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European experience in dealing with intermittency

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European Electricity Markets in Need of Flexibility

William D'haeseleer
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Energy Transition in Europe

- Originally ‘Energy’ not Part of EU Competences
  - Although ECCS (Eur Comm Coal & Steel)
  - Now ‘slight change’ after *Constitution & Energy Union*
- EU Energy Policy was driven ‘indirectly’ by
  - DG Competition ... Energy Markets / Liberalization
  - DG Environment / Climate Action

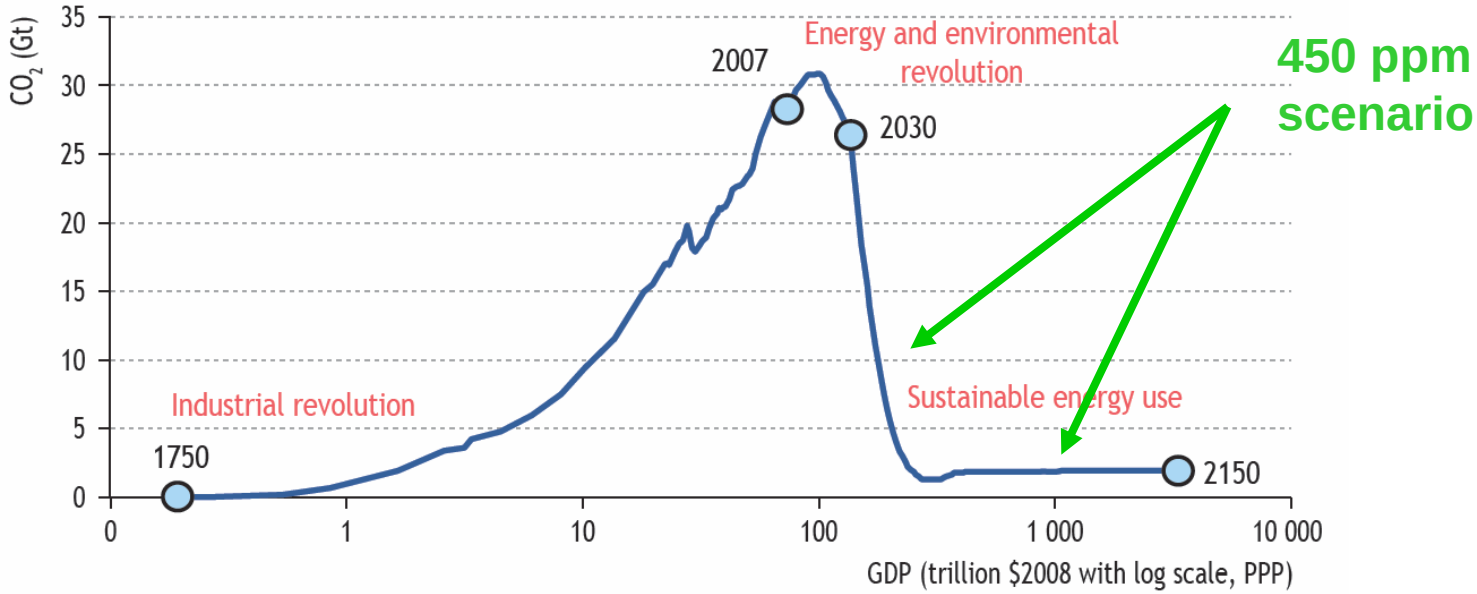
Recently:

mostly driven by <u>Climate Change Agenda</u>

Energy Transition in Europe - Recall

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.

IEA WEO 2009

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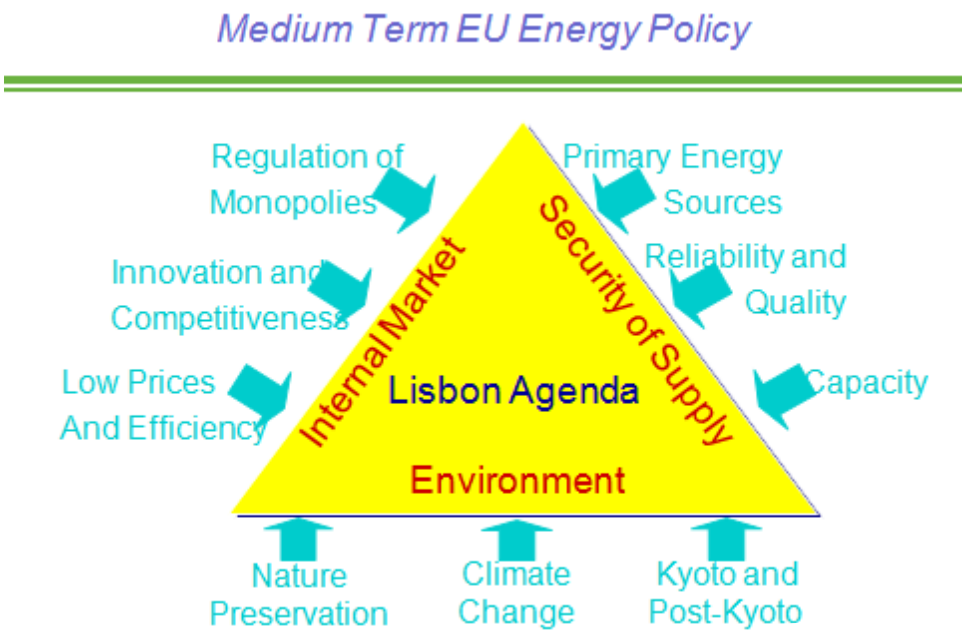
EU's implementation

Major challenge to satisfy all three simultaneously

EU's **trilemma** !



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EU's implementation

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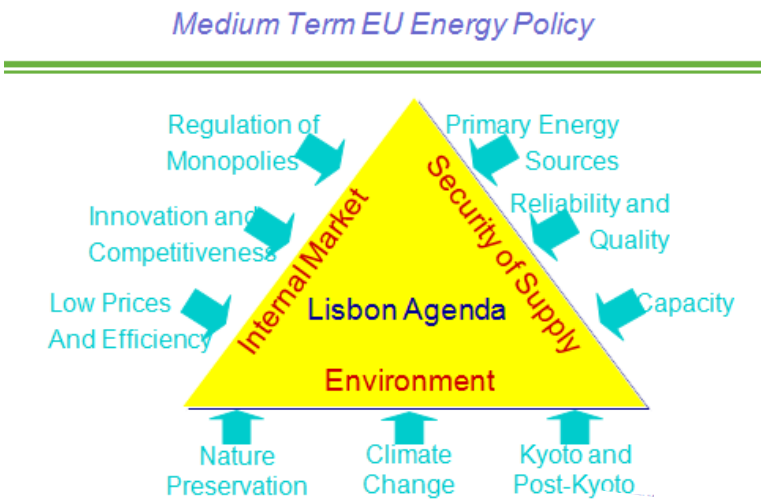

- Objectives
  - 2020 targets (20-20-20)
    - By EU considered as "given" / "decided" / to be implemented
  - 2030 as intermediate step
    - Long enough to do something; close enough to say meaningful things
  - 2050 vision (reduction CO_2 by > 85%)
    - Need **energy revolution / paradigm shift**

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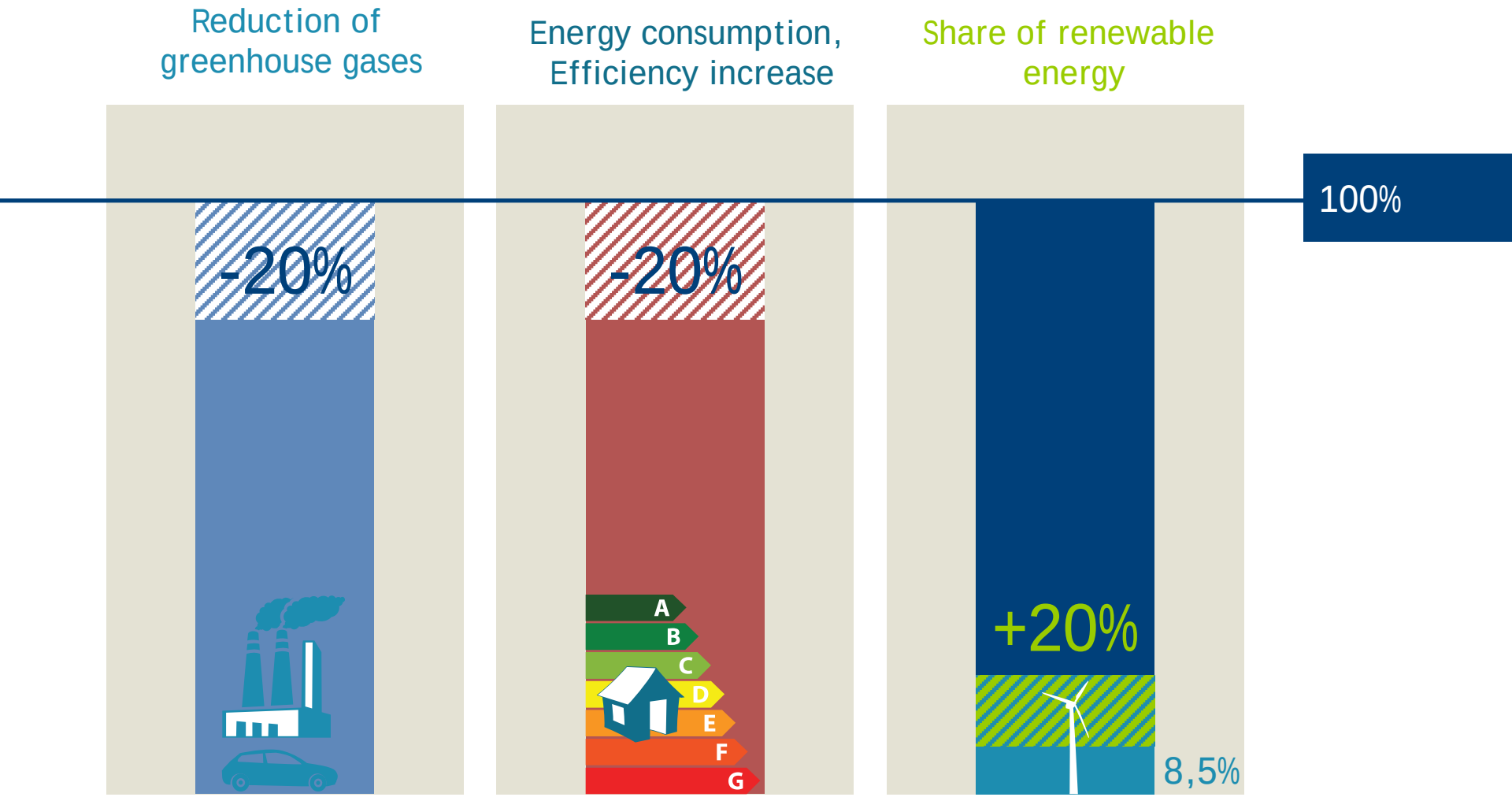
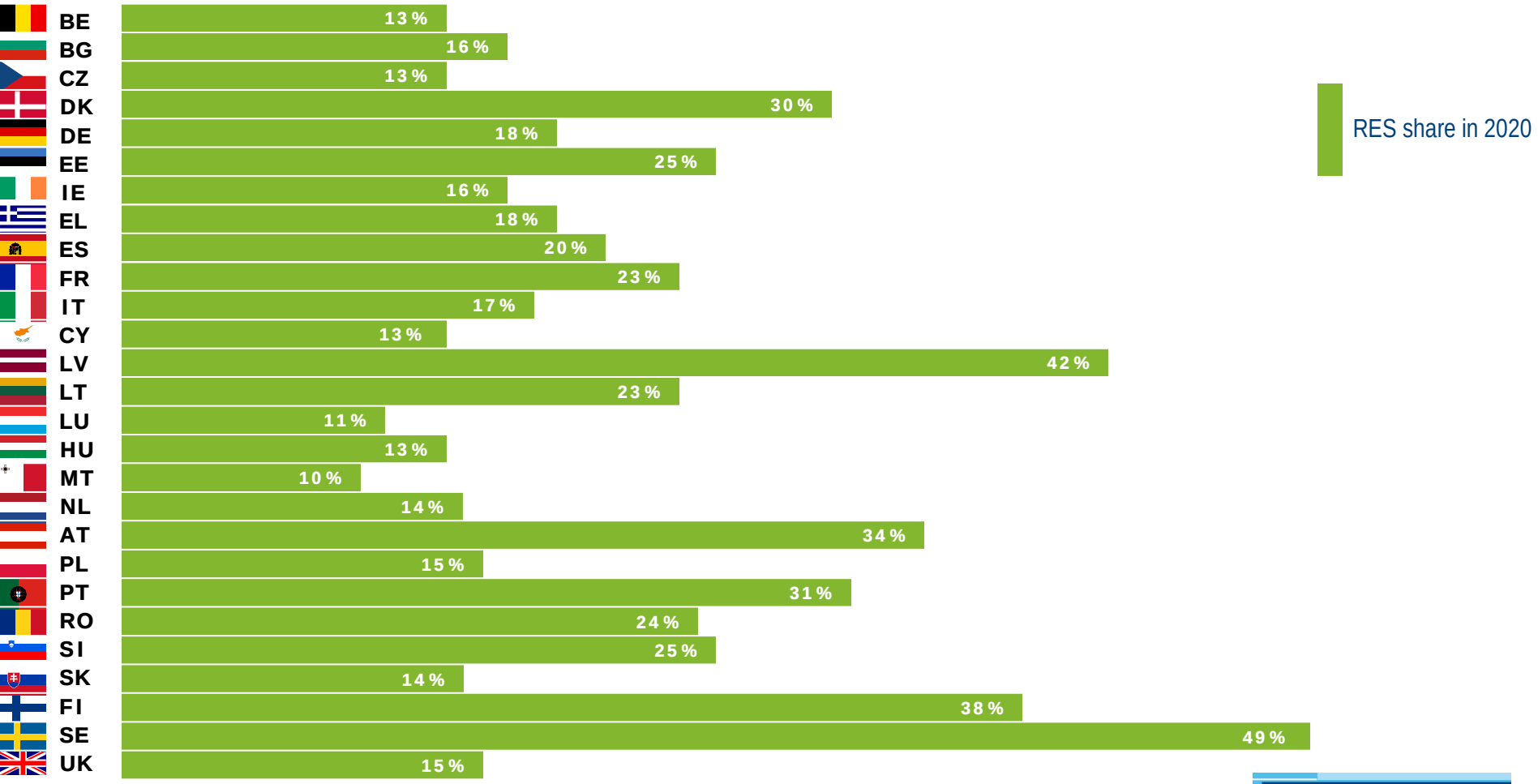
EU 20-20-20 targets by 2020



EU-27 efforts in Renewables



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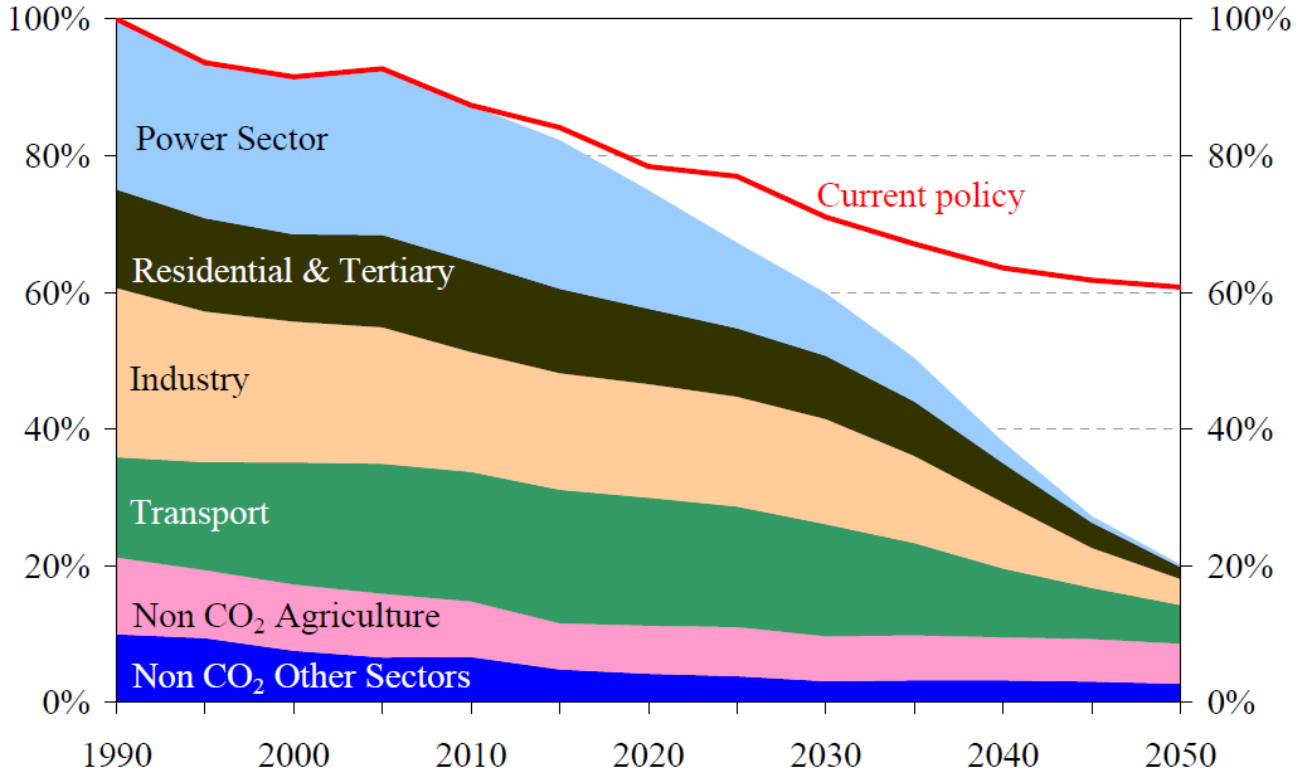
EU's long-term CO_2 reduction targets

