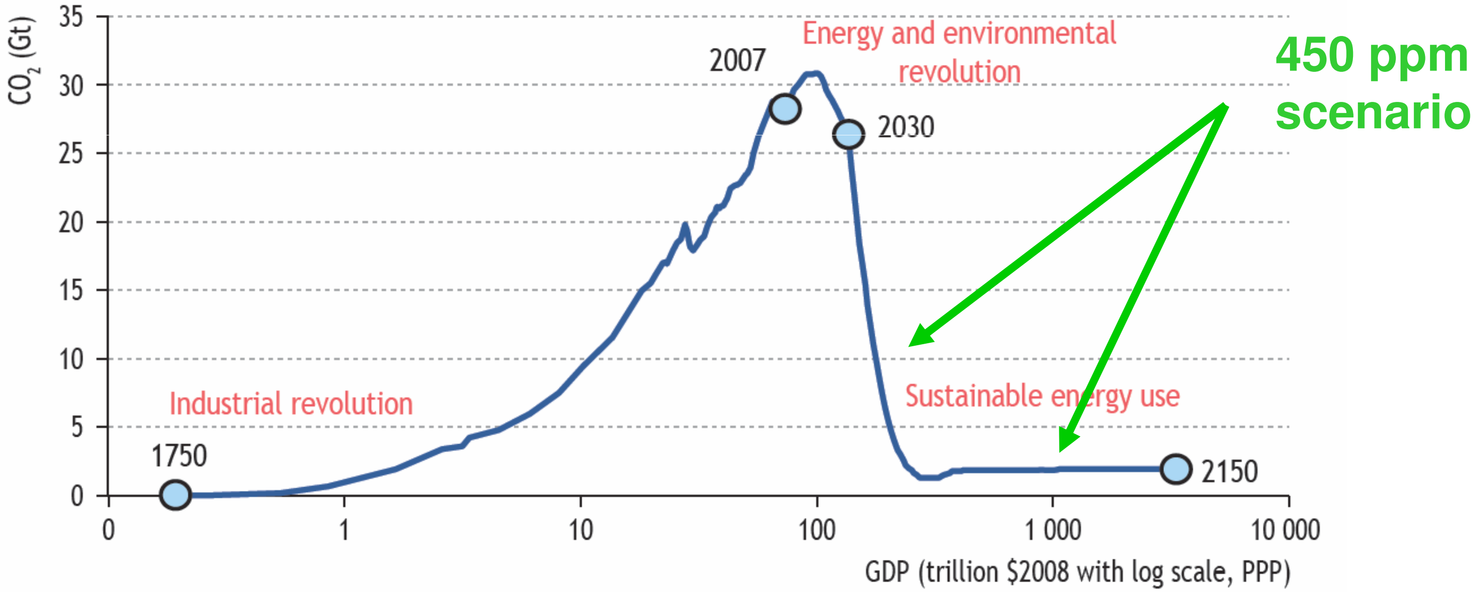
- **GRID:** PROPOSED OR DISCUSSED IN THE PUBLIC DOMAIN
- **GRID:** IN OPERATION OR PLANNING
- **PRINCIPLE HVDC SUBSTATIONS**
- **WIND FARMS:** INSTALLED PLANNED CAPACITY < 1000 MW
- **WIND FARMS:** INSTALLED PLANNED CAPACITY > 1000 MW

* MAP IS INDICATIVE. NO ENVIRONMENTAL IMPACT ASSESSMENT OF LOCATIONS AND SITING OF WINDFARMS AND CABLES HAS BEEN DONE.

Climate-Change Driver

Annual energy related CO_2 worldwide emissions

Figure 4.3 • Historical link between energy-related CO_2 emissions and economic output, and the pathway to achieving a 450 Scenario



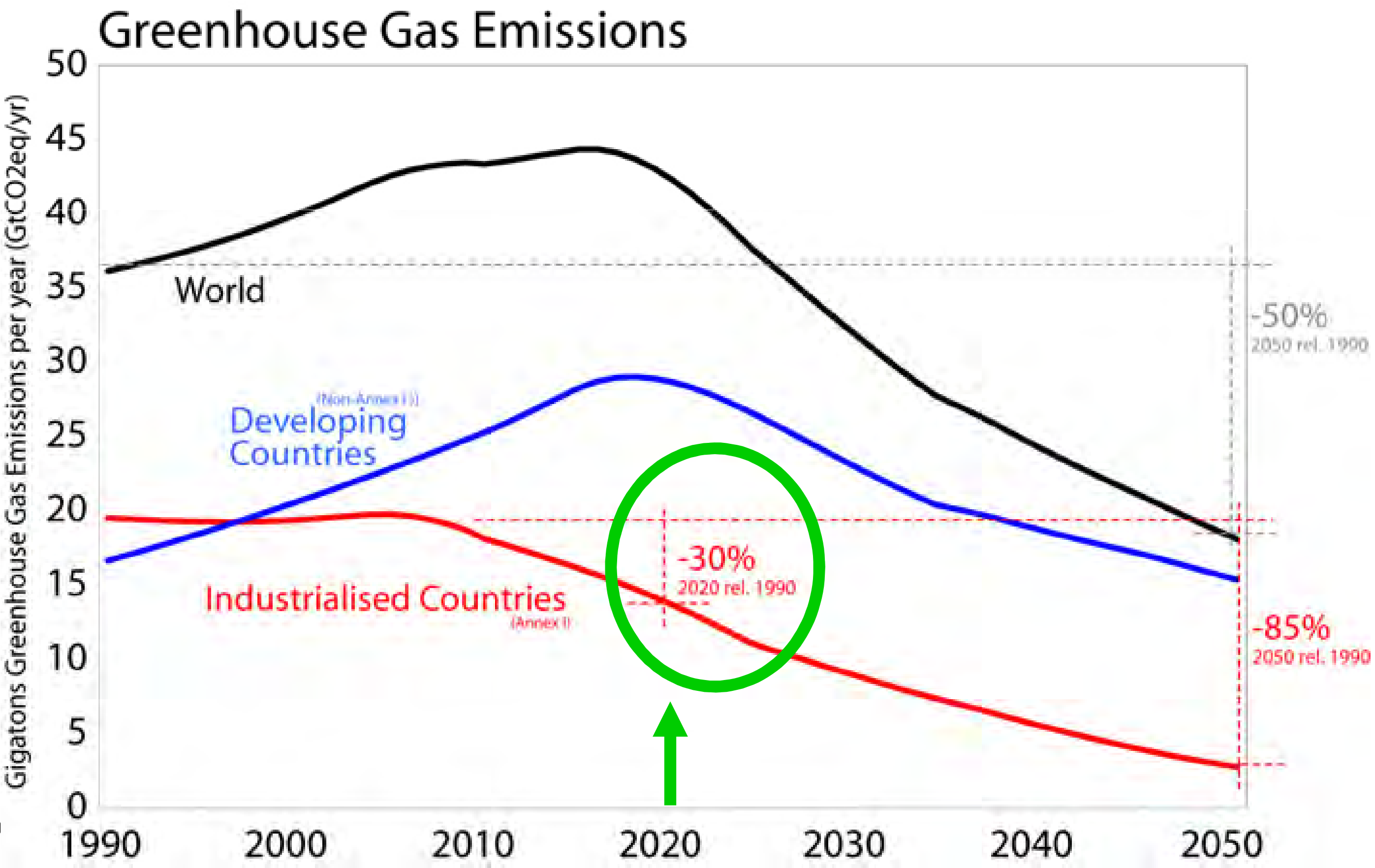
Note: The projected trend approximates that required to achieve long-term stabilisation of the total greenhouse-gas concentration in the atmosphere at 450 ppm CO_2-eq, corresponding to a global average temperature increase of around 2°C. World GDP is assumed to grow at a rate of 2.7% per year after 2030.

Source: IEA databases and analysis.