Climate Change Roadmap - 2050

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



Reference: European Commission COM(2011) 112/4

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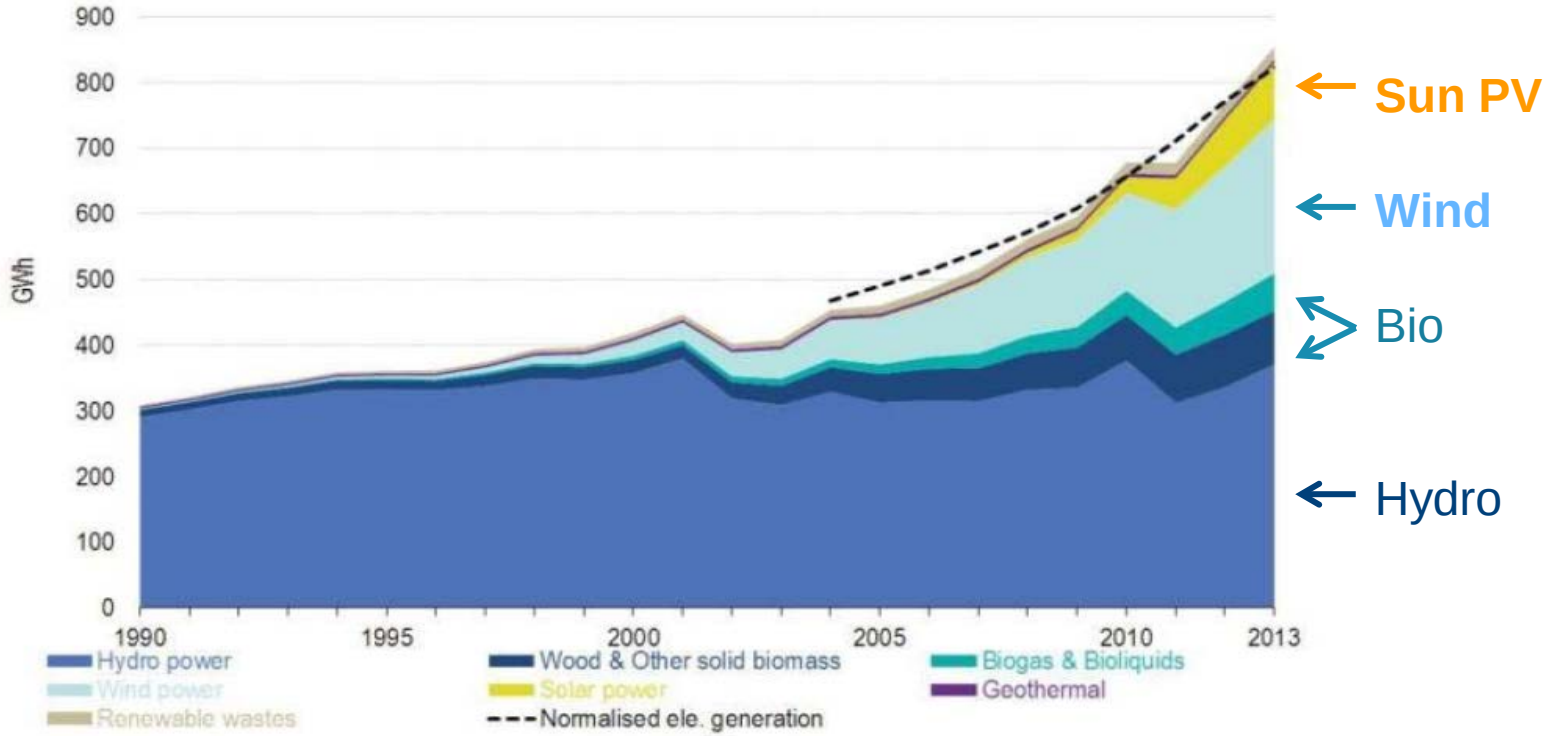
EU's implementation - currently

Figure 3. EU renewable electricity generation in 1990-2013



Source: Eurostat

Ref: EU RES Progress report, 2015

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EU’s implementation - currently

- All this progress seems to be too nice to be true...
  And it is...

- There are major *system effects* that have been neglected and that may jeopardize further success of RES deployment!

- One has gone too rapidly recently, with *danger of losing support of population!*

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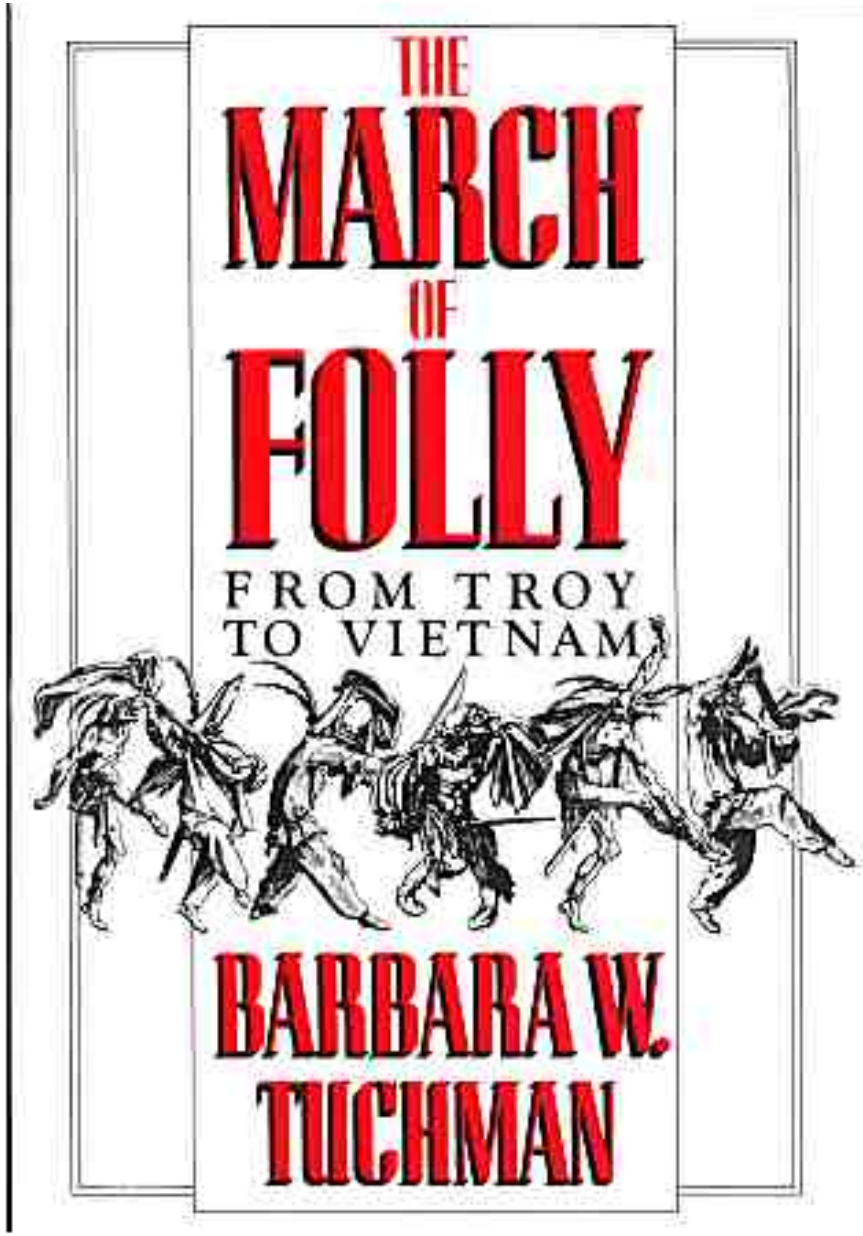


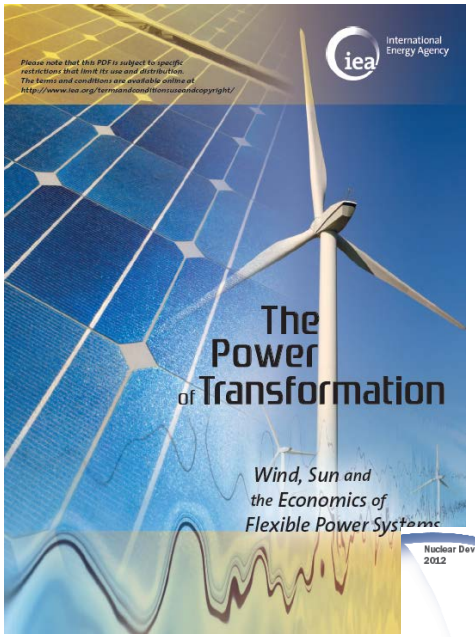
THE MARCH
OF FOLLY

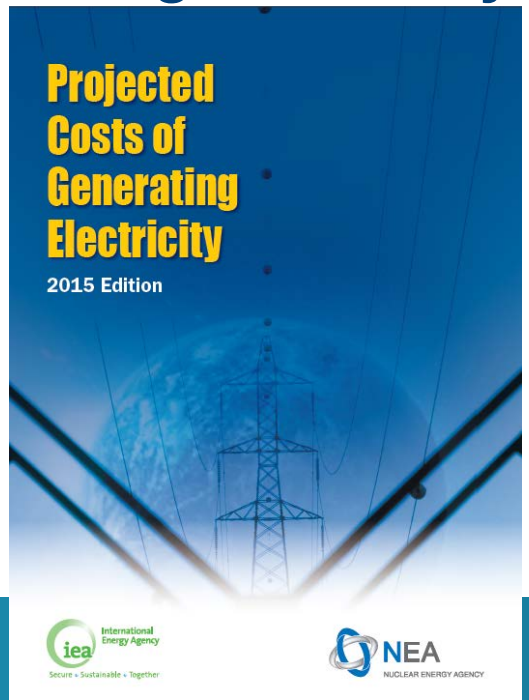
Pursuit of policy

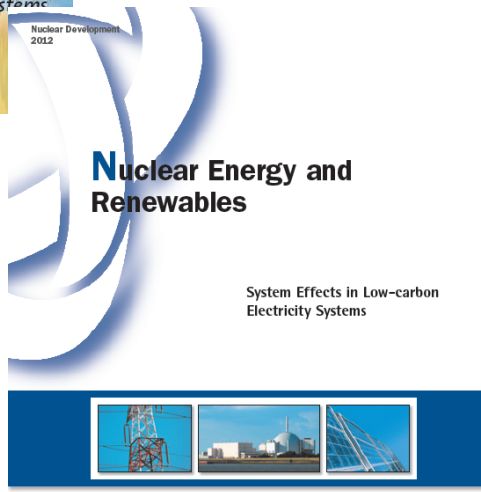
contrary to self-interest

Cost aspects RES – system costs

- Currently exercise to “reconcile” different studies on system cost e.g.: 2015 IEA/NEA report : **“Projected Cost of Generating Electricity”**



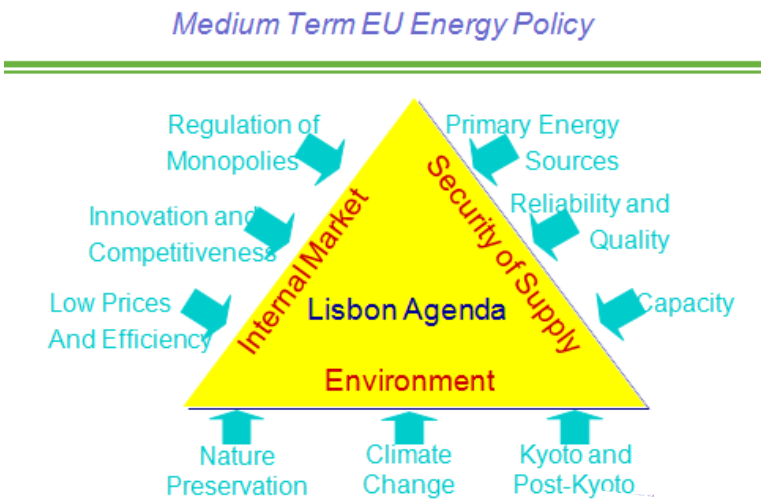




EU's implementation

Major challenge to satisfy
all three simultaneously

EU's **trilemma** !



Textbook example of
"well intended measures"
but ...

because *lack of system thinking*
serious issues / problems

→ EU electricity market in cirisis !!

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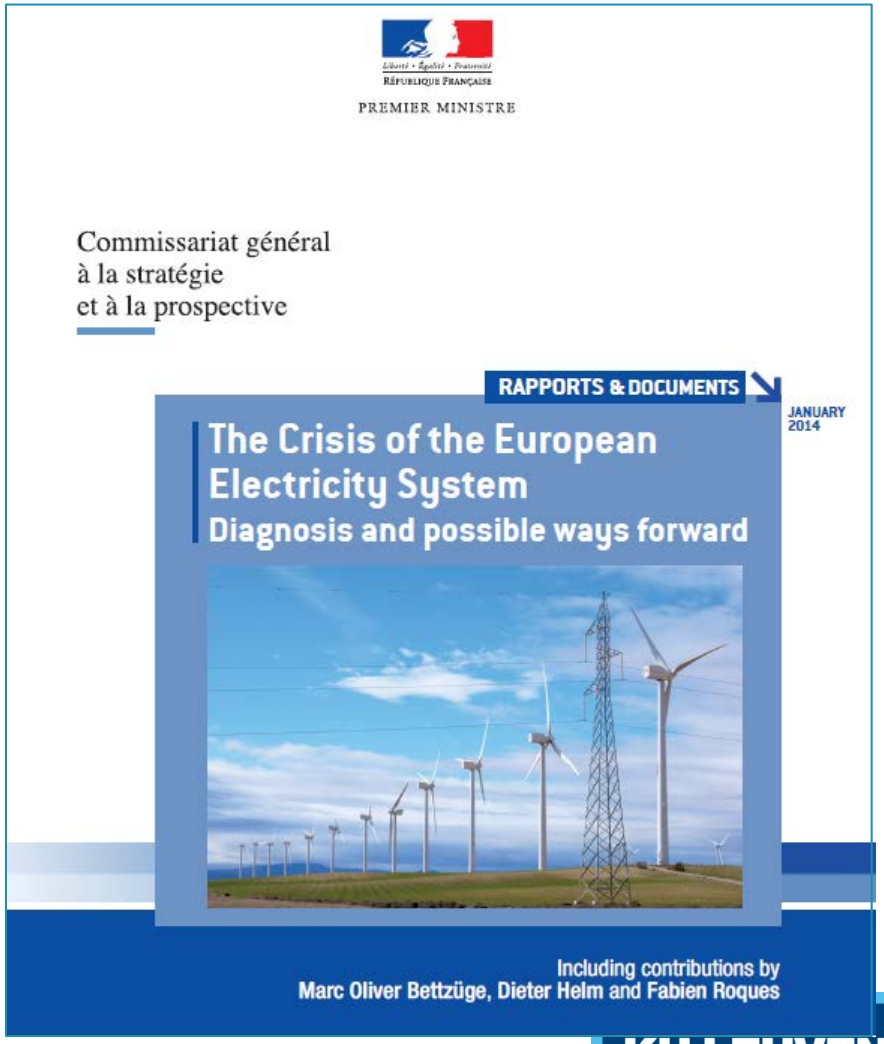
French Report January 2014



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Energy Transition – a comprehensive 'problem'

- Energy transition; all sectors – electricity / heat / transportation

  → But driven by changes in the electricity sector!

- Must define the 'problem' to be solved: CO_2 reductions globally
- Energy issue and transition depends on regions and countries
  - Europe / USA / China, India, Sub-Saharan Africa, …

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Energy Transition – a comprehensive 'problem'

- Be ambitious, but realistic and do not fool yourself *(COP21, ETS);*
- ***some inconvenient truths…***
  - *With INDCs ('promises') of Paris, in 2040 still 75% fossil worldwide (cfr IEA)*
  - *Local electric RES development in EU countries does NOT reduce CO_2 in EU*
  - *Phasing out coal, lignite or nuclear does NOT change CO_2 emissions in EU*
  - *Deployment of large scale CHP does NOT reduce CO_2 emission in EU*

***Because of the cap for ETS** !! Less CO_2 here allows more CO_2 elsewhere!*

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Energy Transition – a comprehensive 'problem'

- Policy and regulation (intentions / stability crucial)
  - ETS good intention; it works – but early mistakes to be corrected…
  - ETS LT signal for investments? Cap reduces with 1.74% up to 2020, and from 2021 by 2.2%/a… But mistrust in policy makers (cfr recent reforms…)
  - **20-20-20** textbook example of well-intended but failed policy…
  - RES and large-scale CHP (elec & efficiency) lower EUA prices… Europe's massive RES/CHP subsidies support cheaper coal in DE and PO
    (cfr Prof. Newbery – Cambridge)
- Pricing / cost issues will be crucial *(wholesale, distribution, system costs)*
- Institutional affairs *(degree free market / state interventions)*
- Important factors: customer behavior (freedom for aggregators) /

  technology & innovation
- Unexpected events *(geopolitics, accidents, environmental concerns)*

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Energy Transition – a comprehensive ‘problem’

- **Transitions take time** *(successes, failures; large system inertia)*

- **Must integrate sectors** *(elec sect, gas sect, heating sect, transport sect)*

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EU’s implementation

Issues / challenges / problems in the EU market

- Technical challenges
- Market-integration problems
- Consequences for the CO_2 emissions
- End-electricity prices for end consumers

EU's implementation

Consequences of renewables quota in end-energy terms (1)

- Total end energy = electric energy + fuel for heat + fuel for transportation
- EU requirement by 2020: 20% of end energy from RES
- For transportation only 10% ... → for electric sector ~ 34%
- Expectations / outcome ("steered" by differentiated *subsidies*):
  - Hydro ~ only small increase possible
  - Biomass ~ moderated increase (protests against co-combustion, imported biomass pellets, sustainability questions)
  - Wind onshore + offshore / ENOH onsh ~ 2200h/a offsh ~ 3500 h/a
  - Solar photovoltaics (PV) / ENOH Belgium ~ 800 h/y
- Total: 8760 h/a → low capacity factors of these intermittent sources

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EU's implementation

Consequences of renewables quota in end-energy terms (2)

- Capacity factors intermittent sources (wind + PV):
  - Wind onshore + offshore / CF ~ 25% - 30%
  - Solar photovoltaics (PV) / CF ~ 10%
- To produce 34% electric energy with something that operates only 10% or 25-30% of the time, you must install a large amount of installed power (called "capacity") → leads to massive overcapacity
- If there is a lot of wind and sun, and low demand (e.g., weekends), then too much electricity produced
- But sometimes in case of cold spell (cfr winter Feb 2012) – with temp inversion... little wind and 'dark' (hence no PV) at 17.00h-18.00h, when peak demand arises in NW-Europe! → very little RES electricity produced

EU's implementation

Consequences of renewables quota in end-energy terms (3)

- *Intermittency*: defined as "variable" and "partly unpredictable"
- How deal with massive "intermittency" in electricity system?

  Five major 'flexibility'-enabling elements:

  - **Back up reserves from *flexible dispachable thermal plants* (+ & -)**
  - **Electric *storage* (large scale electric storage not available)**
  - **Expansion of *transmission grid***
  - **Encourage *active demand response* (ADR)**
  - ***Curtailing* of superfluous RES production / review priority access**

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EU’s implementation

Issues / challenges / problems in the EU market

- Technical challenges
- Market-integration problems
- Consequences for the CO_2 emissions
- End-electricity prices for end consumers

EU's implementation – technical issues

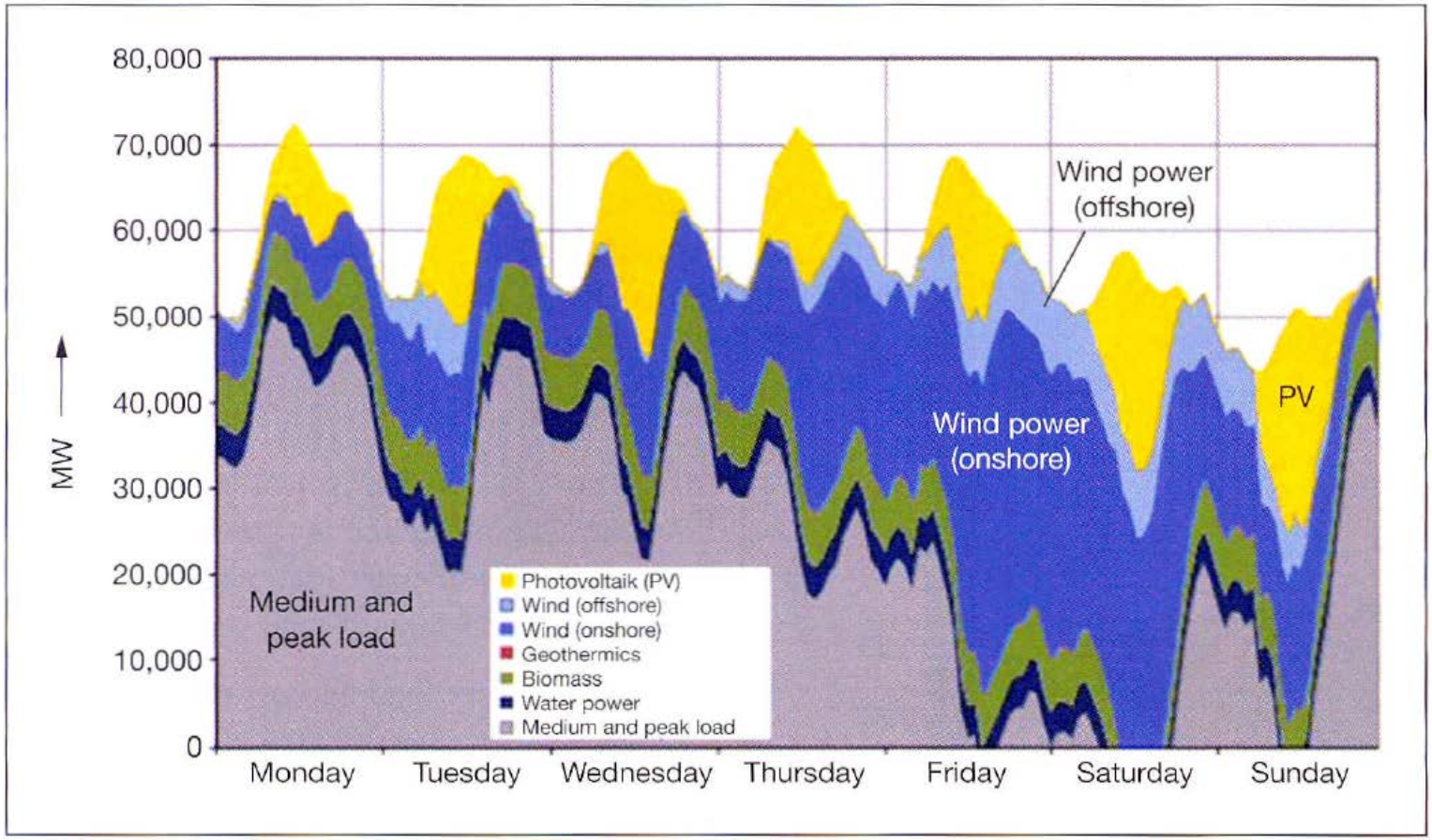

Figure 1. Power generation across one week in July 2020, BEE scenario [6].

Ref: Lehner & Schlipf, VGB Powertech, 8/2011

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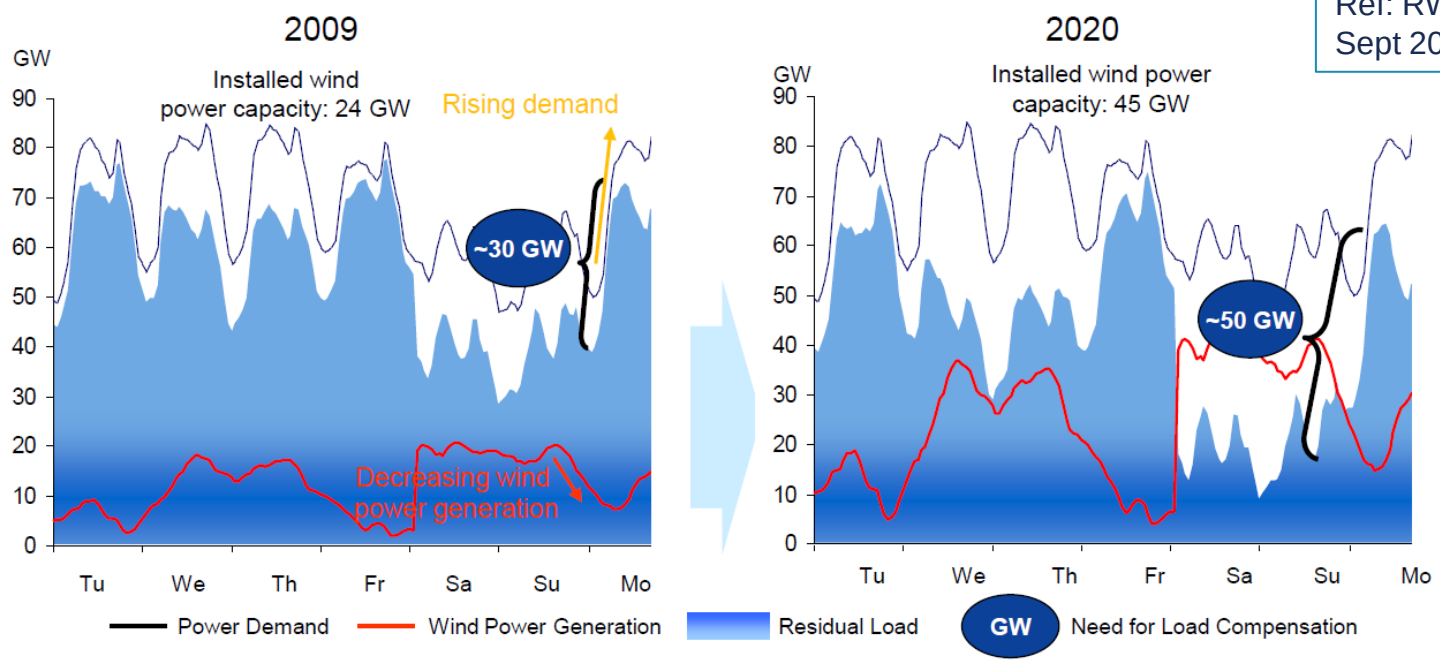
EU's implementation – technical issues

Residual power demand in Germany February 2009 and projection to 2020

Ref: RWE – ALSTOM
Sept 2011



→ thermal plants must balance very quickly

→ **challenging requirements for thermal power plants!**

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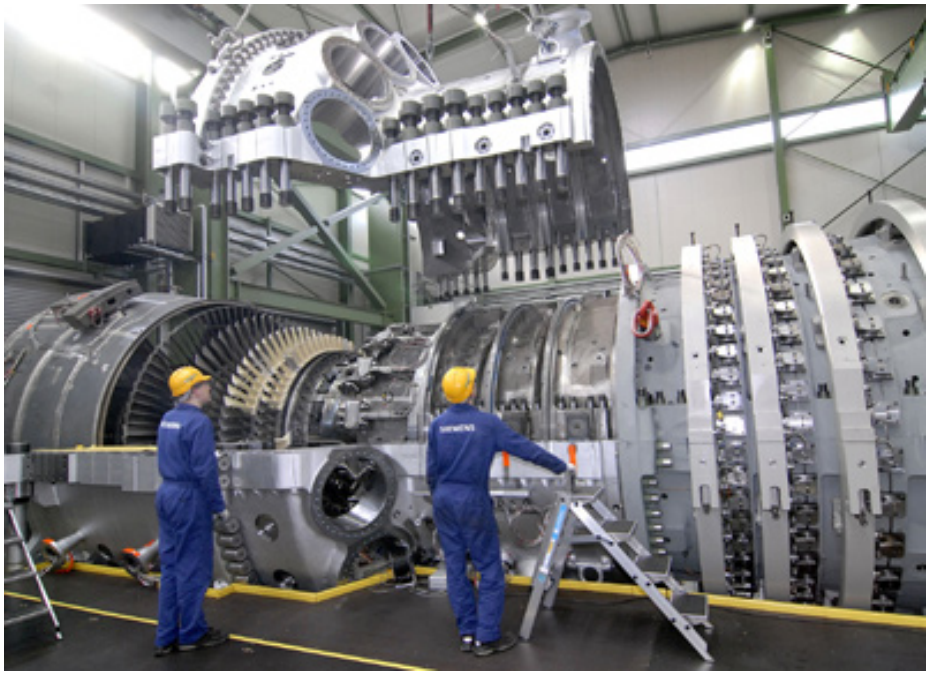
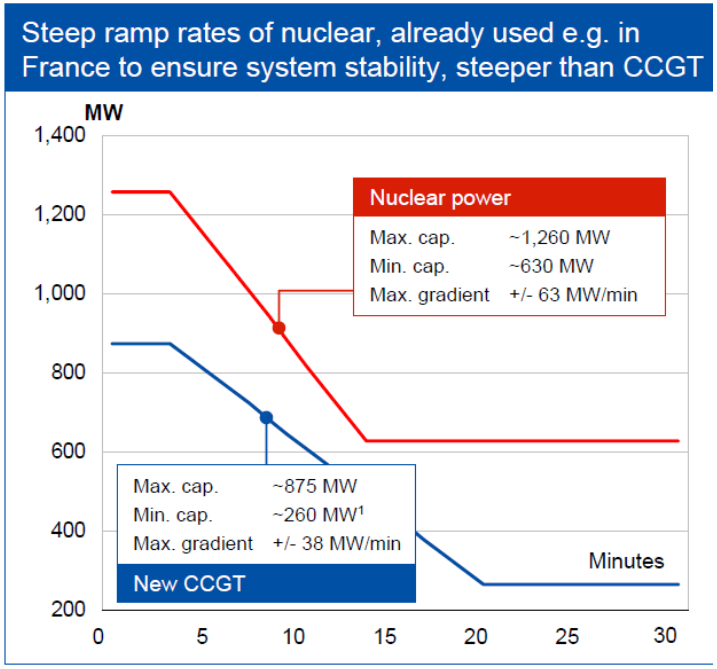
EU's implementation – technical issues

- What are critical generation-technology parameters?
  - Ramp rates compatible with technology
  - Overall dynamic behavior





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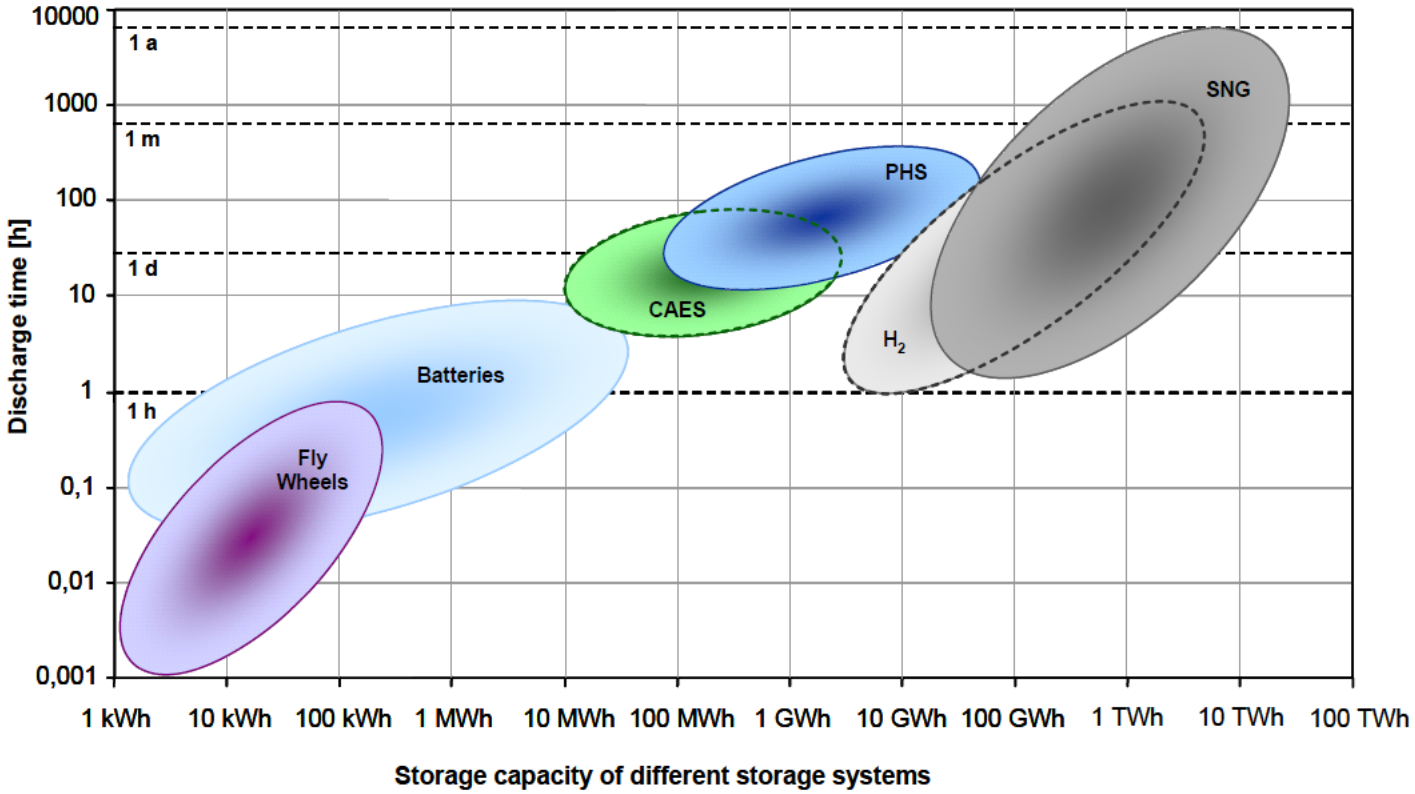
EU's implementation – technical issues

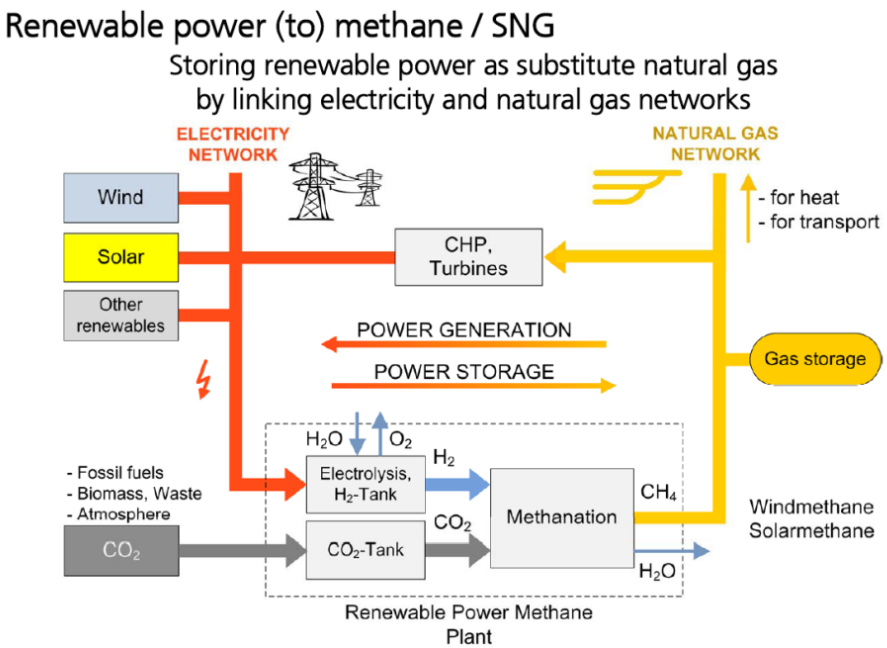
Comparision of storage capacity and discharge time of RE-SNG

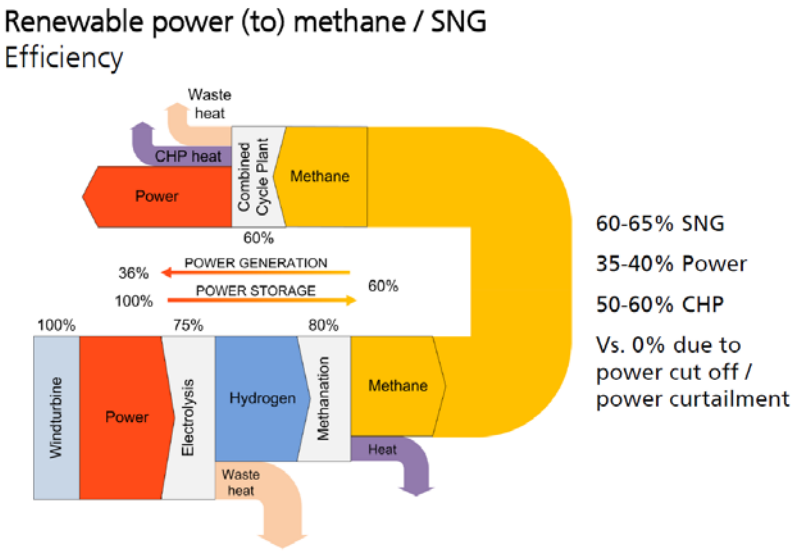


Different solutions for different tasks: ancillary vs. arbitrage

LT Seasonal Storage P2G?

- To what extent will there be a shift of imbalance/fluctuations to other carriers/networks?
  - Shift to synfuel storage?





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Short term Battery Storage?