William D'ŀ
IEA WEO 2009

Climate-Change Challenge

To limit temperature increase to 2℃ above pre-industrial level

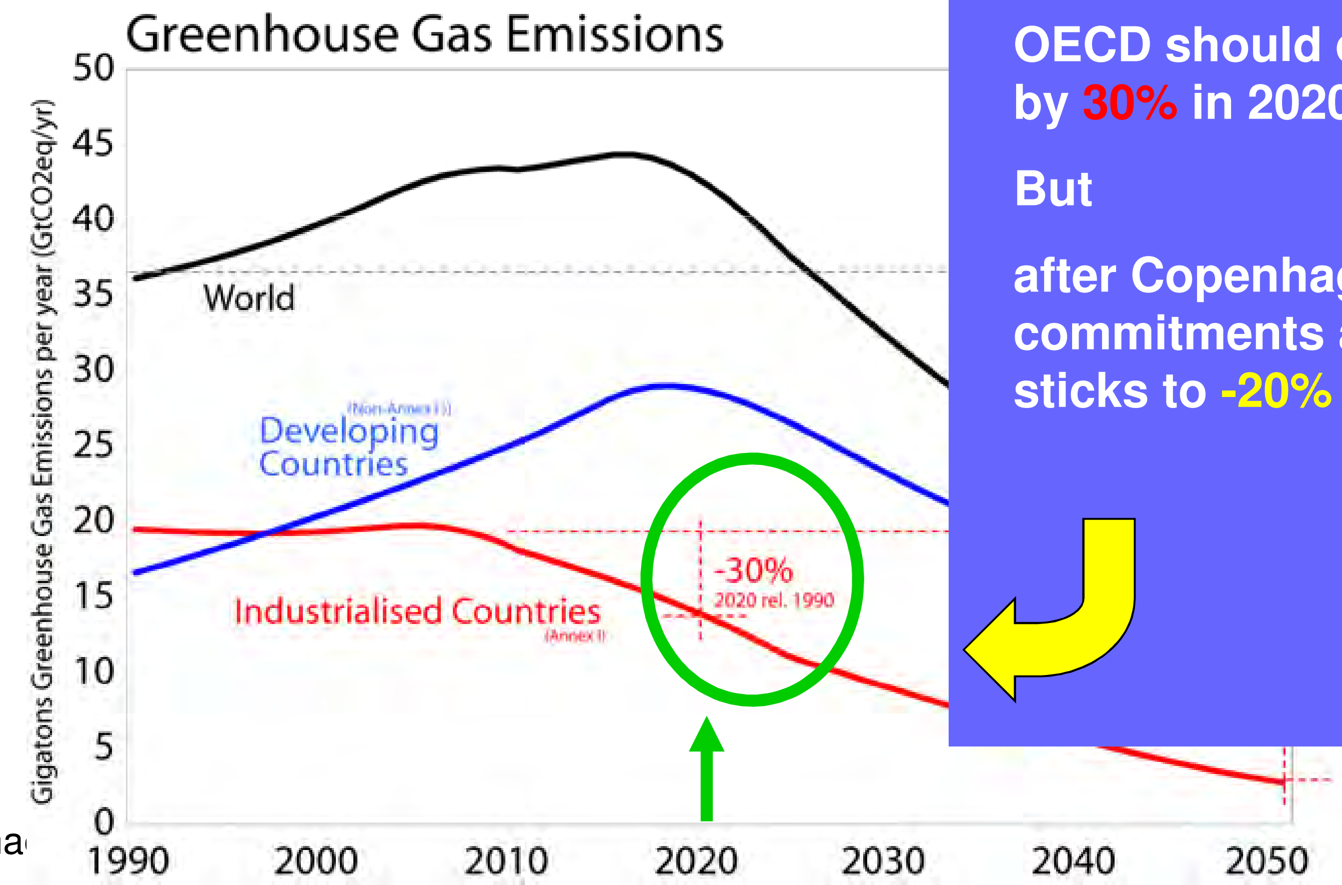


Ref:

Jos Delbeke, CEU

False Start with Copenhagen?

To limit temperature increase to 2℃ above pre-industrial level



OECD should decrease by 30% in 2020

But

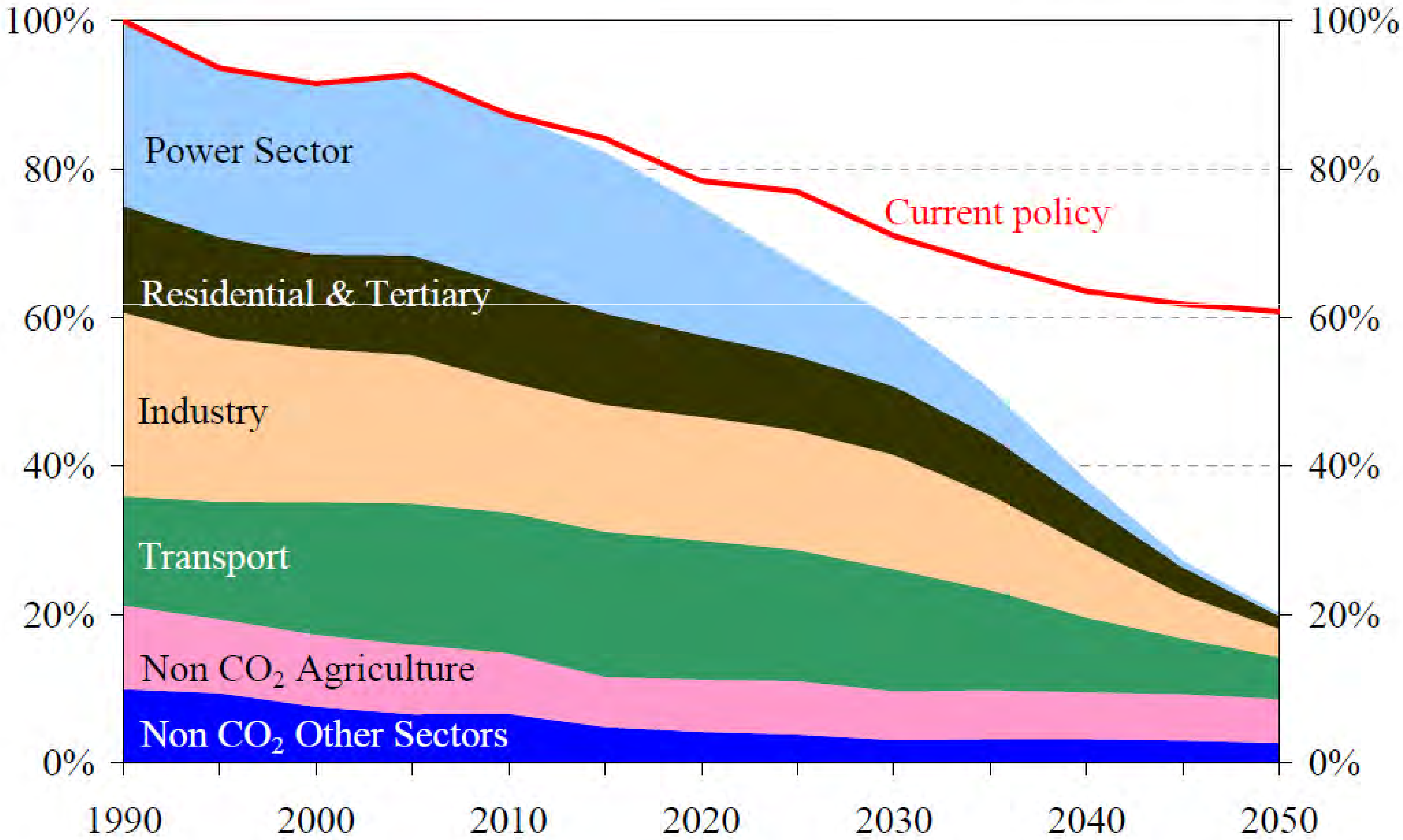
after Copenhagen, no commitments and EU sticks to -20%

Ref:

Jos Delbeke, CEU

Europe's Challenge

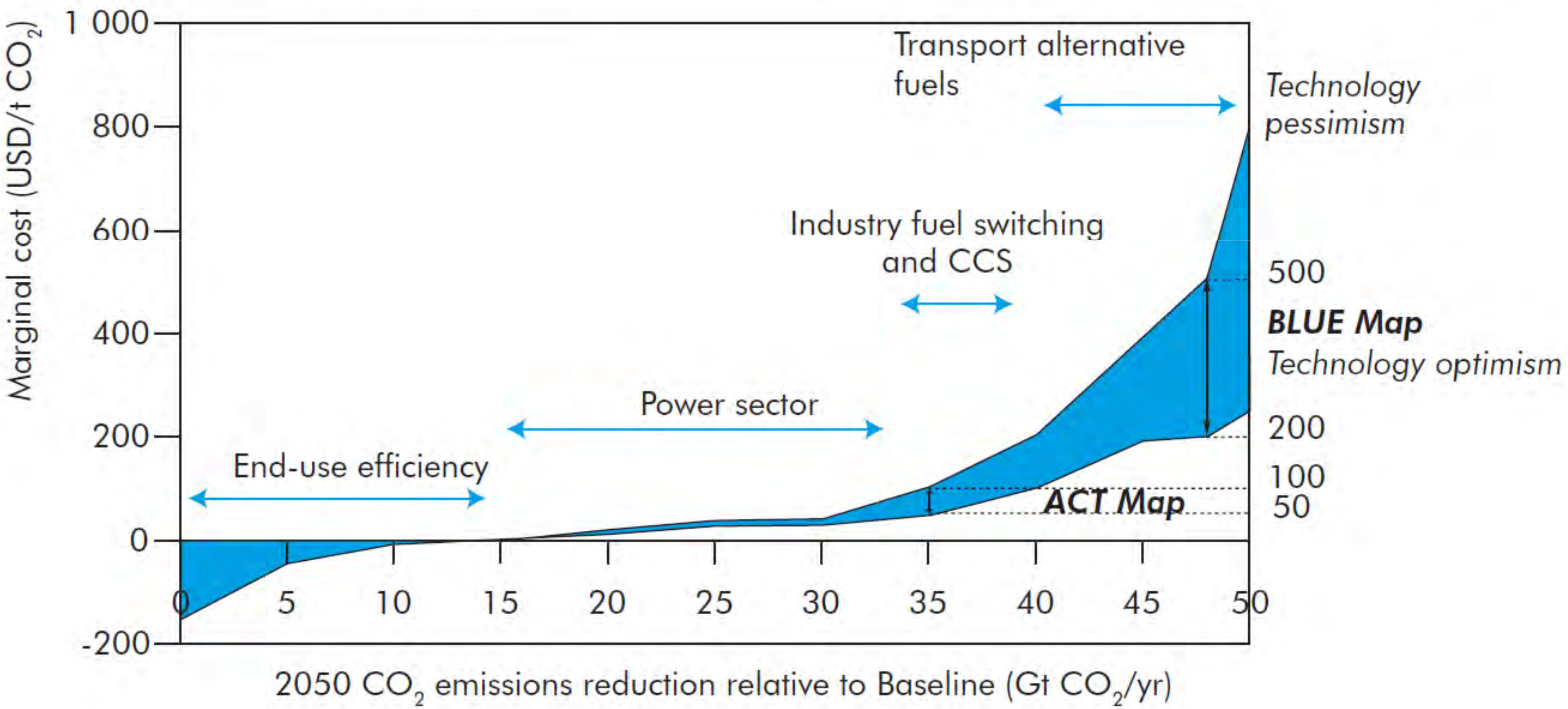
Figure 1: EU GHG emissions towards an 80% domestic reduction (100% =1990)



Reference: European Commission COM(2011) 112/4

Ample Possibilities but often Expensive

Figure ES.1 ▶ Marginal emission reduction costs for the global energy system, 2050



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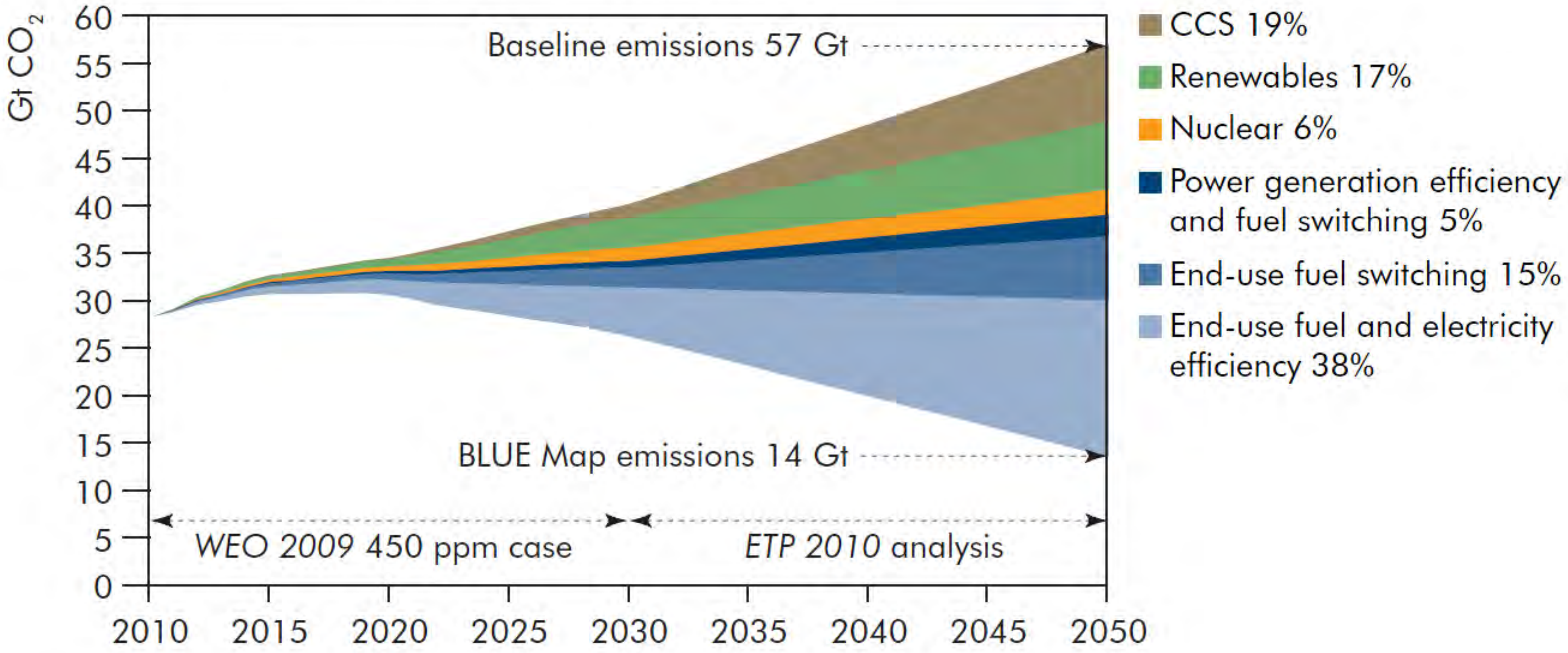
Ref: IEA ETP 2008

All Means Will be Necessary

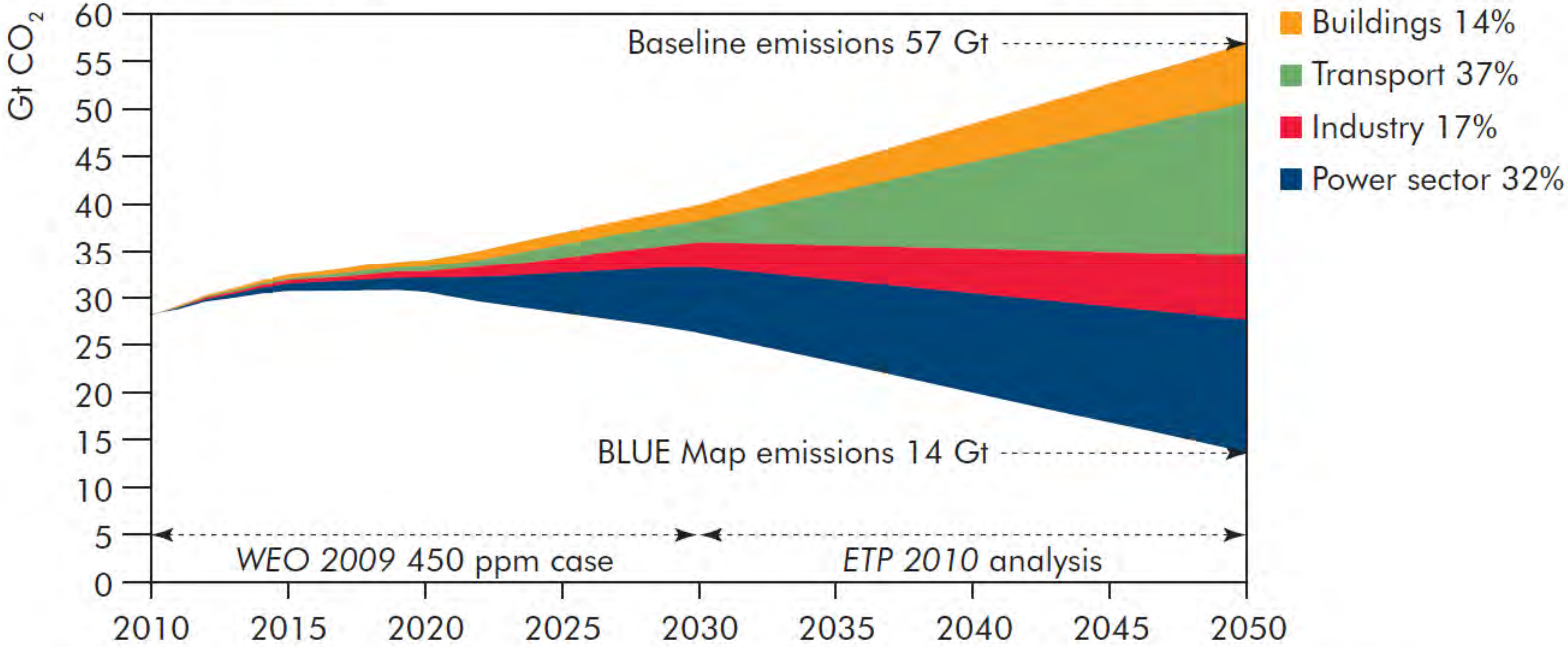
Figure 2.2 ▶ Key technologies for reducing CO_2 emissions under the BLUE Map scenario



Ref: IEA ETP 2010

All Sectors Must Participate

Figure 2.3 ▶ CO_2 emissions reductions in the BLUE Map scenario by sector

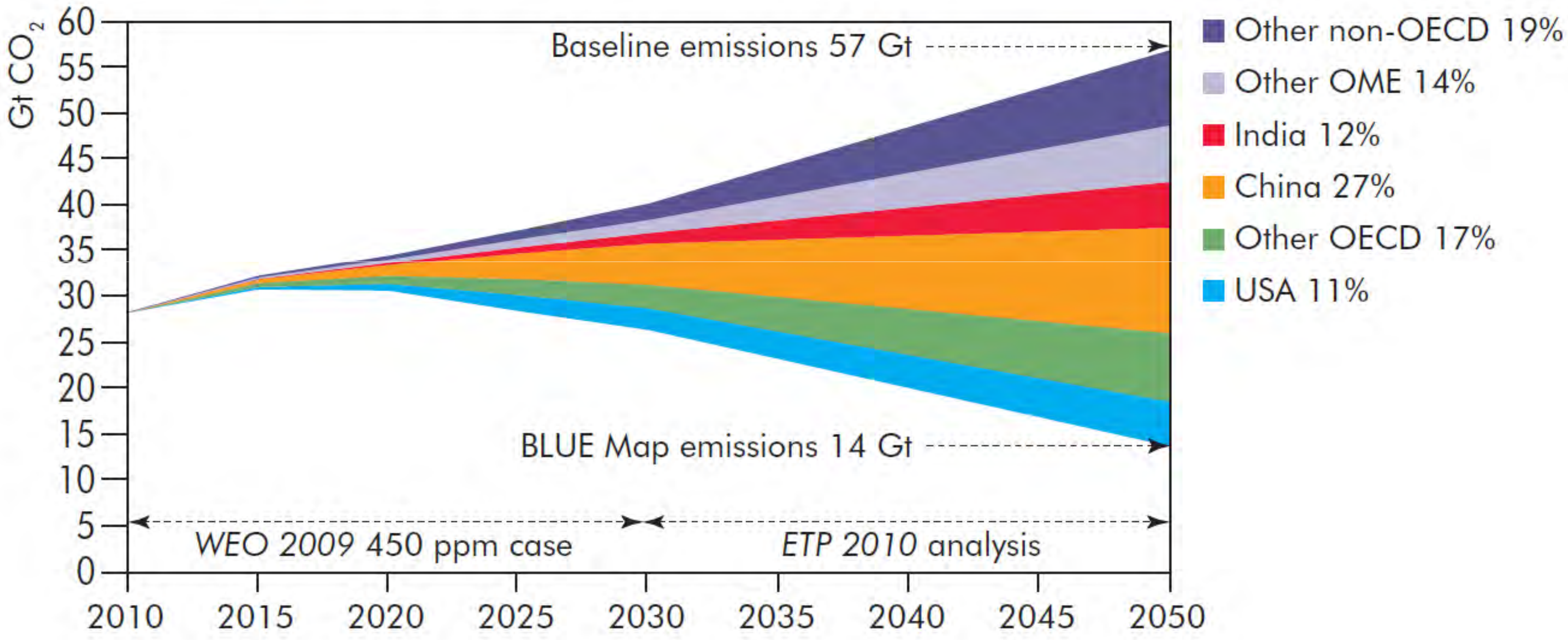


Note: CO_2 emission savings from fuel transformation have been allocated to the transport sector and the CO_2 reductions from electricity savings are allocated to end-use sectors.