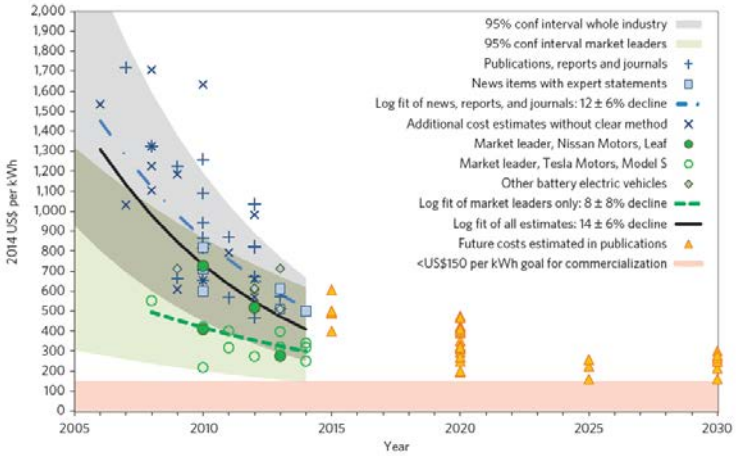
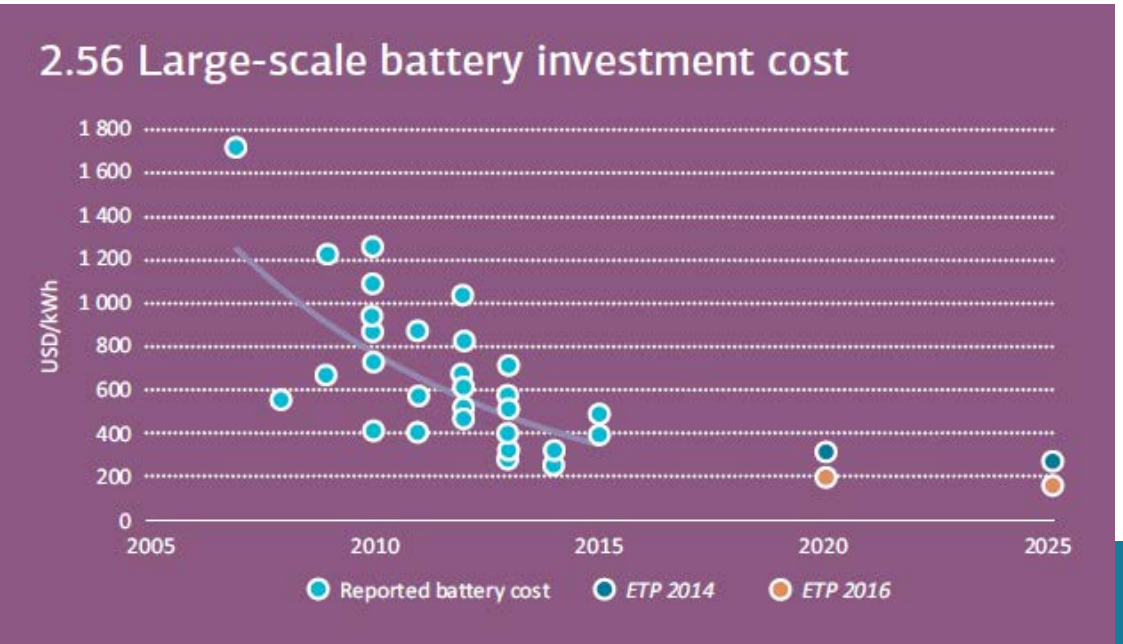


Figure 1 | Cost of Li-ion battery packs in BEV. Data are from multiple types of sources and trace both reported cost for the industry and costs for market-leading manufactures. If costs reach US$150 per kWh this is commonly considered as the point of commercialization of BEV.



IEA, ETP June 2016

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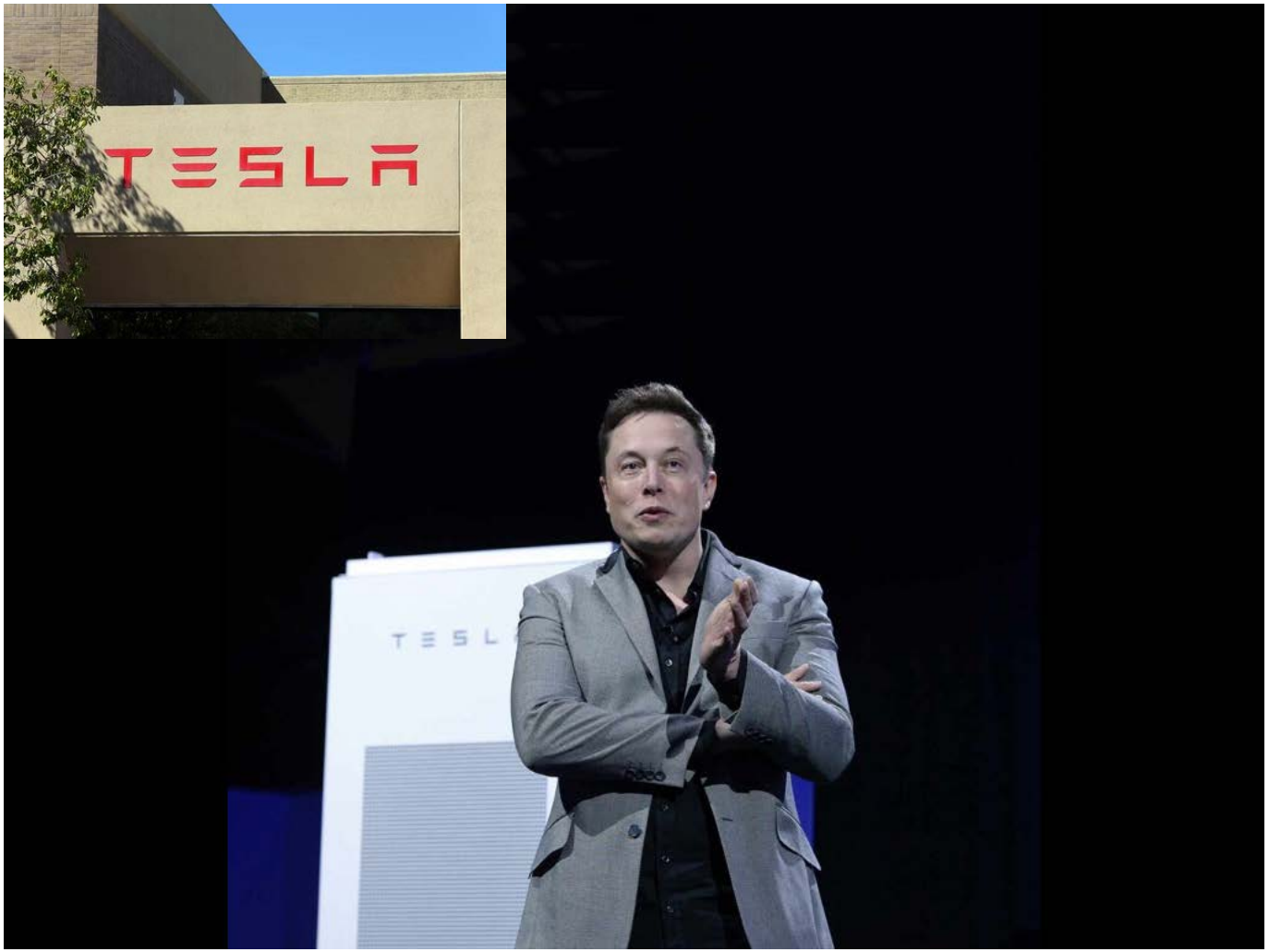
Battery Revolution of Tesla?



TESLA

Powerwall = similar to wall boiler
- for the home -

7 kWh unit
3,000 $ ~ 2,700 €

10 kWh unit
3,500 $ ~ 3,100 €

Powerpacks for industrial applications
Packs of 100 kWh

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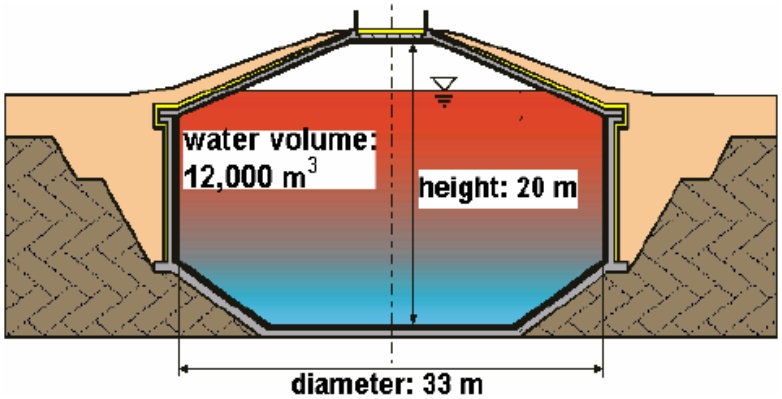
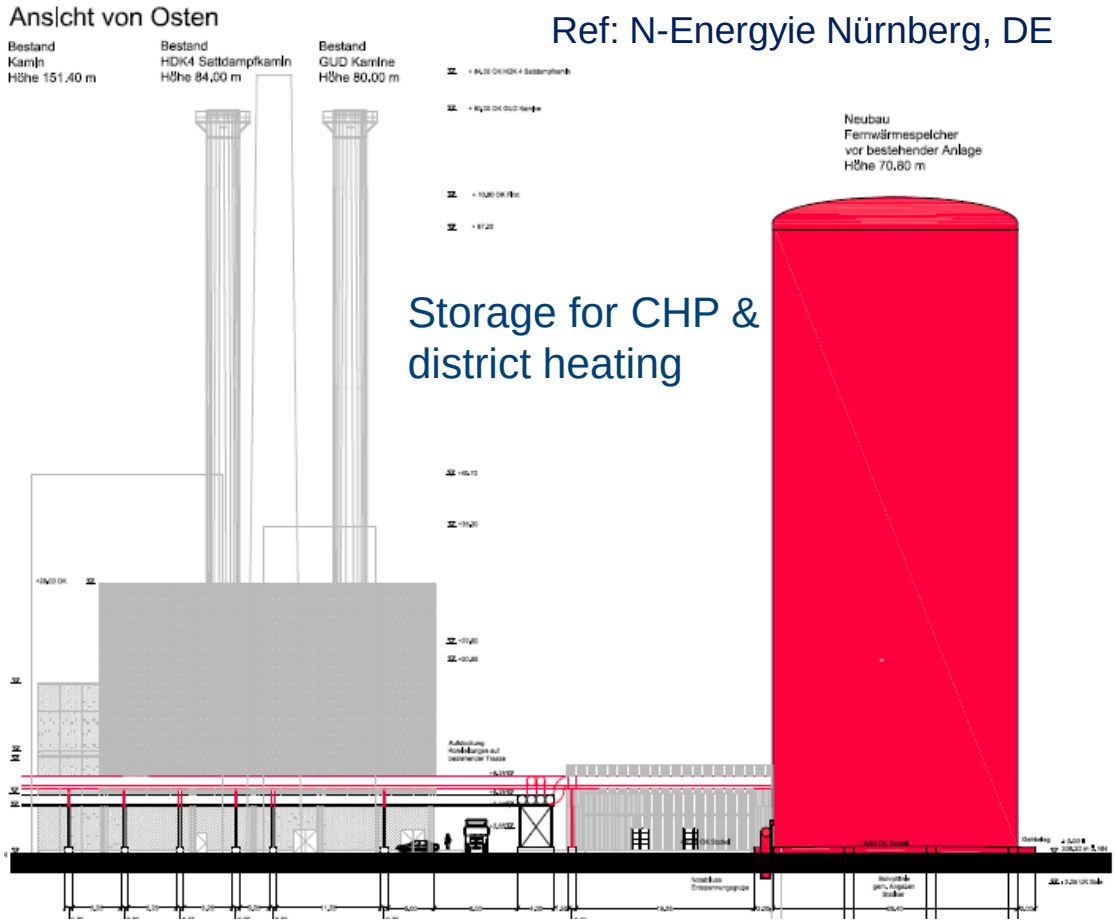
System Integration:
Interaction with Thermal Sector

Thermal storage in hot water

Originally:
seasonal hot water storage



Ref: Solites, DE

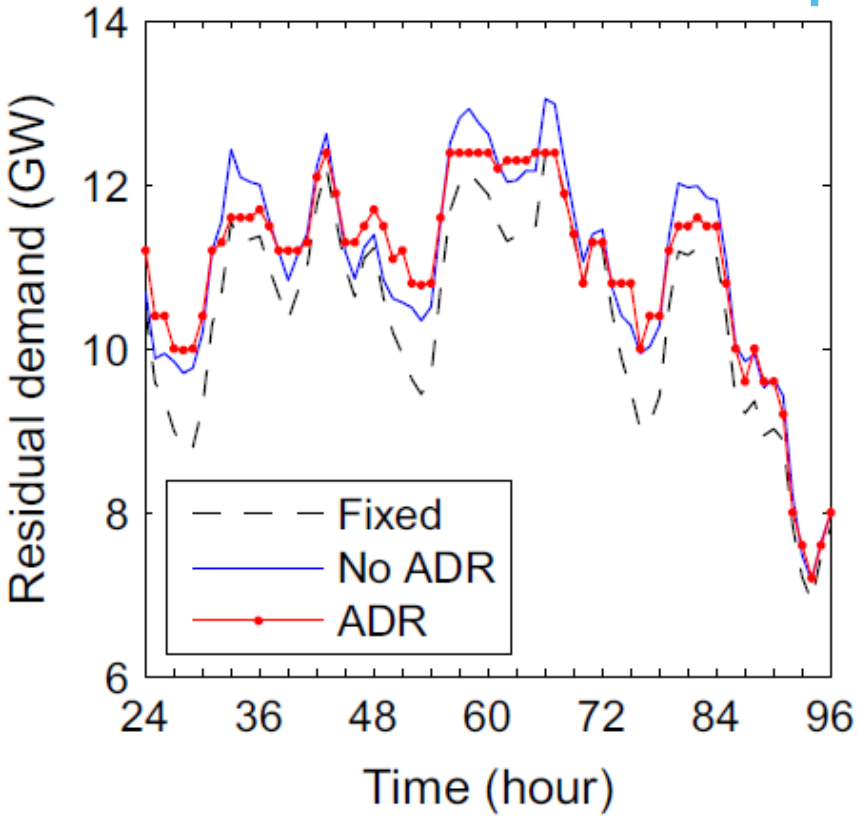


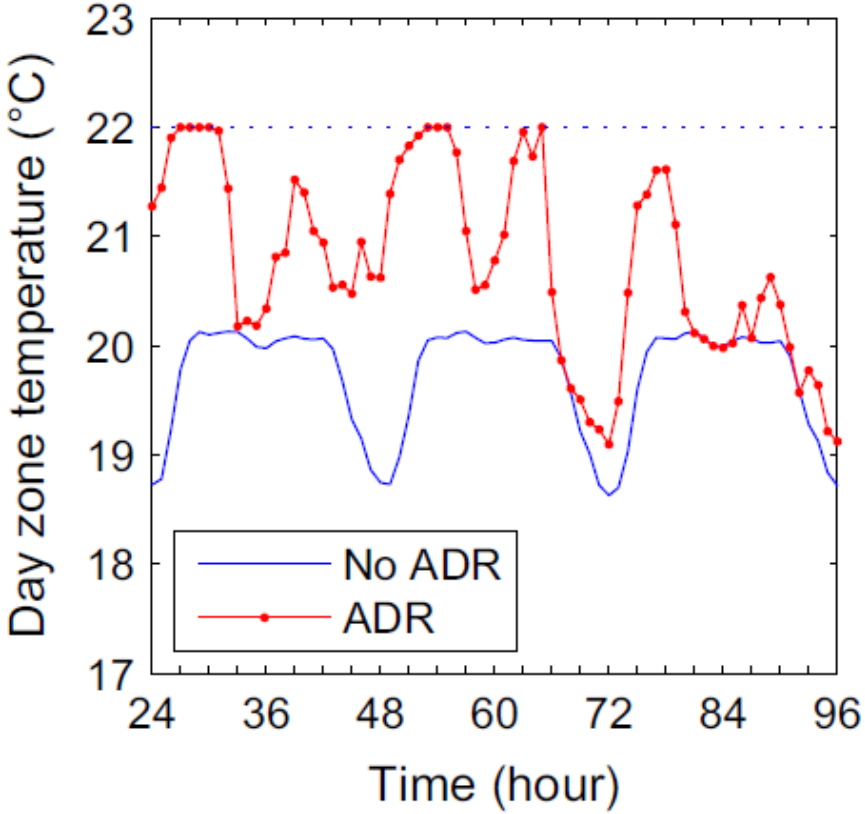
Ref: N-Energyie Nürnberg, DE

Storage for CHP & district heating

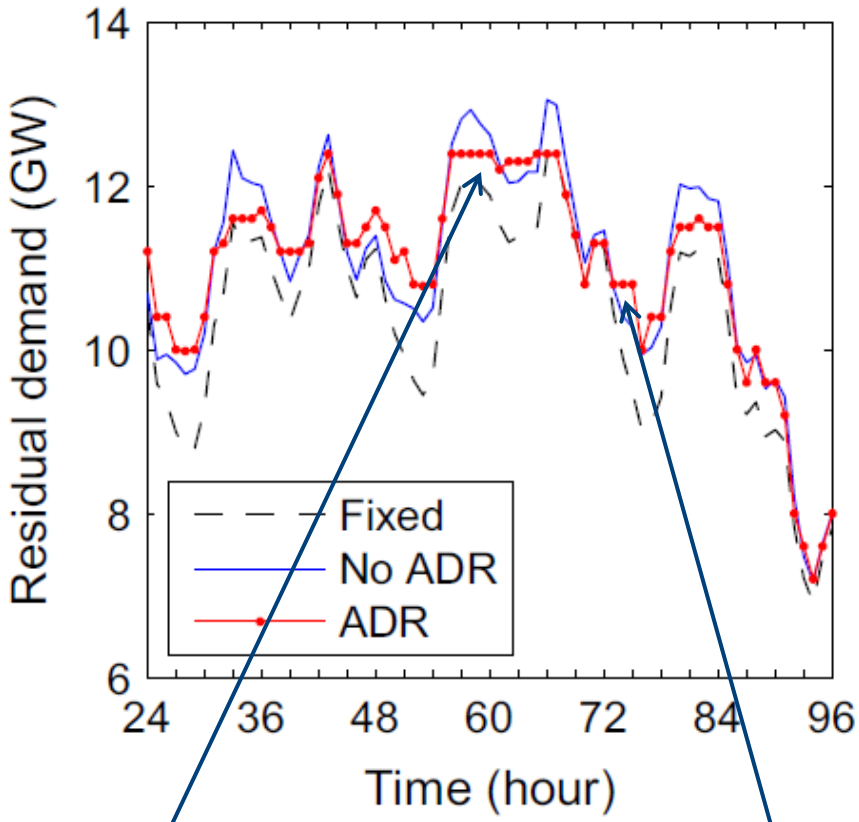
Can be used to dump superfluous electric energy
→ "electric boilers" – used in Denmark!