Ref: IEA ETP 2010

All Regions Must Participate

Figure 15.2 ▶ World energy-related CO_2 emission abatement by region



Ref: IEA ETP 2010

Long Term Energy Studies

- Simplistic approaches misleading and lead to loss of credibility
- Must think in terms of ***energy fluxes*** ("power flows") not energy "packages"

  Get energy at right place at right time
- Storability of energy fundamentally important
- Must optimize full integrated system with full dynamic characteristics

Solutions ?

- Need ***paradigm shift*** for energy provision
- Completely different system by 2050-…:
  - Maybe via Hydrogen?
    - H_2 as energy carrier (electrolysis… fuel cell)
    - H_2 via electrolysis, combined with CO_2→methanol
  - Maybe 2-nd & 3-rd gen biofuels successful (?)
  - Maybe new synthetic liquid fuels from CO_2 capture by means of solar light (?)
  - But likely ***much more electrified!***

Solutions ?

- Solutions must rely on **technology**

- Clever *combination* of existing technologies

- New, perhaps revolutionary technologies

- But these are theoretical statements… many ***uncertainties*** and ***challenges*** for practical realization!

Uncertainties / Challenges

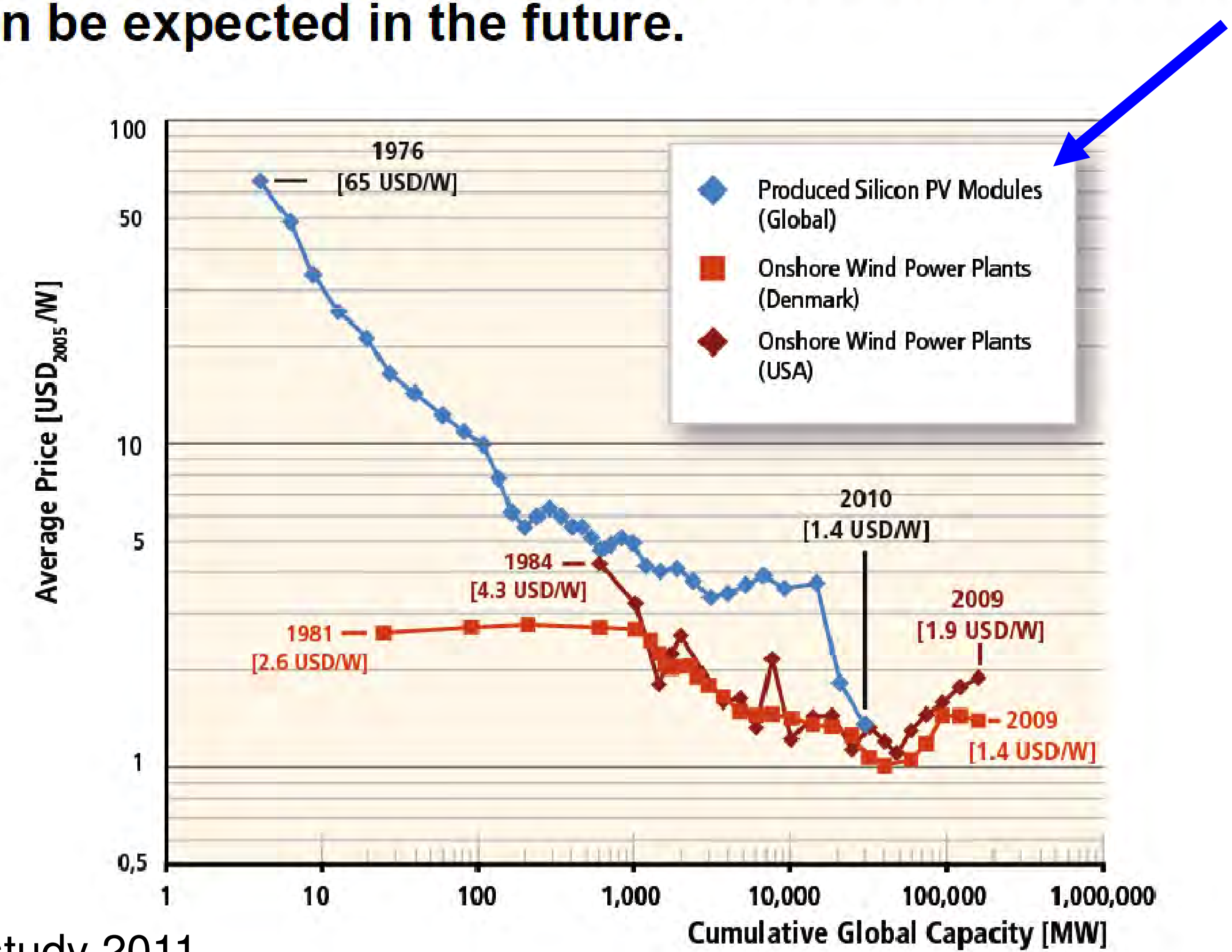
- Role of ***nuclear power after Fukushima***
  - Renaissance (Gen iii and up to Gen iv)?
  - Reaction of China, India, Russia?
  - Reaction of USA?
  - Reaction within the EU (FR, GB, FIN… vs … DE, IT, BE… new MS…)?

Uncertainties / Challenges

- ***Cost evolution of PV*** towards 2050
  – Does the dramatic cost decrease continue (module vs system)

Future cost of renewables?

RE costs have declined in the past and further declines can be expected in the future.



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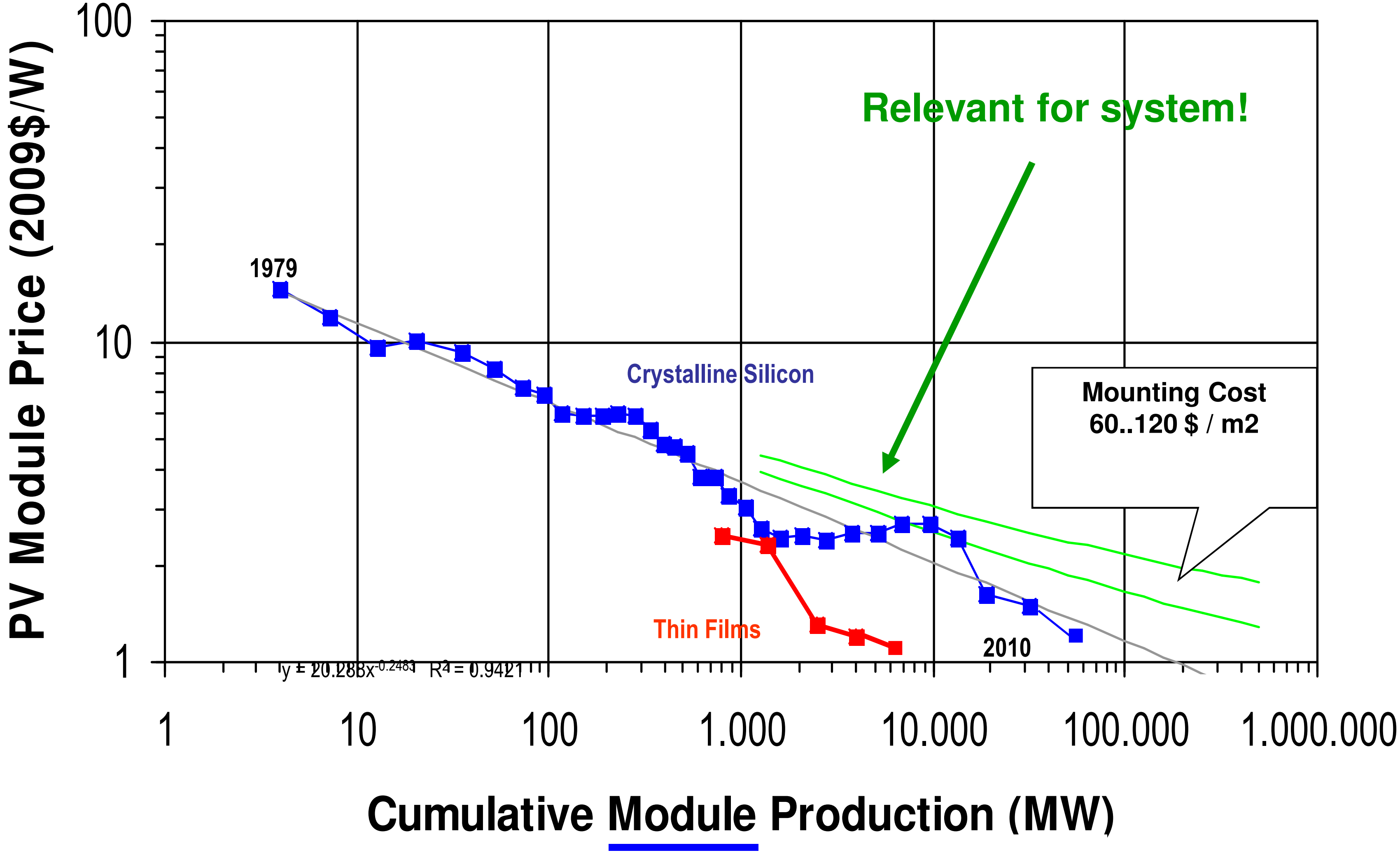
Future cost of renewables?

PV Technology Learning Curve



Ref: Heinz Ossenbrink, LDP Round Table Florence May 2011

Uncertainties / Challenges

- ***Cost evolution of PV*** towards 2050
  - Does the dramatic cost decrease continue (module vs system)

- Success of affordable ***off shore wind***?

- System integration.. Clash of the ***grids*** (cfr DE)
  - HV grids … supergrids… corridors
  - Local smart distribution grids / DSM / virtual PPs

Uncertainties / Challenges

- Battle for future grids… which grids???

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German nuclear review throws up nev problems

By Stephen Evans
BBC News, Berlin

Germany's dramatic rethink over nuclear power has thrown up new problems, as the consequences of a retreat from atomic technology emerge.

Just after Japan's Fukushima nuclear disaster in March, Chancellor Angela Merkel announced a review of energy policy and ordered Germany's oldest reactors to be shut down immediately, and perhaps permanently.

Only a few months earlier, she had decided to keep the reactors running past their original shutdown dates.

But only now comes the hard bit. Power companies have warned of higher prices because of the shutdown; Germany has imported electricity to meet peaks in demand; analysts have warned that coal-fired power stations will be

Chancellor Merkel is pinning her hopes expansion of wind power

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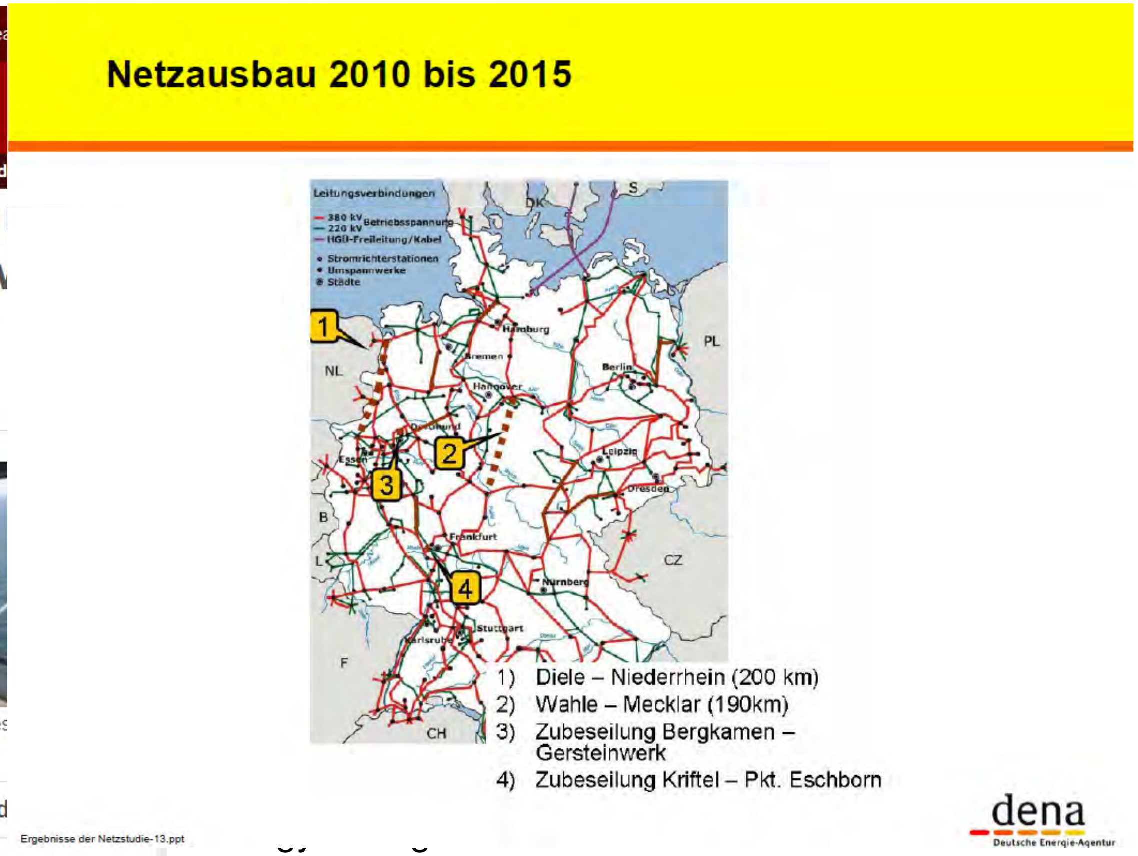
Protests urge end to atomic power



ne 2-3 2011

Uncertainties / Challenges

- Availability of affordable and ***flexible storage***
  - Batteries (in synergy with electric vehicles)
  - CAES
  - Hydrogen via RES – fuel cell chain
  - Hydrogen via RES & $CO_2 \rightarrow$ Methanol
  - Hydro storage / artificial islands

Uncertainties / Challenges

- 2-nd and 3-rd generation ***biofuels***
  - To fuel PHEV
  - To fuel peak turbines
- ***Biogas & sustainable biomass***
  - For power plants (100% or co-combustion)
  - Allows CHP to continue in carbon-constrained world
- ***Synthetic fuels*** from sunlight & CO_2
  - Would be the "perfect" storage medium!

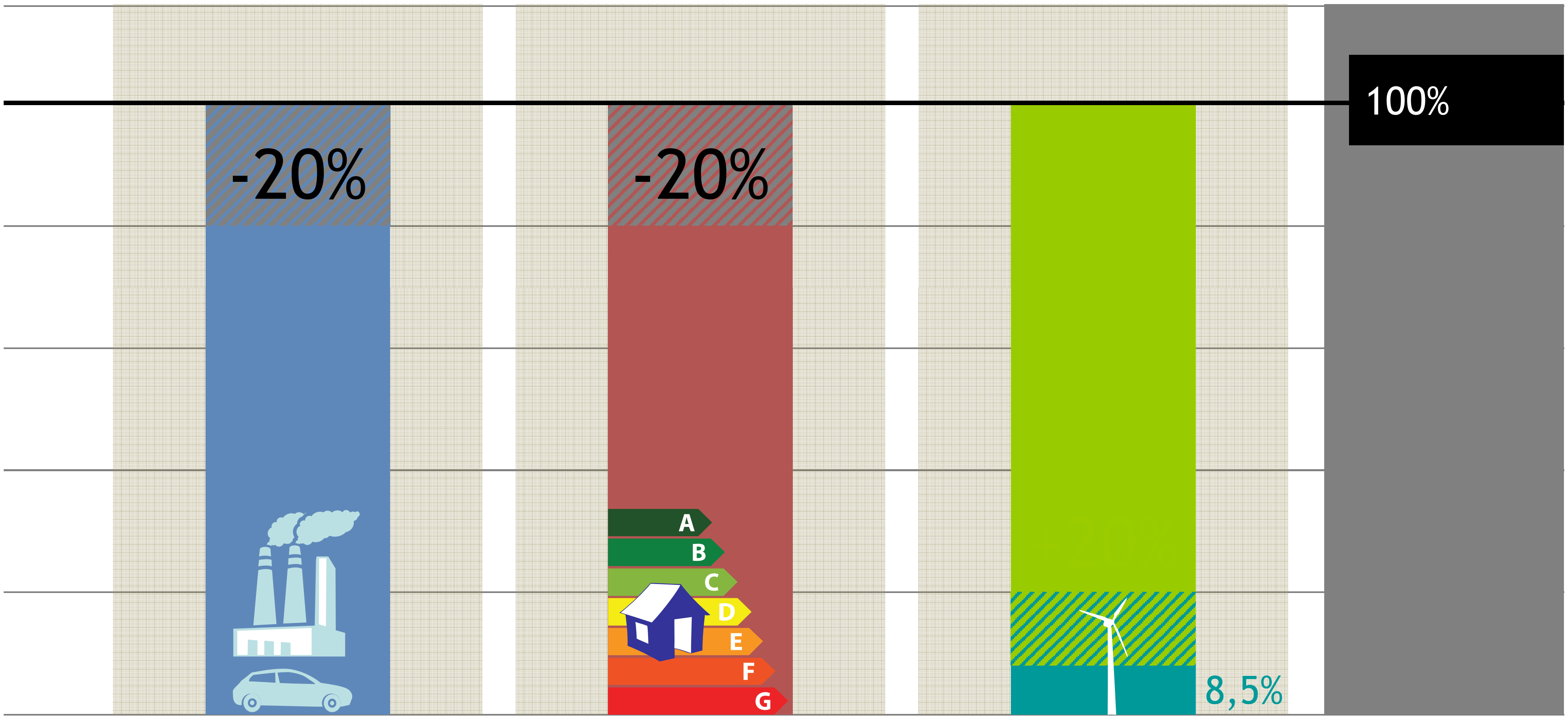
How get to 2050?