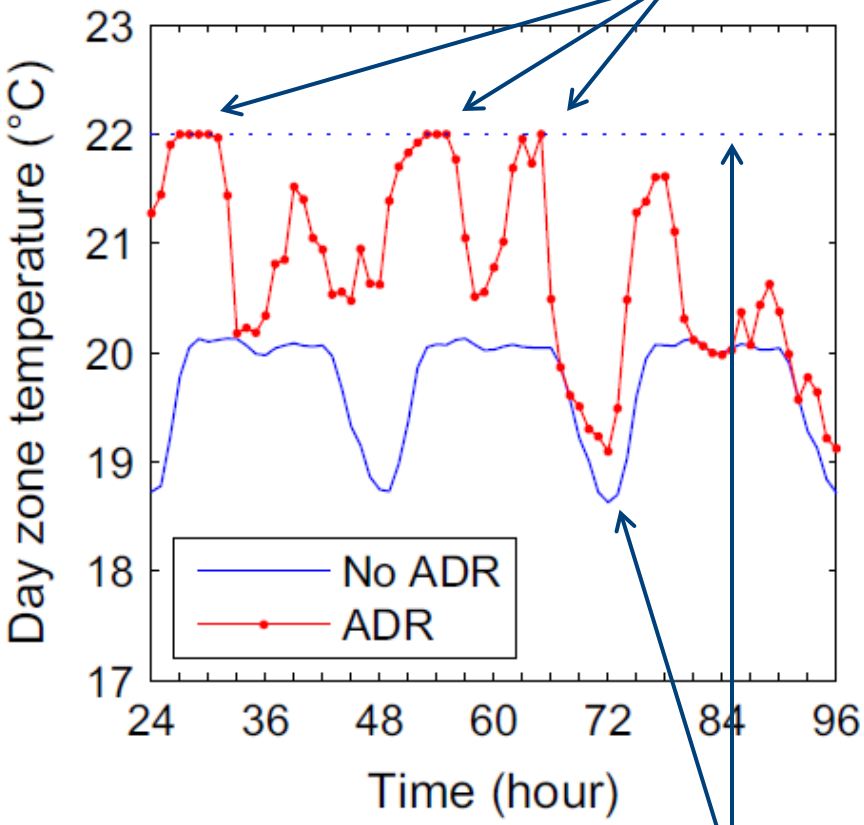
Active Demand Response in Thermal Sector (1)





- Power system inspired on possible future setting of BE power system;
- 250,000 heat pumps + Thermal Storage Buffer (Taks and House intertia);
- Building properties represented via an 'average' building (detached dwelling);
- 52 user behavior profiles.





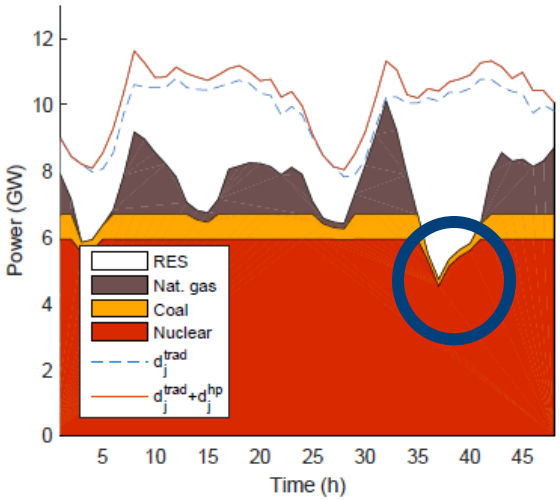
Preheating

Peak shifting

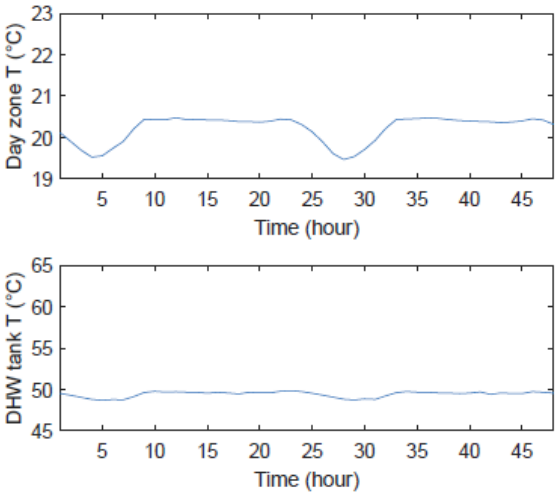
Valley filling

Guaranteed thermal comfort

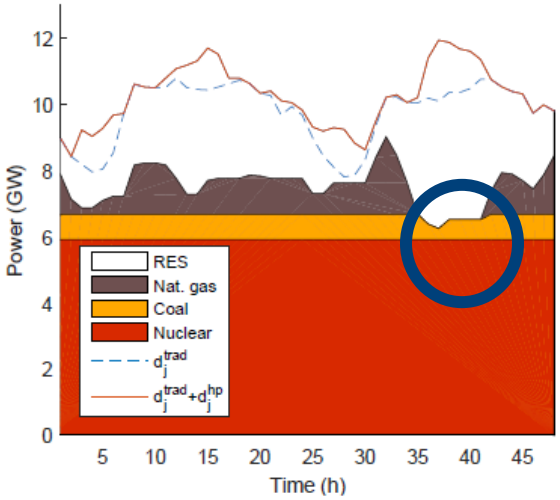
Active Demand Response in Thermal Sector



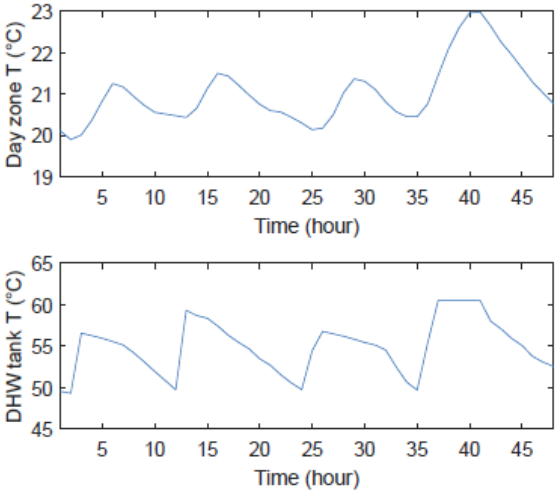
(a) Electricity generation, no DR



(b) Mean temperatures, no DR



(c) Electricity generation, with DR



(d) Mean temperatures, with DR

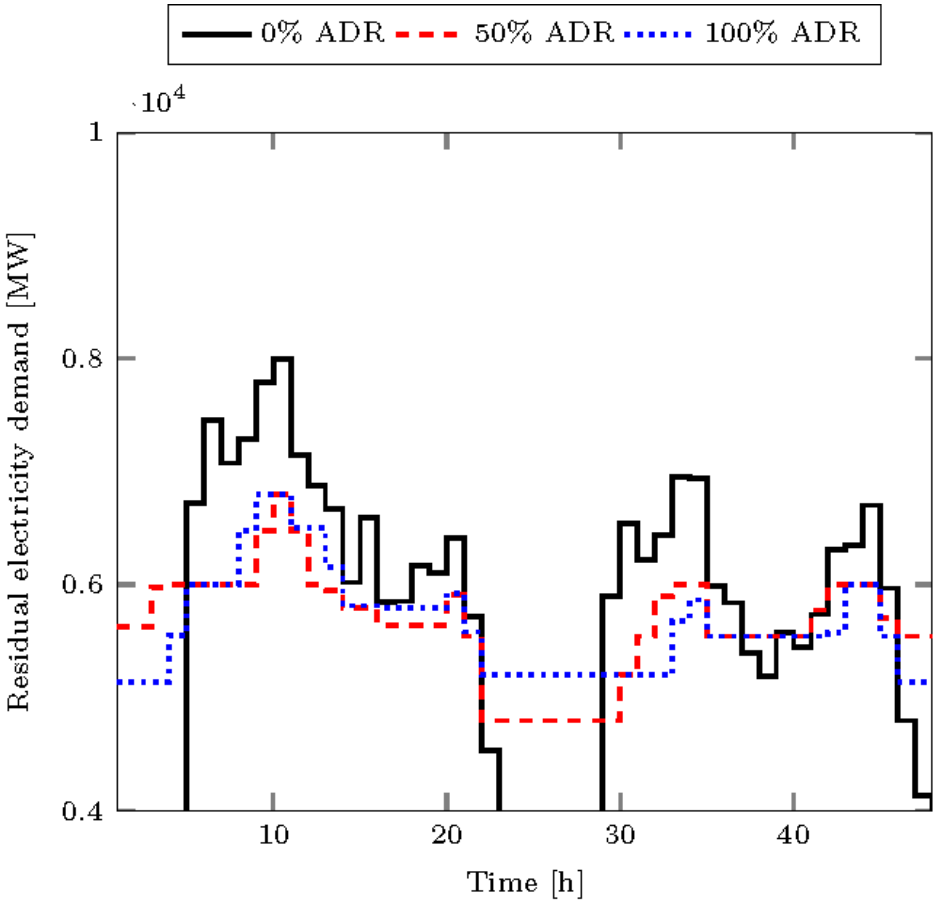
2nd Case Study:

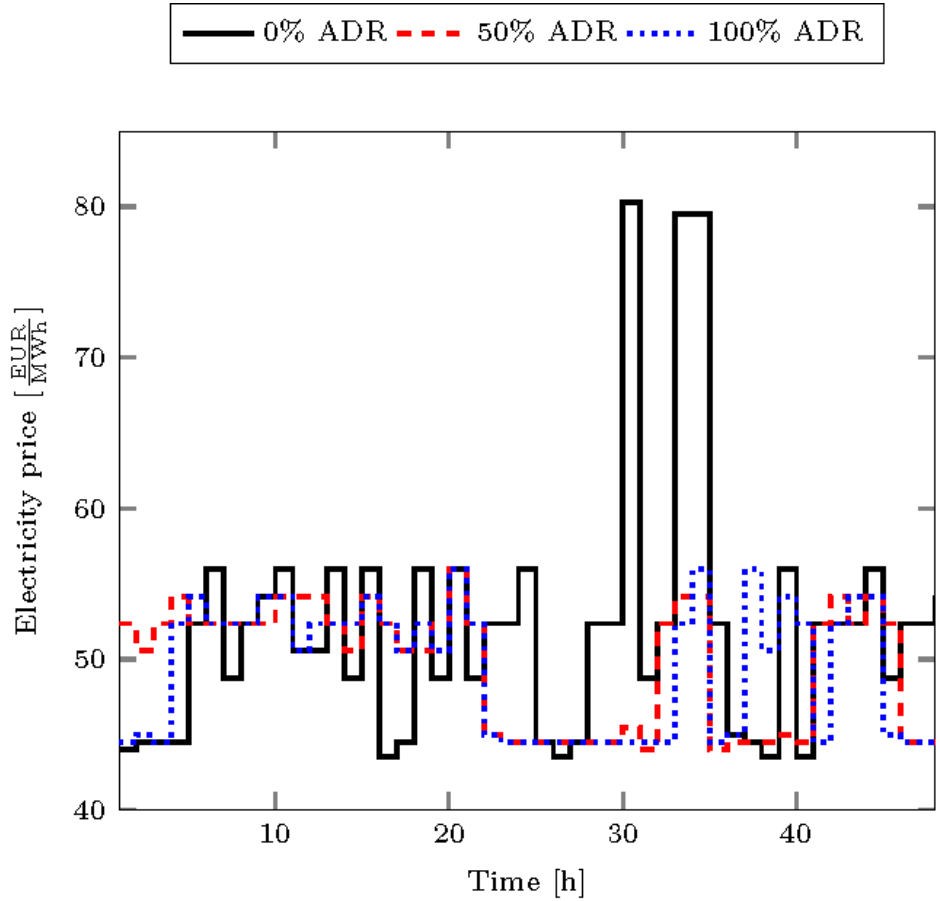
- Power system inspired on possible future setting of BE power system;
- 250,000 heat pumps;
- Building properties represented via an 'average' building (detached dwelling);
- 52 user behavior profiles.

ADR helps reinstating baseload!

Active Demand Response in Thermal Sector

3rd Case Study

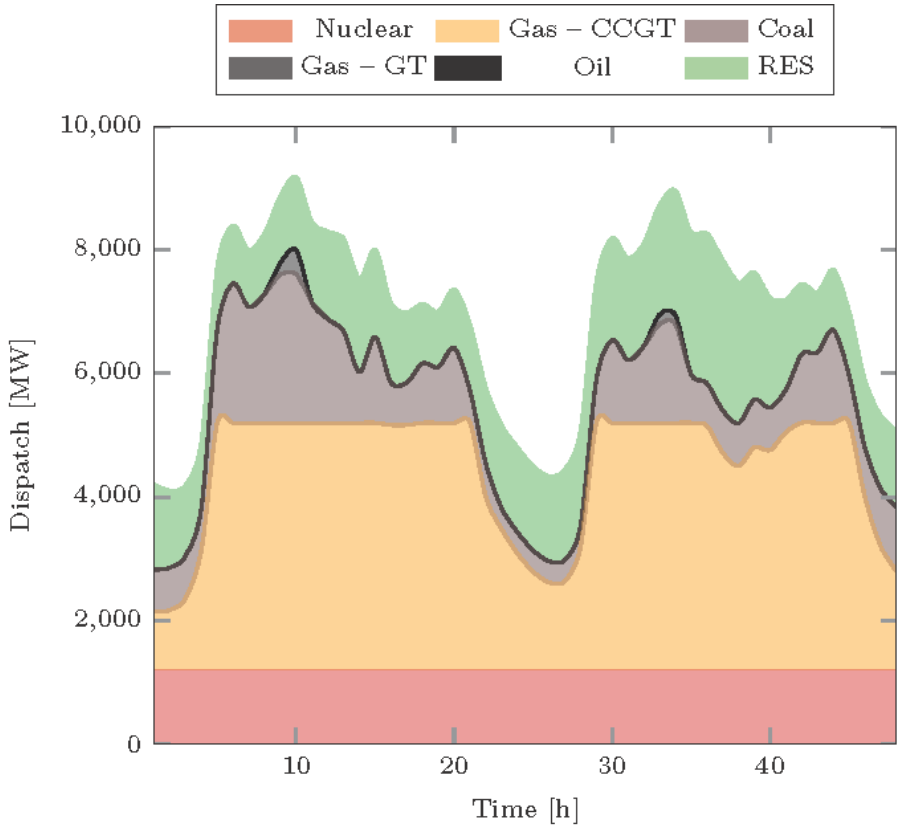


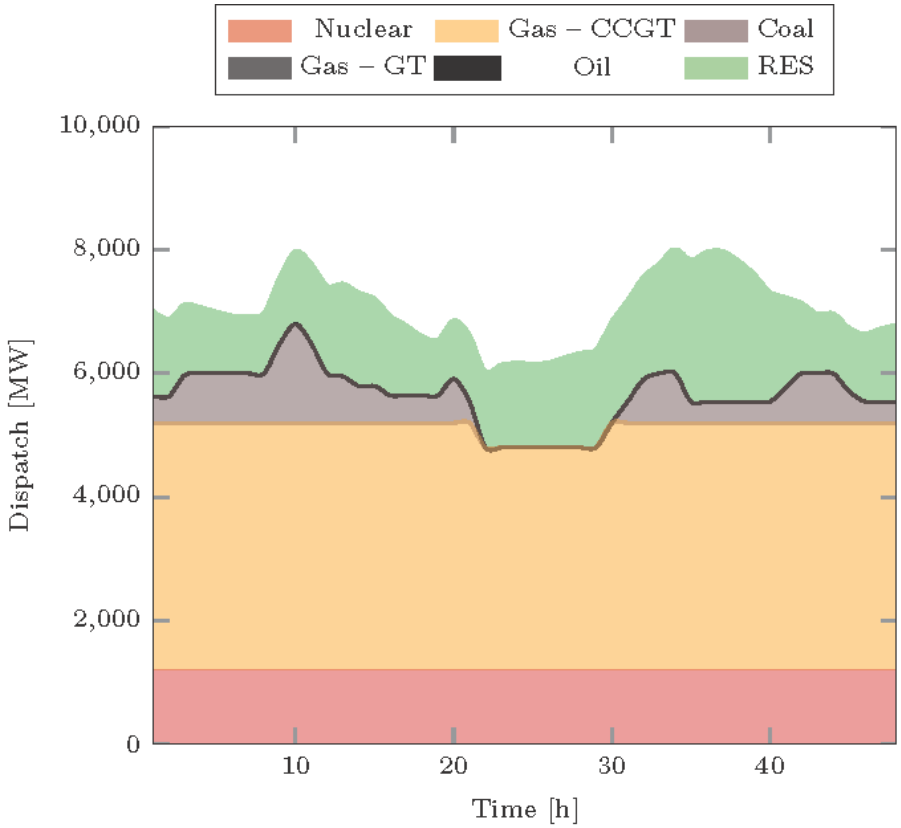


The residual electricity demand (left) and electricity price (right) in three cases of ADR participation (0%, 50%, 100%).

Active Demand Response in Thermal Sector

3rd Case Study





Output of the committed power plants in case of 0% (left) and 50% (right) ADR participation.

ADR helps reinstating baseload!

Storage and Baseload?

- ADR does reinstate baseload directly
- Storage does not reinstate baseload directly
- But cheap storage reinstates ‘continuous generation’ indirectly: nuclear generated output can be stored cheaply
  (Ref. Manuel Baritaud, IEA)

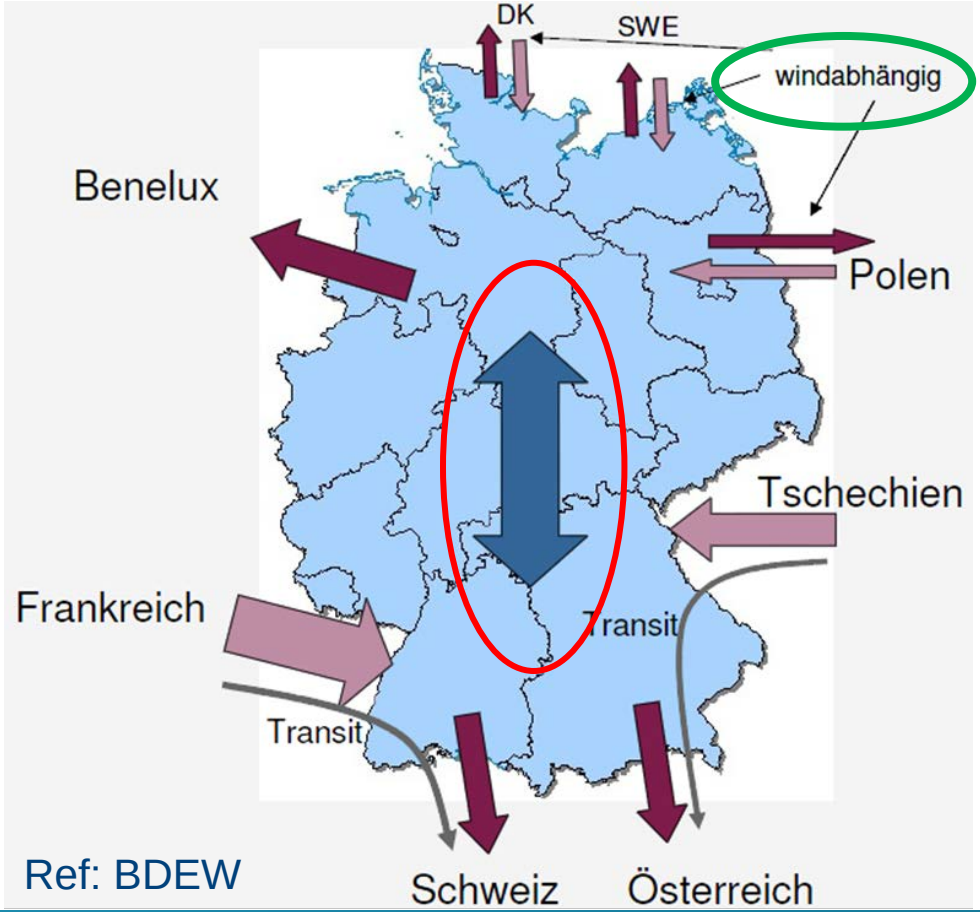
EU's implementation – technical issues

Unplanned flows (loop flows / transit flows)

- Grids guide power flow from generation to consumption
- Electric power follows path of least resistance / impedance
- Transmission capacity high-voltage line:
  - Part needed for unexpected occurences
  - Must keep part for unintended flows (driven by electric resistance)
  - Remainder for actual commercial cross border transactions

EU's implementation – technical issues

Unplanned flows (loop flows / transit flows)



Ref: BDEW

Typical exchanges between Germany and neighboring countries

Major problem in DE:
insufficient lines N → S

Wind in North
NPPs shut down in South
Industrial demand in South
PV in South

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EU's implementation – technical issues

Unplanned flows (loop flows / transit flows)

- **CEE Region**: DE→PL→CZ→AT→DE and DE→CZ→DE
- **CWE Region**: DE→NL→BE→FR→DE

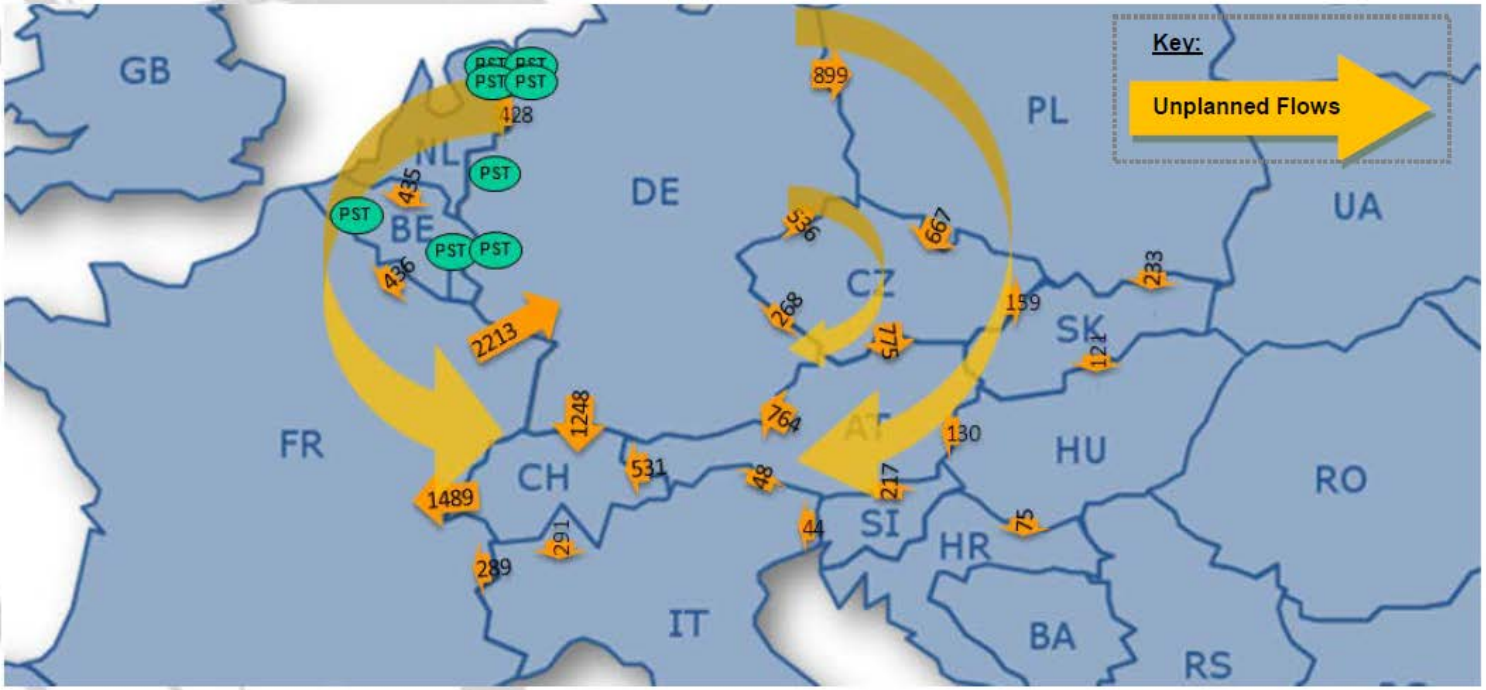

Figure 4. Average Unplanned Flows in Europe [MW], 01.2011–12.2012

Ref: CEPS et al, Jan 2013

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EU's implementation – technical issues

Unplanned flows (loop flows / transit flows)

- Can be "avoided" via *phase-shift transformers*

  = a faucet/valve to "control" the flows (i.e., inhibit unplanned flows)
- But system becomes much more "nervous"...

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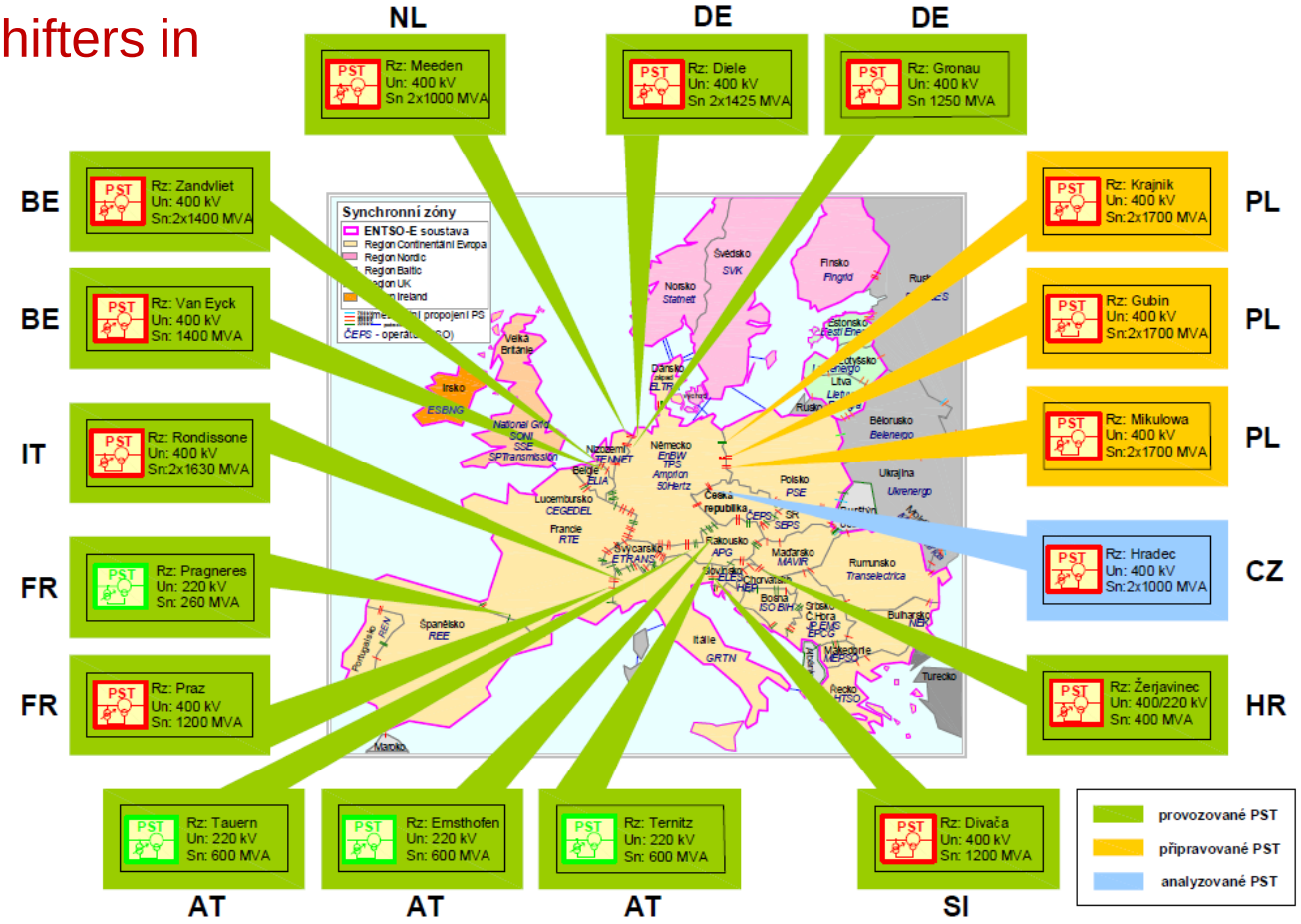
EU’s implementation – technical issues

Phase shifters in Europe



Source: Polish Energy Regulatory Office

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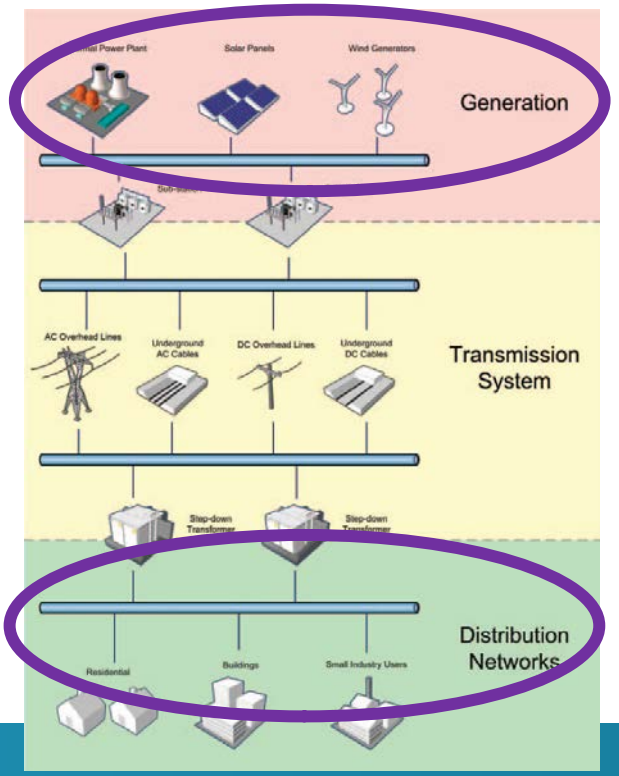
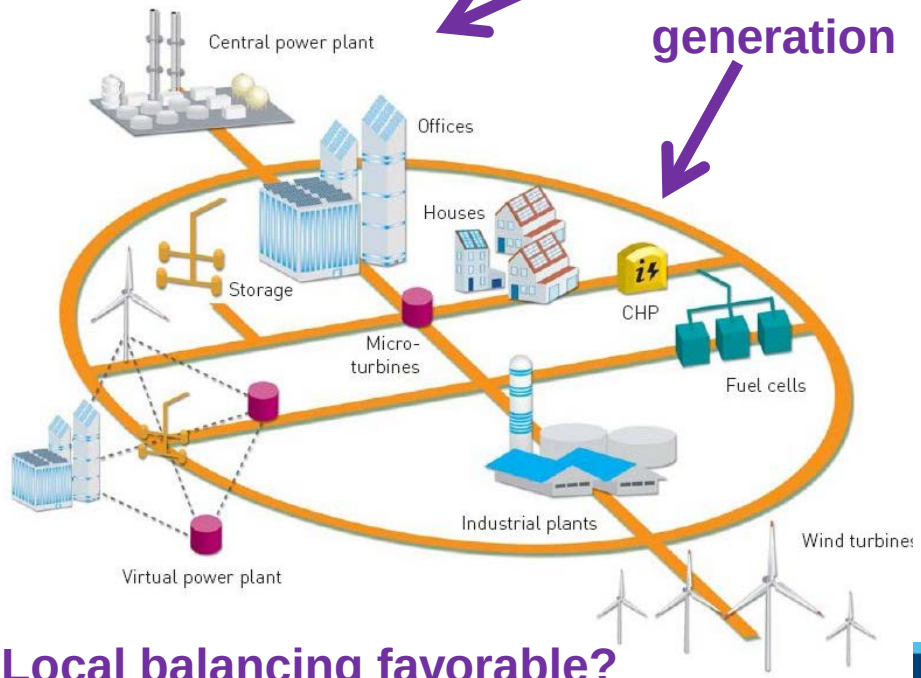
EU's implementation – technical issues

- Where to perform the balancing (at which level)?
  - Should houses/neighborhoods/cities aim for a net load profile as flat as possible?
  - What are the proper objective functions?



Centralized & decentralized generation



Local balancing favorable?

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EU's implementation

Issues / challenges / problems in the EU market

- Technical challenges
- Market-integration problems
- Consequences for the CO_2 emissions
- End-electricity prices for end consumers

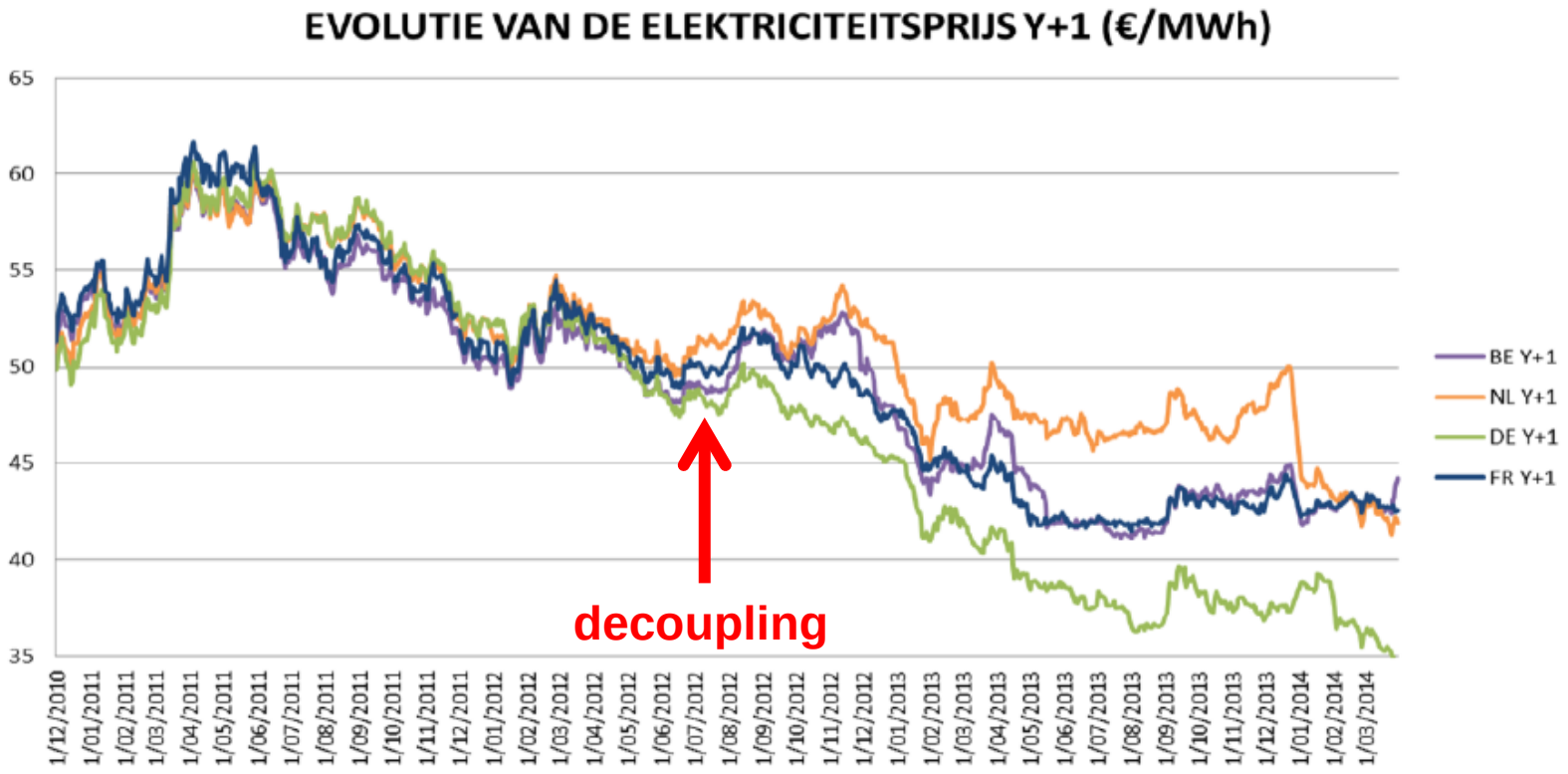
EU's implementation – market issues

- Common EU electricity market started in 1996,...then 2003, ...then 2009
- At present 'third package' being implemented
- Better European coordination through ENTSO-E, ACER
- Unbundling (generation, transmission, distribution, supply)
- "Alligned" grid codes...

- Market integration elements in place, was bearing fruits...

EU's implementation – market issues

But ... Recent developments... !!!