Need fertile ground for **energy revolution**

EU Strategic Energy Technology plan

– 2020 *targets* **<u>decided</u>; to be obtained**

EU 20-20-20 targets
by 2020



How get to 2050? - 2020

Need fertile ground for **energy revolution**

EU Strategic Energy Technology plan

– 2020 *targets* **decided; to be obtained !**

How get to 2050? - 2020

Correct implementation fundamentally important:

- to reach goals by 2020 (e.g., grid expansion…)

- to start right **transition** towards 2050
  - set up stable & transparent framework,
  - no lock in of technologies,
  - no premature exclusion of technologies,
  - right instruments; correct regulation, … →

How get to 2050? - 2020

- Influence support schemes / subsidies
  - Perhaps ‘effective’ in some countries
  - But not economically ‘efficient’
    - Exaggerated PV support in Northern countries
    - High cost for premature far sea off shore
  - RES targets lead to low CO_2 prices
  - Risk for inverse Robin Hood effect
  - EU subsidies launch economies in BRICS?

Short term
Uncertainties / Challenges

How get to 2050?

Uncertainties

- Popular uprisings MENA

How get to 2050?

Uncertainties

- Stability of EURO zone?

Need **investments!**

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Portugal and Greece downgraded on debt worries

Ratings agency Standard & Poor's has downgraded struggling Greece and Portugal on further debt worries.

S&P says investors in their bonds could lose out under the terms of a new eurozone bail-out package.

The move pushed up the countries' borrowing costs as lenders demanded a higher rate of return for buying government bonds.

The downgrades left Portugal one notch above junk rating and Greece's creditworthiness below that of Egypt.

Portugal's austerity measures sparked widespread protests, but may not go far enough

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How get to 2050?

Uncertainties

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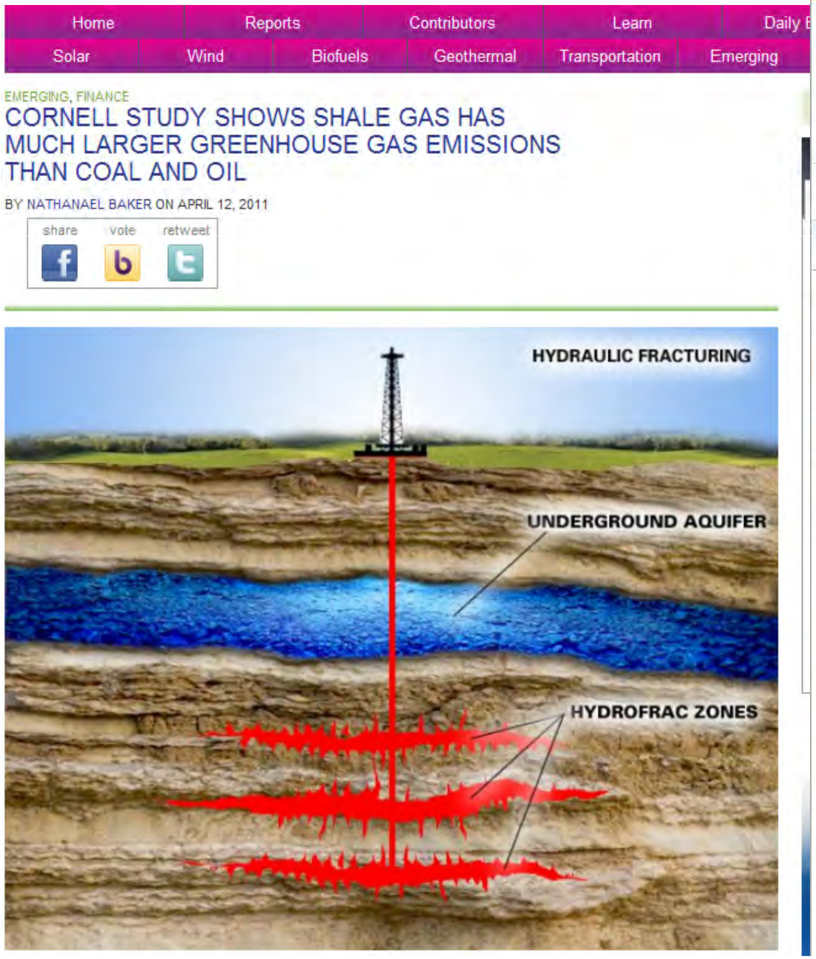

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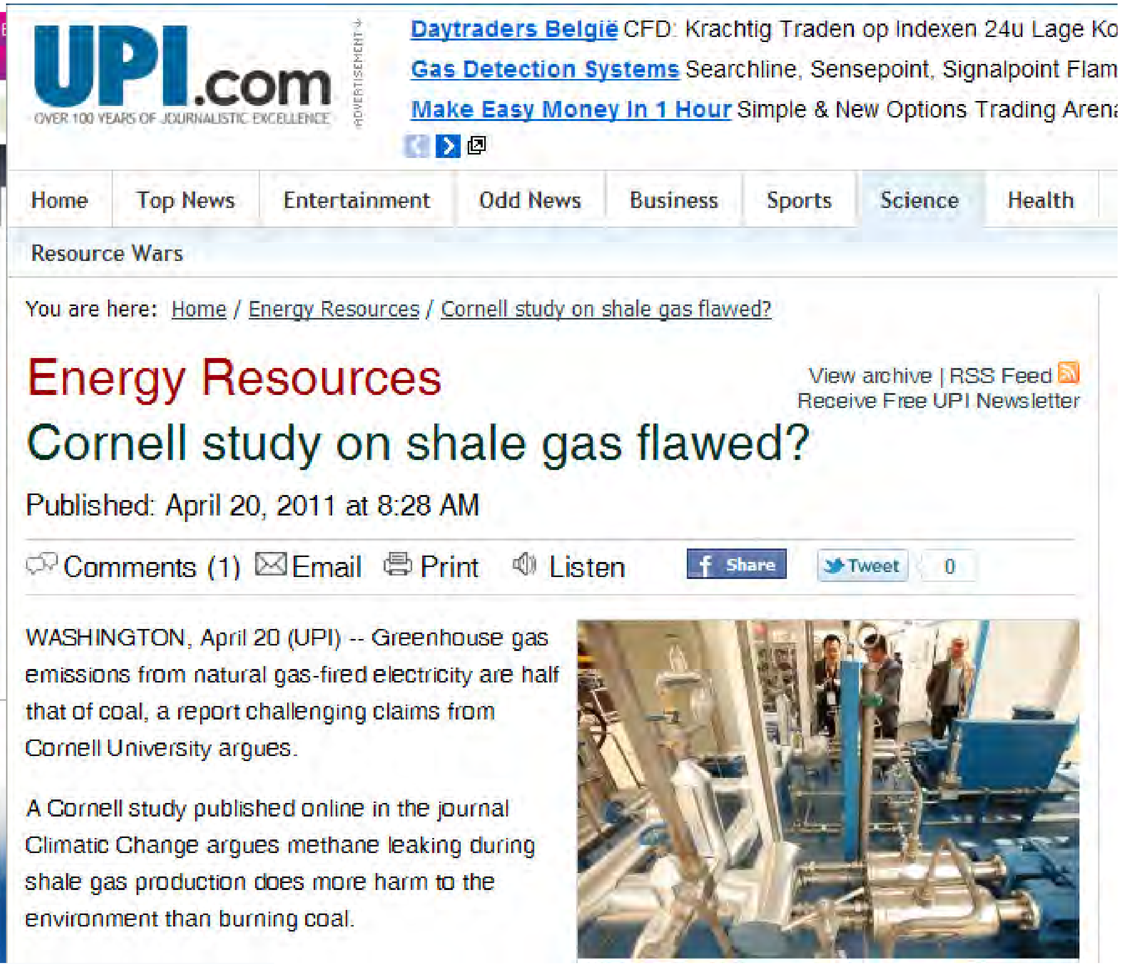

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Published: April 20, 2011 at 8:28 AM

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WASHINGTON, April 20 (UPI) -- Greenhouse gas emissions from natural gas-fired electricity are half that of coal, a report challenging claims from Cornell University argues.

A Cornell study published online in the journal Climatic Change argues methane leaking during shale gas production does more harm to the environment than burning coal.

How get to 2050? - 2050

Need fertile ground for **energy revolution**

EU Strategic Energy Technology plan

- 2020 *targets*
- 2050 *vision → based on R&D*

R&D part to be done right!