Ref: CREG 2014

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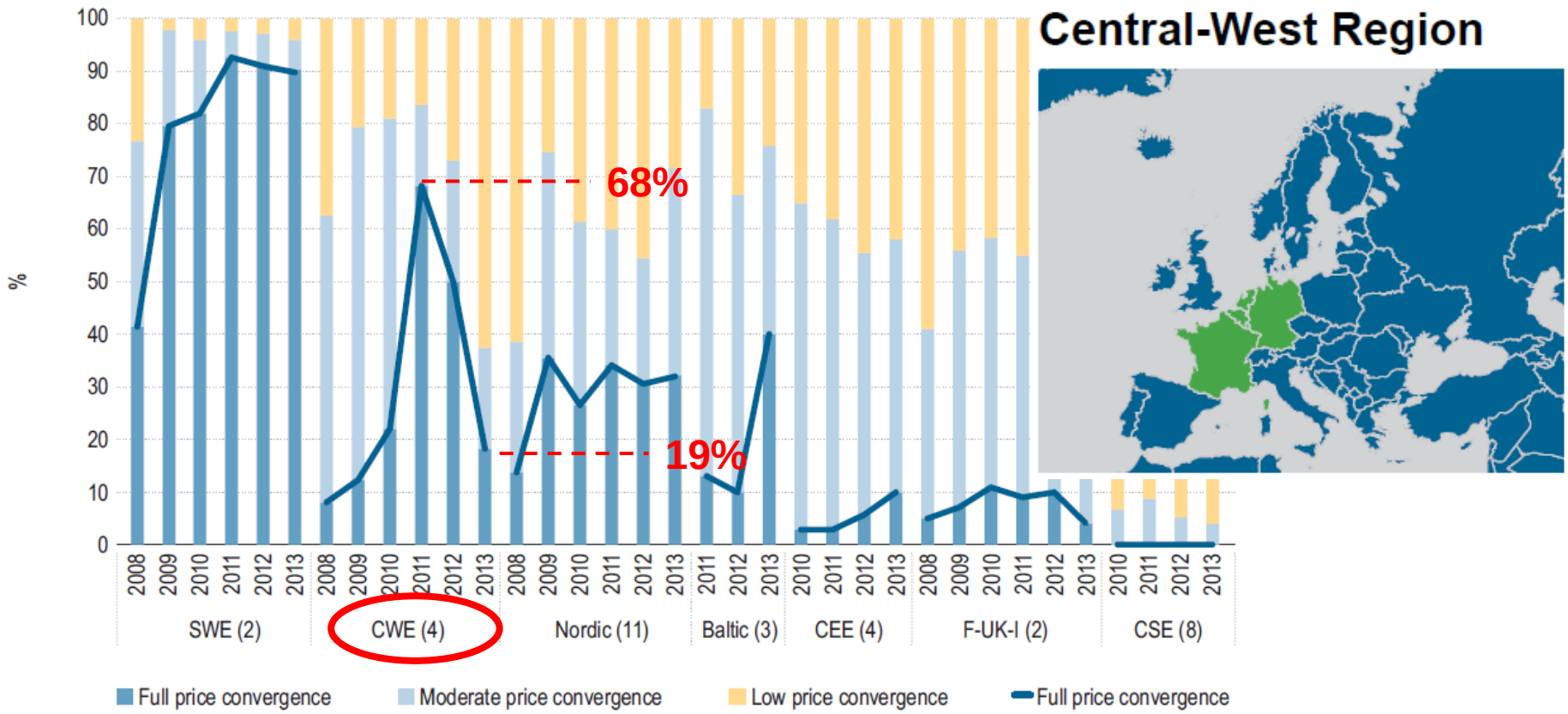
EU's implementation – market issues

Figure 37: Price convergence in Europe by region (ranked) – 2008–2013 (% of hours)



Source: Platts, PXs and data provided by NRAs through the ERI (2014) and ACER calculations

Note: The numbers in brackets refers to the number of bidding zones per region included in the calculations.

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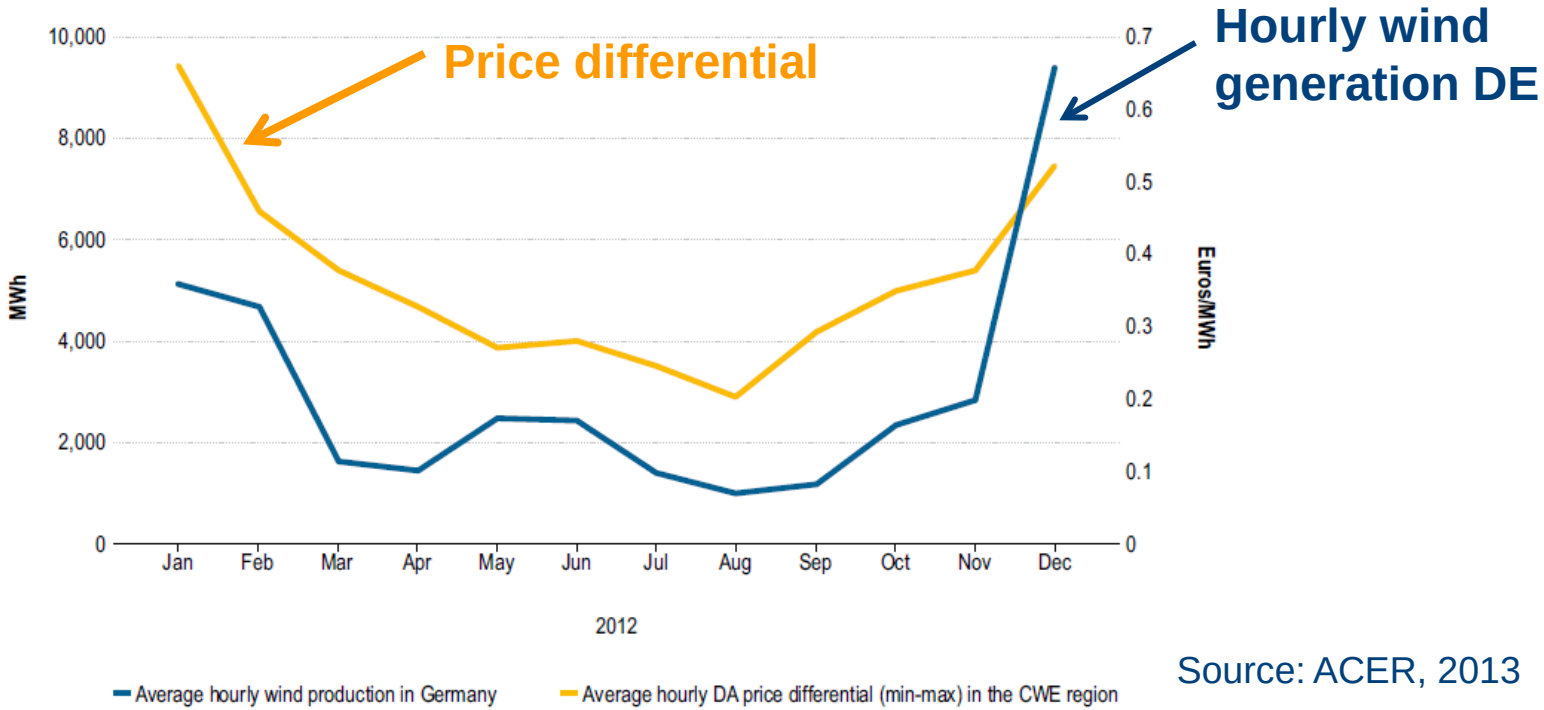
EU's implementation – market issues

But ... Recent developments...

!!!

Figure 14: Monthly average hourly wind production in Germany compared to price differentials in the CWE region – 2012 (MWh and euros/MWh)



Source: ACER, 2013

Source: Platts and German TSOs (2013) and ACER calculations

Note: The price differentials are calculated as the hourly difference between the maximum and minimum price of the bidding zones of the CWE region. In 2012, the lowest price was recorded in Germany for around 70% of the periods.

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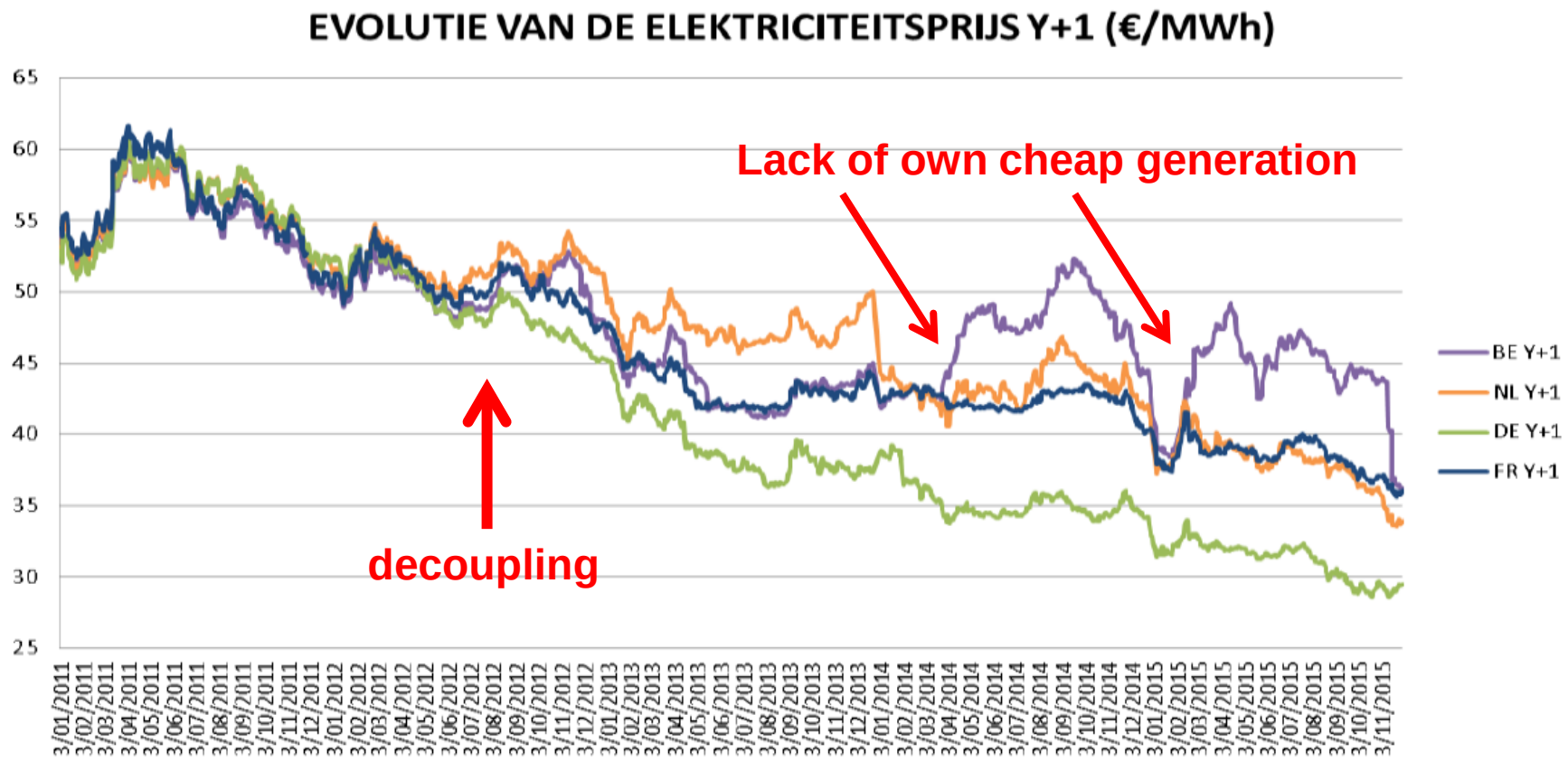
EU's implementation – market issues

But ... Recent developments... !!!



Ref: CREG December 2015

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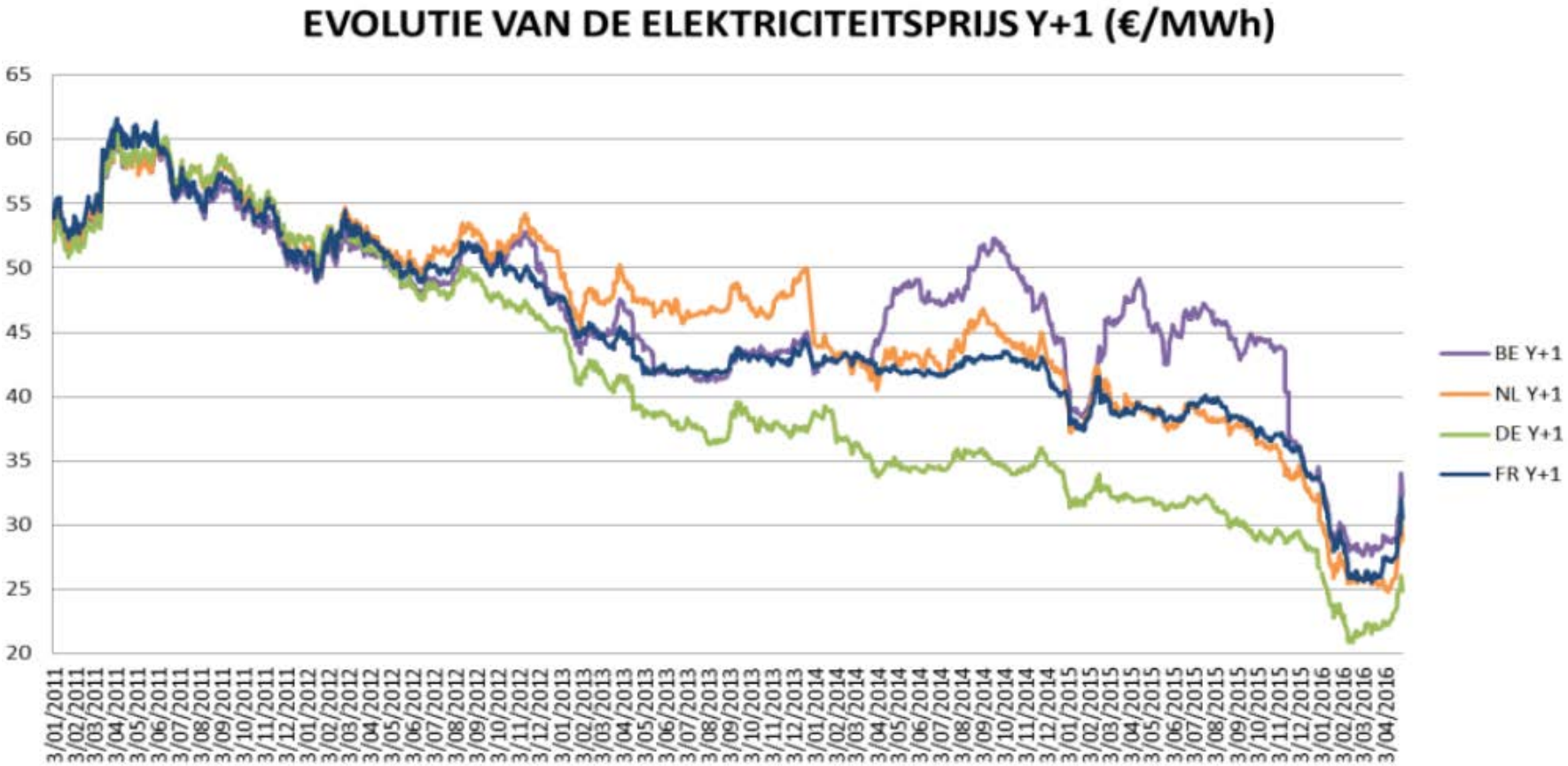
EU’s implementation – market issues



Ref: CREG May 2016

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EU's implementation – market issues

But ... Recent developments... !!!

- *Decoupling prices* shows 'poorer' functioning of market
- *Lower* wholesale prices seem to be good news (?)
- But they lead to major problems for *owners/operators of thermal plants which are needed for balancing*!
- And ironically, end-consumer prices increase rather than decrease (to pay for the levies/subsidies)

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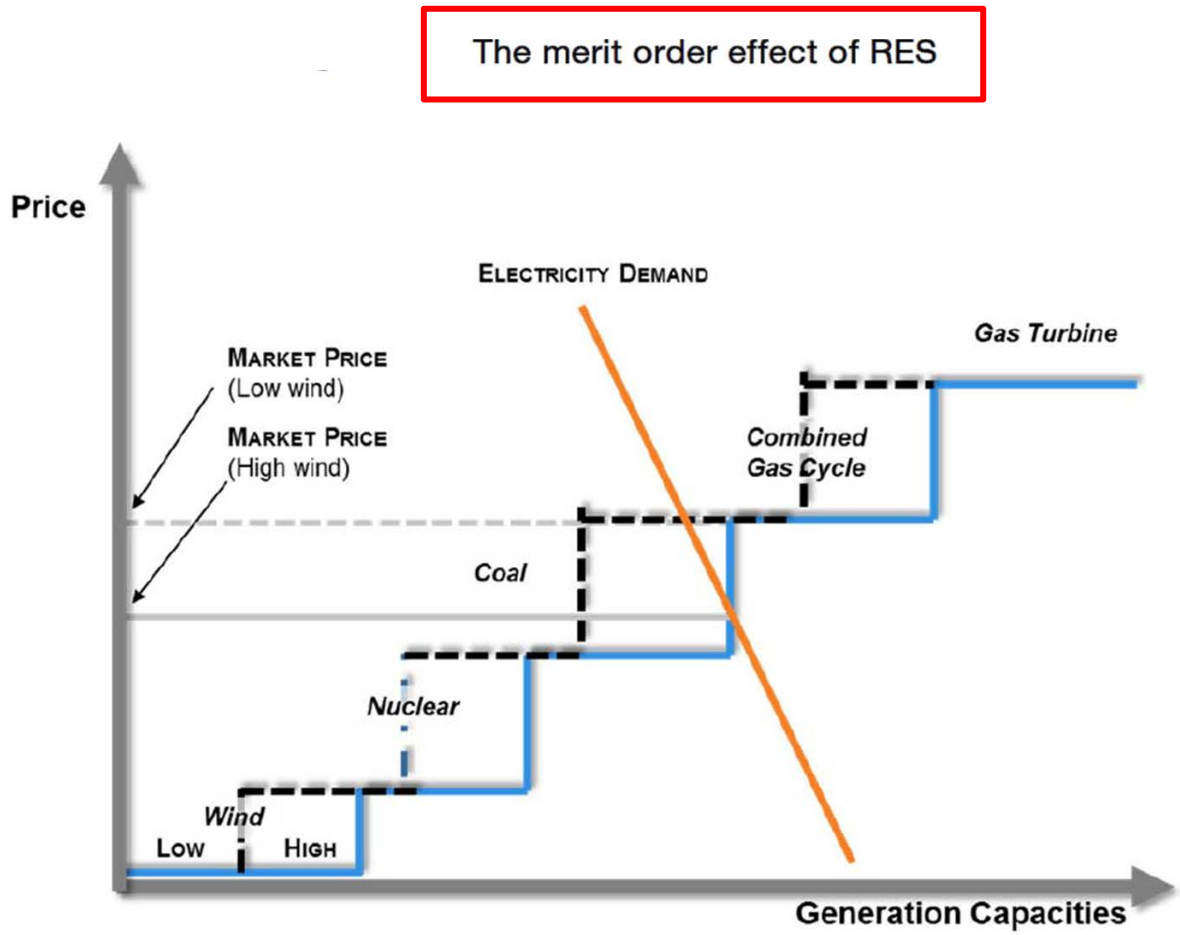
EU's implementation – market issues



Ref: F. Roques in "The crisis of the European Electricity System" – FR 2014

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EU's implementation – market issues

But ... Recent developments... !!!

- These effects were not foreseen in "liberalized market design"...
- Due to **massive injection of zero marginal cost generation (RES)**
- Most efficient & flexible plants (CCGTs) are pushed out of merit order ... Tendency for mothballing
- Leads even to negative wholesale prices !!
- Need completely different philosophy whith massive RES, where 'holding' capacity is to be remunerated ?? → capacity mechanisms ??