Importance of R & D

Classical R & D ideas

-Wind

-PV solar

-CCS

-Nuclear Gen iv

-Smart grids

-…

versus

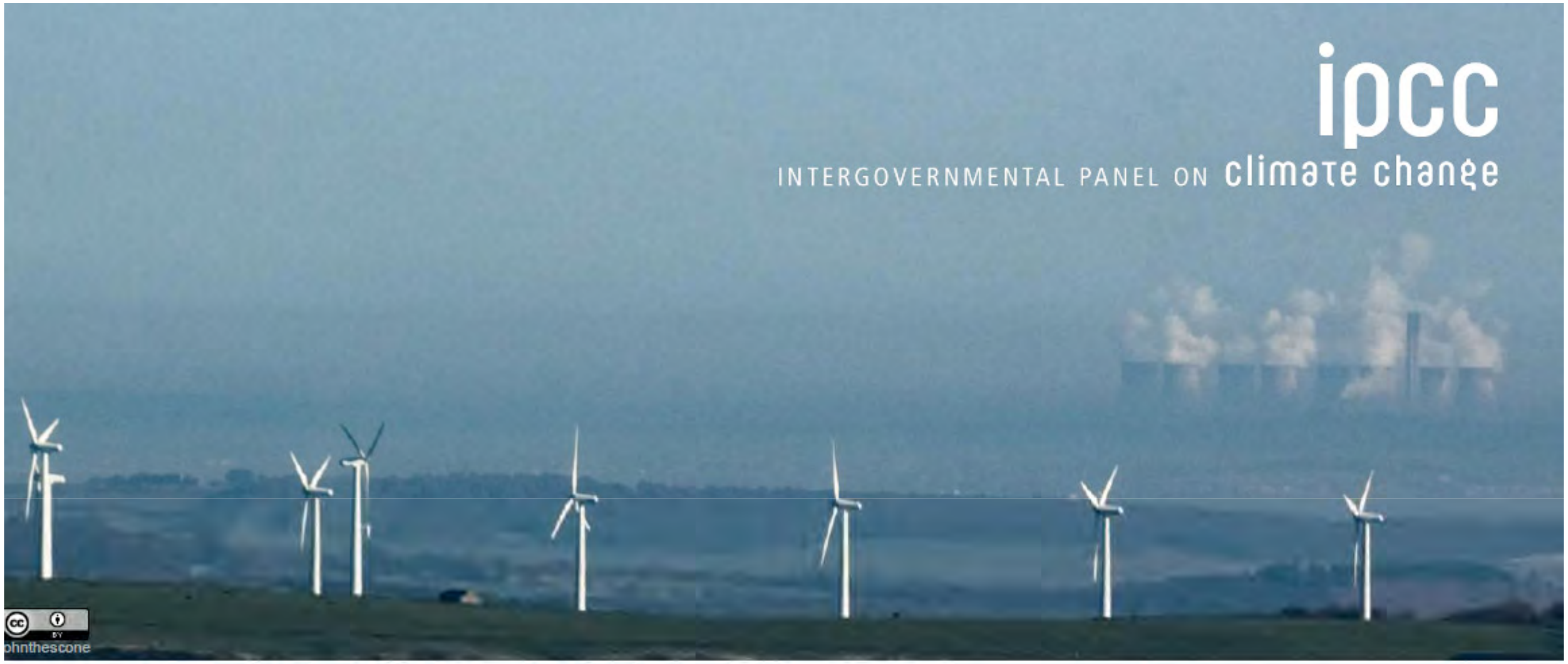
How get to 2050?

How to implement energy revolution?

- Must take the right decisions now to turn ocean liner !
- Daring, visionary but consistent policies
- But thorny challenges & inconveniences

Comparison of 2050 studies

Some cost elements…



The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

Wi

WMO UNEP

Looked at 164 long-term scenarios up to 2030 and 2050

The IPCC Special Report on
Renewable Energy Sources and
Climate Change Mitigation

WMO UNEP

SPM available at www.ipcc.ch
Full report to be released June 14 2011

st Europe Energy Dialogue
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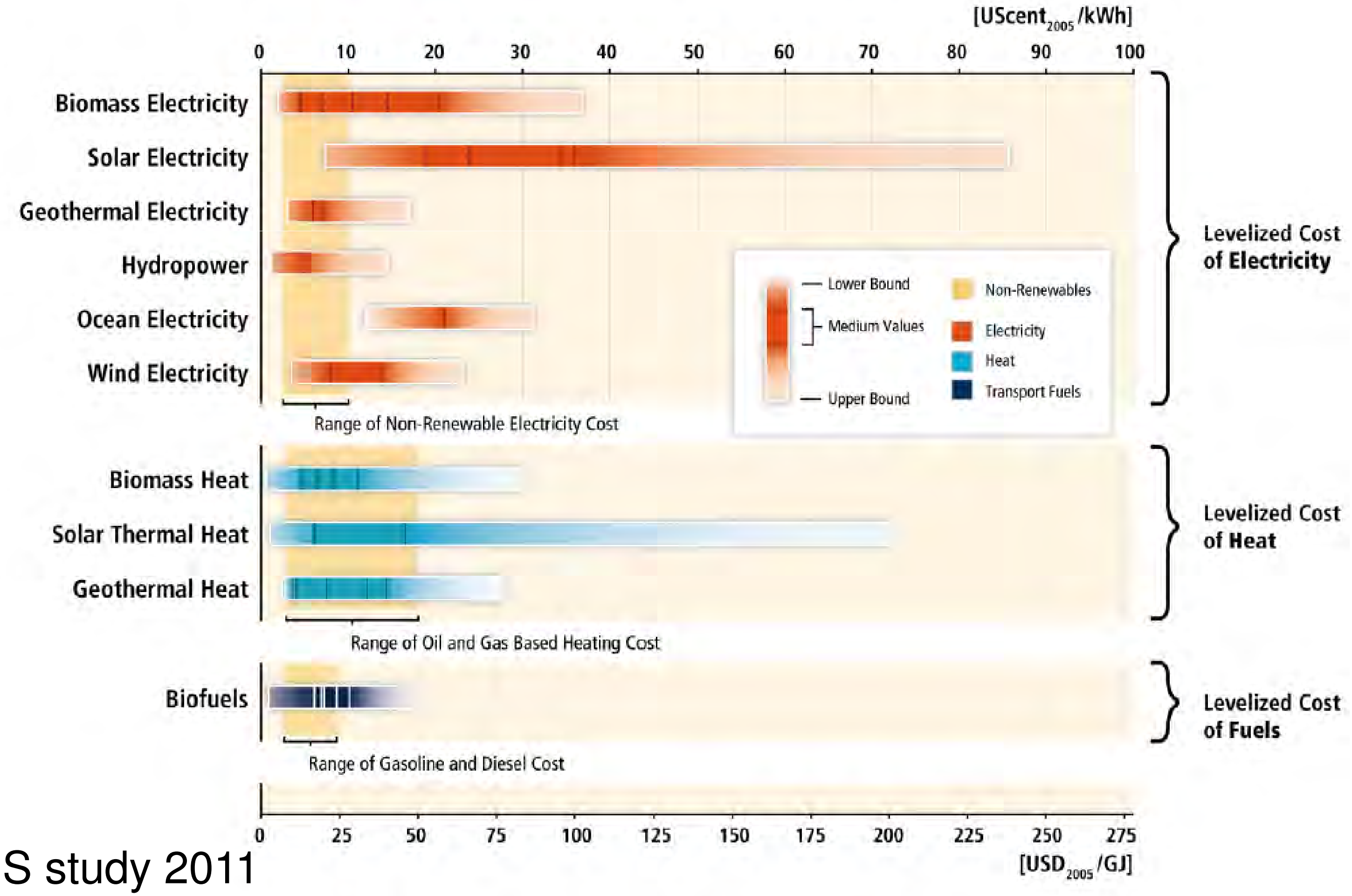
Future cost of renewables?

RE costs are still higher than existing energy prices, but in various settings RE is already competitive.



IPCC RES study 2011

Decarbonizing the European Electric Power Sector by 2050: A tale guided by different studies

E. Delarue, L. Meeuws, R. Belmans, W. D'haeseleer, J-M Glachant

Working Paper – Submitted fro publication

Comparison of 2050 studies

Overview of considered studies and scenarios, with their main features.

Organization	Study/Scenario	Release date	European region	Power sector emissions 2050
Eurelectric	Power Choices	June 2010	EU27	25 kg/MWh
European Climate Foundatio (ECF)	Roadmap 40% RES Roadmap 60% RES Roadmap 80% RES	April 2010	EU27 (+ CH and NO)	10 kg/MWh
International Energy Agency (IEA)	BLUE Map	July 2010	OECD Europe	15 kg/MWh
Greenpeace and European Renewable Energy Council (EREC)	Energy Revolution Advanced Energy Revolution	June 2010	OECD Europe	4-17 kg/MWh
European Renewable Energy Council (EREC)	100% RES Energy Vision	April 2010	EU27 + CH and NO	0 kg/MWh
European Gas Advocacy Forum (EGAF)	low gas price high gas price low gas price + nuclear constraint	February 2011	EU27	10 kg/MWh

Comparison of 2050 studies

Comparison of relative electricity generation by technology.

	2010	2050											
		Eur-electric	ECF			IEA-ETP	Greenpeace		EREC	EGAF		
			40% RES	60% RES	80% RES		ER	AER		low gas	high gas	low gas + nucl constr
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Hydro	10.3	7.5	12.0	12.0	12.0	17.1	15.0	12.3	9.0			
Wind onshore	4.8	11.6	9.0	11.0	15.0	14.2	36.3	31.9	31.1			
Wind offshore	0.5	8.7	2.0	10.0	15.0	7.9						
Biomass	3.5	6.9	8.0	8.0	12.0	7.1	17.9	12.3	9.9	11.0	11.0	11.0
Biomass + CCS	0.0		0.0	0.0	0.0	0.4	0.0	0.0	0.0			
Solar PV	0.5	4.3	4.0	12.0	19.0	3.9	12.6	15.0	27.0			
Solar CSP			3.0	5.0	5.0	2.2	3.8	10.7	7.7			
Geothermal	0.2		2.0	2.0	2.0	1.7	4.4	10.8	12.1			
Ocean	0.0	1.4	0.0	0.0	0.0	0.7	1.6	4.3	3.2			
Other	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Total RES	19.8	40.4	40.0	60.0	80.0	55.2	91.5	97.3	100	43.0	41.0	45.0

Comparison of 2050 studies

Comparison of relative electricity generation by technology.

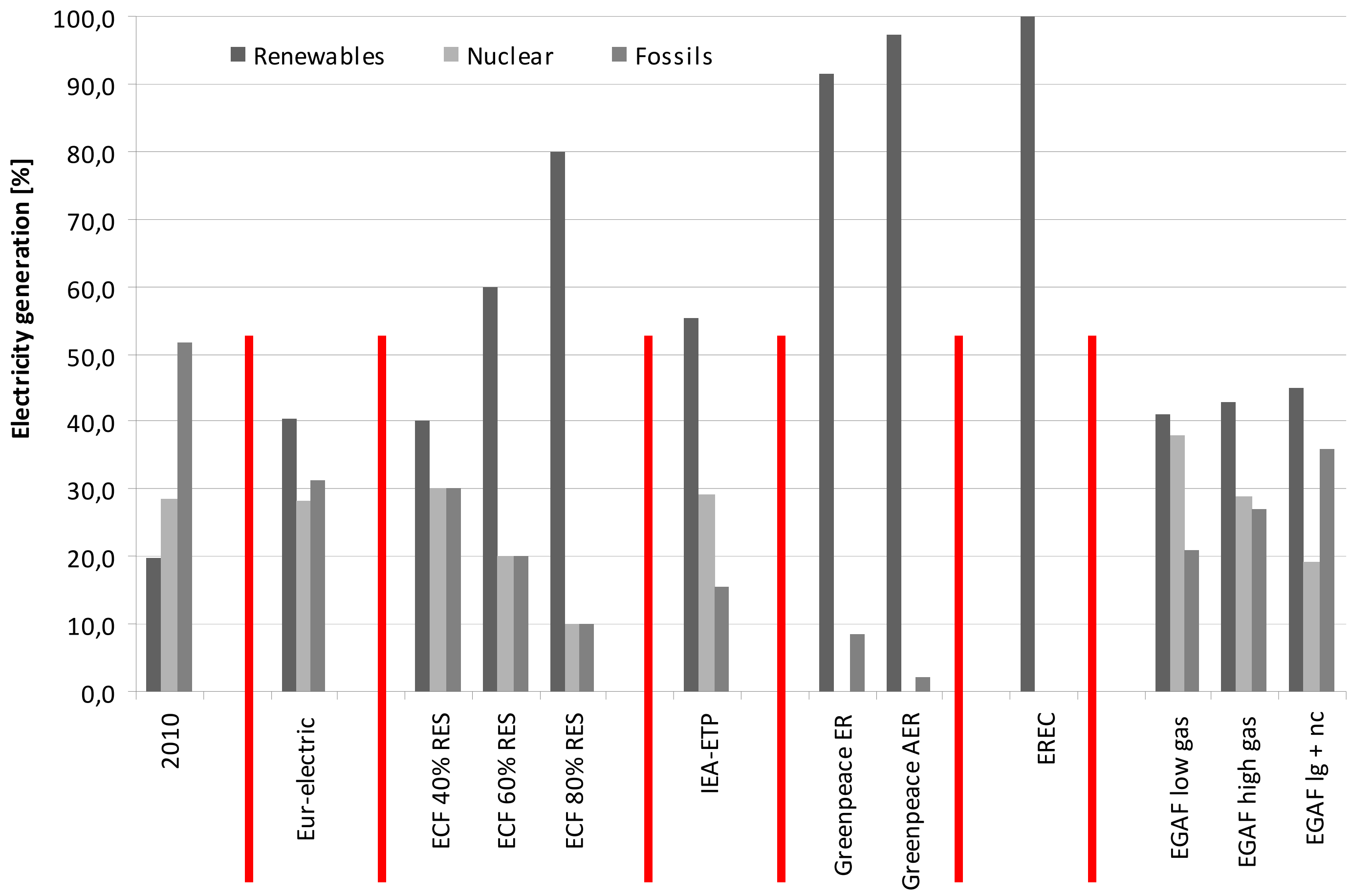
	2010	2050											
		Eur-electric	ECF			IEA-ETP	Greenpeace		EREC	EGAF		
			40% RES	60% RES	80% RES		ER	AER		low gas	high gas	low gas + nucl constr
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Nuclear	28.5	28.4	30.0	20.0	10.0	29.3	0.0	0.0	0.0	29.0	38.0	19.0
Coal + CCS	0.0		10.0	7.0	3.0	11.0						
Coal + CCS retrofit	0.0	16.9	5.0	3.0	2.0	0.0	0.2	0.0	0.0	8.0	7.0	2.0
Other solids	25.5		0.0	0.0	0.0	0.0						
Gas	24.3	13.6	0.0	0.0	0.0	1.5	8.3	2.2	0.0			
Gas + CCS	0.0		15.0	10.0	5.0	3.0				19.0	14.0	34.0
Oil	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot	100	100	100	100	100	100	100	100	100	100	100	100

Comparison of 2050 studies

Installed capacity [GW] of wind, PV and overall system, in the envisaged scenarios

	2010	2050										
		Eur-electric	ECF			IEA-ETP	Greenpeace		EREC	EGAF		
			40% RES	60% RES	80% RES		ER	AER		low gas	high gas	low gas + nucl constr
	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]	[GW]
Wind	82	382	165	295	435	358	448	483	462			
Solar PV	23	125	195	555	815	125	348	510	962			
Total system	853	1318	1280	1700	2020	1350	1252	1537	1956	1200	1200	1200

Comparison of 2050 studies



Comparison of different generation mixes in the different studies/scenarios (EGAF lg + nc stands for the "EGAF low gas + nuclear constraint" scenario).

Willian

Comparison of 2050 studies_cost

Cost aspects of these studies

- Higher cap costs → upfront *investments*
  - Because high costs RES, nuclear CCS
  - Because higher installed capacity (intermittent RES)

Comparison of 2050 studies_cost

Cost aspects of these studies

- **Eurelectric:**
  - invest in pwr gen 1.75 T€ (12% higher than BL)
  - Invest in pwr grid 1.5 T€ (35% or 0.4 T€ higher than BL)
  - Total extra cost over BL in pwr sector is ~25% or 0.6 T€)

Comparison of 2050 studies_cost

- **ECF:**
  - invest in pwr generation
    - In BL: 27 G€/y (2010) … 35 G€/y (2050)
    - In zero carbon pathways: 55 - 70 G€/y period 2025-2035, then slight decrease
  - invest in pwr transmission
    - In BL: 10 G€
    - In zero carbon pathways: 53 G€ - 182 G€ (aggregated 2010-2050)
  - invest in back-up generation
    - In BL: 32 G€
    - In zero carbon pathways: 93 G€ - 131 G€ (aggregated)

Comparison of 2050 studies_cost

- **IEA-ETP 2010:**
  - Additional investment power sector ~780 G€ in period 2010-2050
- **Greenpeace:**
  - No numbers on cost…
- **EREC:**
  - Cumulative investment for electricity ~2 T€ by 2050

Comparison of 2050 studies_cost

- **EGAF:**
  - Investment for electricity ~675 G€ - 750 G€ by 2050
  - Of which transmission ~73 G€ - 94 G€

Compare to CEU Roadmap on Climate Change 2050

- **CEU Rd map:**
  - invest for pwr gen ~ 2.2-2.6 T€ by 2050 (vs 1.7 T€ BL)
  - invest for pwr grid ~ 1.6-2.0 T€ by 2050 (vs 1.3 T€ BL)

Comparison of 2050 studies_cost

Remarkable differences on cost

- Difference grid expansion
  - ECF 53 - 182 G€ for expansion 65% - 390 %
  - Eurelectric 1.5 T€ for expansion 40%

Comparison of 2050 studies_cost

Cost recovery due to lower operational/fuel cost

- Electricity prices per kWh ~same as BL

But

- Depends on international price levels oil & gas
- Depends on assumptions on storage, DSM
- Depends on expansion HV grids → influences back up capacity

Cost of low CO_2 transition

- Economic growth
  due to development of new technologies
  "**product development**"?

- Try to be the first mover?

Cost of low CO_2 transition

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Economic impacts from the promotion of renewable energy technologies: The German experience

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ABSTRACT

The allure of an environmentally benign, abundant, and cost-effective energy source has led an increasing number of industrialized countries to back public financing of renewable energies. Germany's experience with renewable energy promotion is often cited as a model to be replicated

Cost of low CO_2 transition

A B S T R A C T

The allure of an environmentally benign, abundant, and cost-effective energy source has led an increasing number of industrialized countries to back public financing of renewable energies. Germany's experience with renewable energy promotion is often cited as a model to be replicated elsewhere, being based on a combination of far-reaching energy and environmental laws that stretch back nearly two decades. This paper critically reviews the centerpiece of this effort, the Renewable Energy Sources Act (EEG), focusing on its costs and the associated implications for job creation and climate protection. We argue that German renewable energy policy, and in particular the adopted feed-in tariff scheme, has failed to harness the market incentives needed to ensure a viable and cost-effective introduction of renewable energies into the country's energy portfolio. To the contrary, the government's support mechanisms have in many respects subverted these incentives, resulting in massive expenditures that show little long-term promise for stimulating the economy, protecting the environment, or increasing energy security.

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Cost of RES transition

- Overall net subsidy cost of PV installed in 2000-2010 leads to ~ 65 G€
- Overall net subsidy cost of wind installed in 2000-2010 leads to ~ 11-20 G€
- Example: FIT in 2007 totaled 7.6 G€ compared to 0.4 G€ for energy R&D and 0.2 G€ for renew R&D (a mere 3% R&D…)
- CO_2 abatement cost of PV now ~ 700-1000€/ton

Cost of RES transition

- FIT and especially for PV are counterproductive for ETS;
- Increased consumer prices;
- Net employment effects very doubtful;
- Less SoS since more gas imports for balancing
- Technological innovation very low compared to money spent (FITs too high; no incentive to innovate) → better spent on R&D?

Cost of low CO_2 transition

- Depends on price level of other fuels
  - Oil & prices at 23-30 $/bbl ←→ 78-80$/bbl ←→ 100-120 $/bbl

- Depends on price level CO_2 penalty

- *Transition*-related decisions are important
  - use of appropriate instruments;
  - important clear regulation;
  - …

Conclusions

- Major energy revolution needed to 2050
- Many challenges & uncertainties
- Transition important – no lock in
- Product-development questionable
- Cost depends on competition other fuels

- **Try to make good/honest analyses,**
  - **Bases on energy/power flows**
  - **Including all costs, subidies, support, taxes,…**