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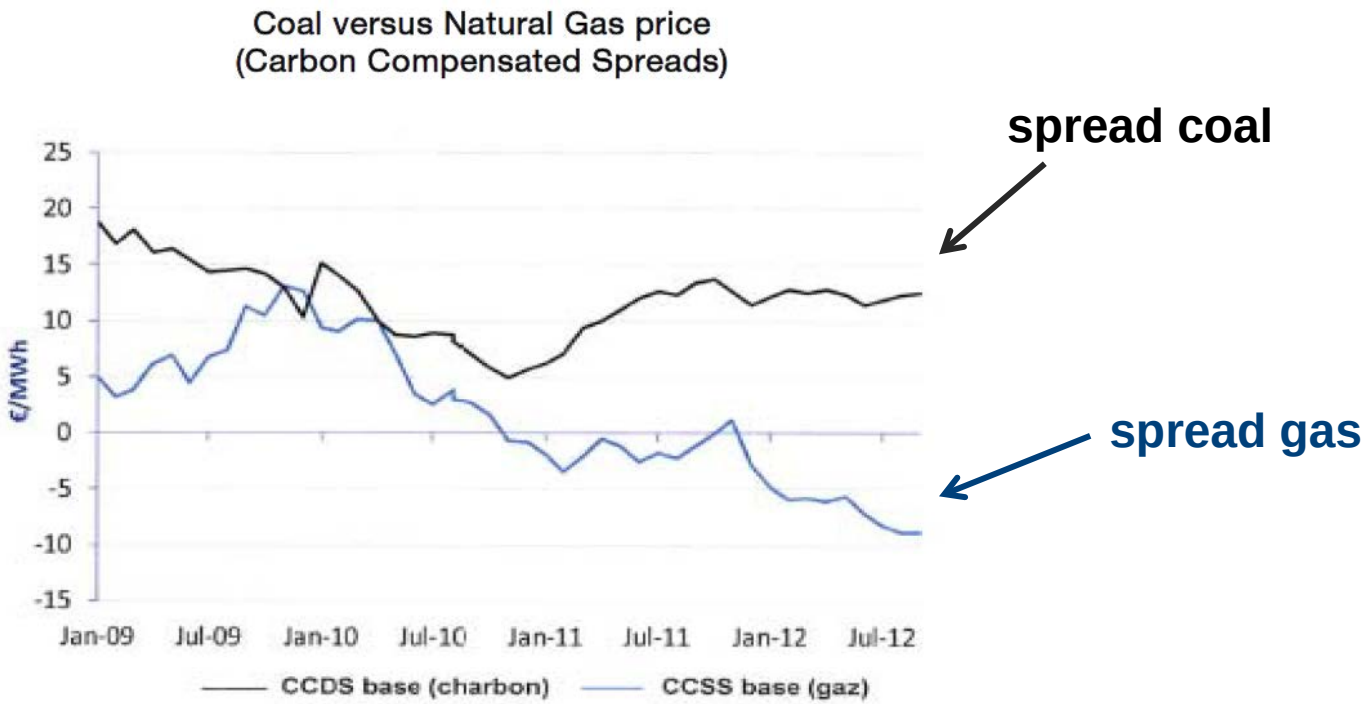
EU's implementation – market issues

Prices too low for covering operational cost of gas plants



Evolution of CDS and CSS between 2009 and 2012 – Source: GDF Suez

Spread =
difference price & production cost = gross operational profit

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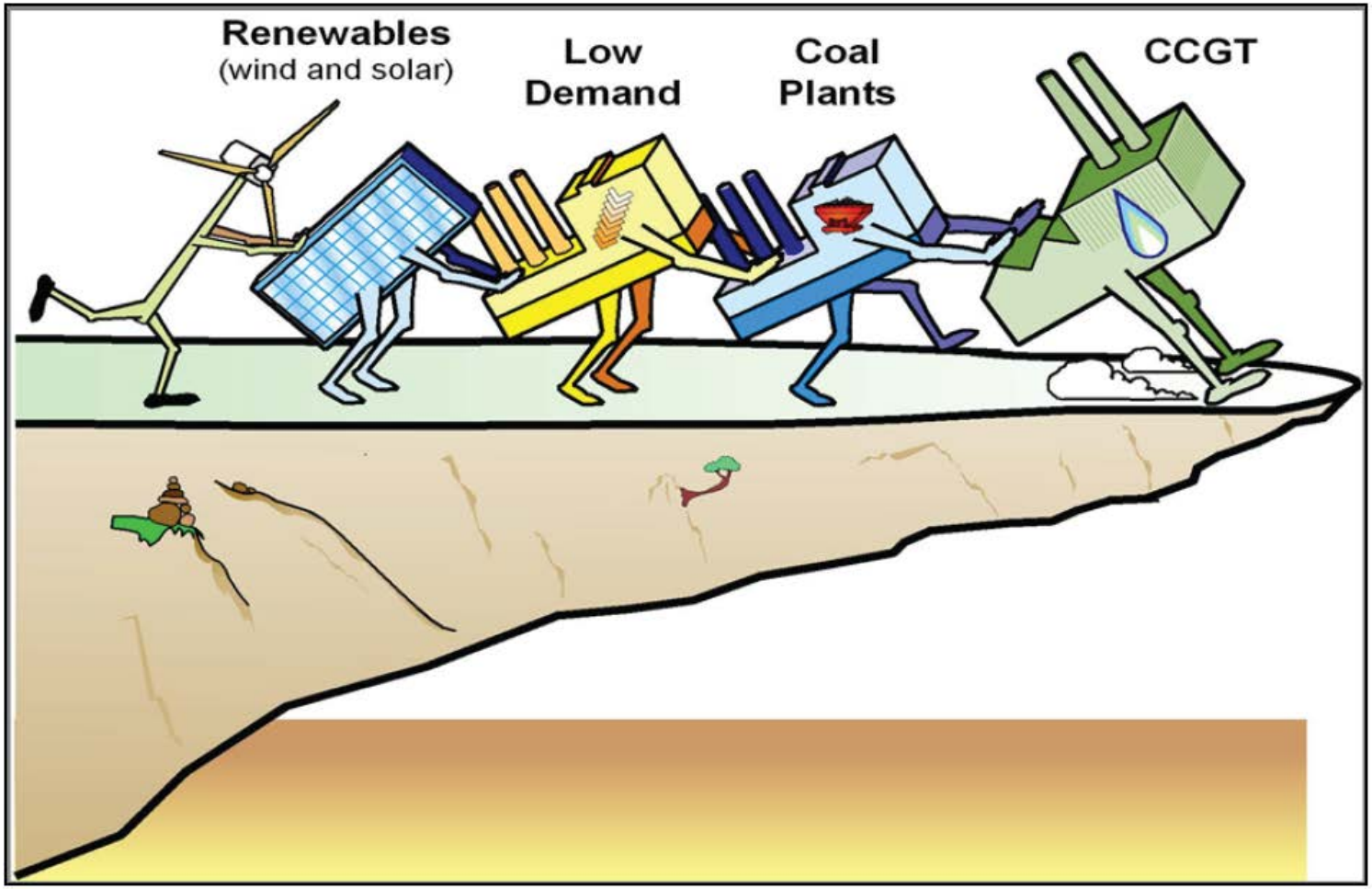
EU's implementation – market issues



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EU's implementation – market issues

The "missing money problem" !!

- The most efficient plants (gas-fired combined cycles – CCGT) are pushed out of the merit order

→ their capacity factor becomes too low to recover investments

→ the prices are too low to cover operating costs

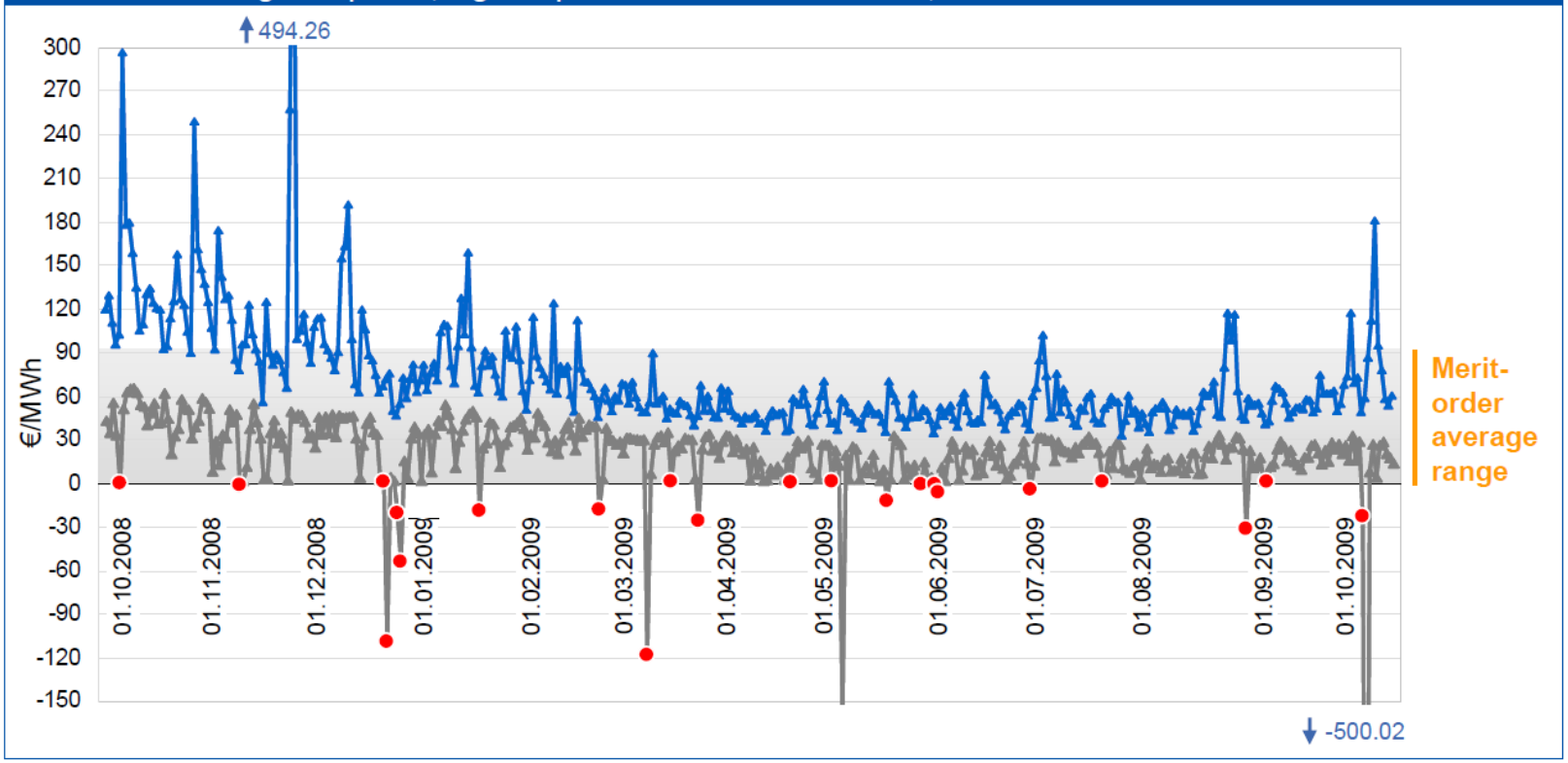
→ **many CCGTs are currently shut down and will be mothballed or shut down permanently!**

→Risk: insufficient capacity (generation adequacy) to do the back up

EU's implementation – market issues

Negative prices in Germany in period October 2008-October 2009

Growing proportion of renewables leads to higher price volatility. October 2008 to October 2009:
60 hours with negative prices; highest price reached: +€500/MWh, lowest -€500/MWh



Daily maximum price — Daily minimum price (indicated in red when negative)

Source: EEX spot prices.

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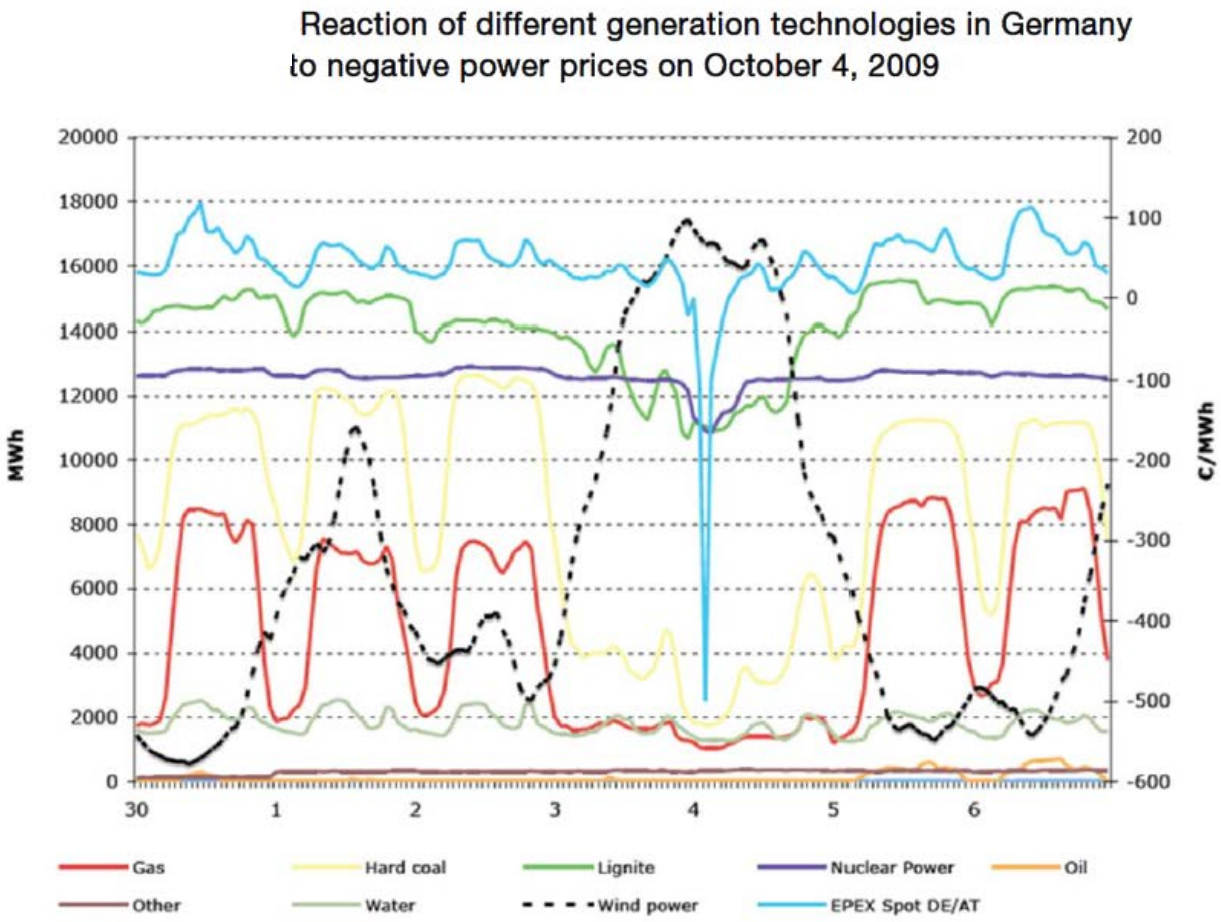
Negative Wholesale Electrivity Prices



Source: Vassilopoulos P. (2010) based on EEX Transparency and EPEX Spot data

Ref: F. Roques in “The crisis of the European Electricity System” – FR 2014

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EU's implementation – market issues

Negative prices in Belgium June 2013

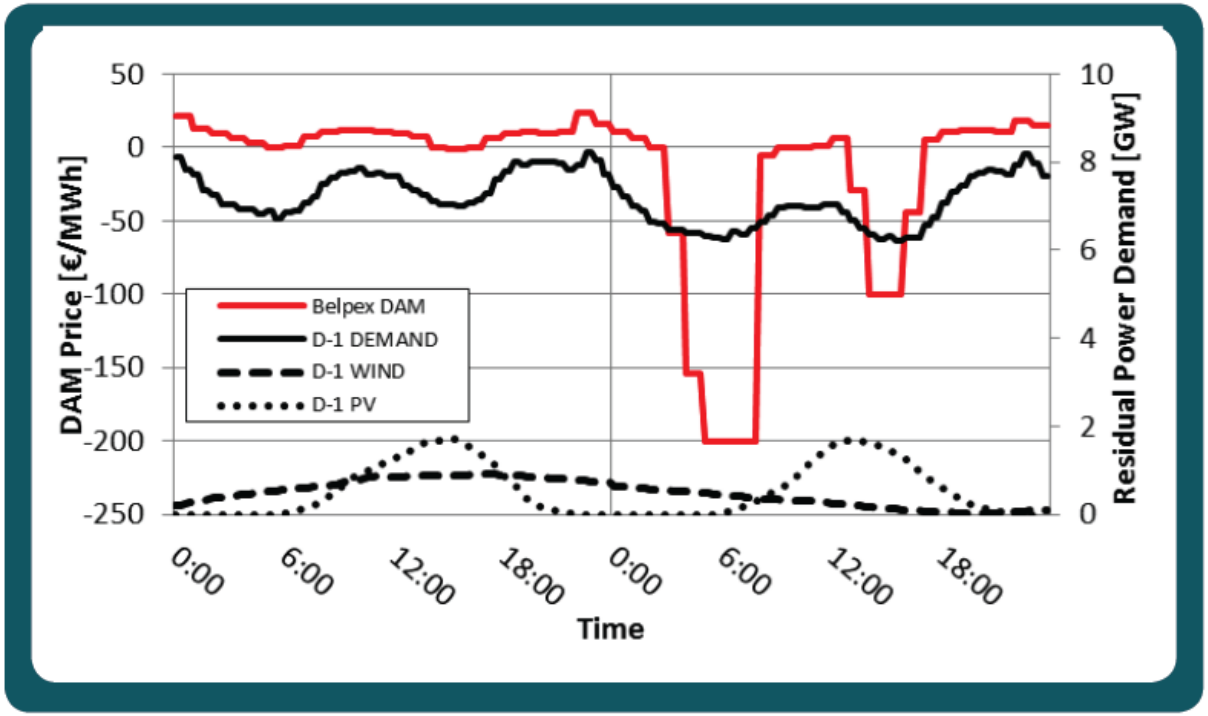

Figure 3: Belgian Day-Ahead Market Operation June 15-16 June 2013 (data: Elia System Operator and Belpex Power Exchange)

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EU's implementation – market issues

Belgium: the "missing money problem" + nuclear phase out

Recall:

→Risk: insufficient capacity (generation adequacy) to do the back up

- In case of shortage, peak prices would skyrocket!
- But peak prices not high enough to compensate "losses"
- Need for **capacity remuneration mechanisms?**

- In Belgium: combined with nuclear phase out...
- → "**Strategic Reserves**" (Plan Wathelet)

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Security of Electric Power Supply BE

Adequacy

- Components
  - Generation
  - Demand
  - Interconnection Capacity

Lessons Learned on Missing Money

- Generation adequacy at stress
  - Major decrease of flexible generation capacity
  - Uncertain generation from renewables

- Result:
  - High dependency on (uncertain) imports to meet peak demand
  - **Challenging integration of the growing share of renewables due to loss of flexible generation capacity**

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EU's implementation

Issues / challenges / problems in the EU market

- Technical challenges
- Market-integration problems
- Consequences for the CO_2 emissions
- End-electricity prices for end consumers

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A shared effort between sectors and MS

GHG Target:

-20% compared to 1990

-14% compared to 2005

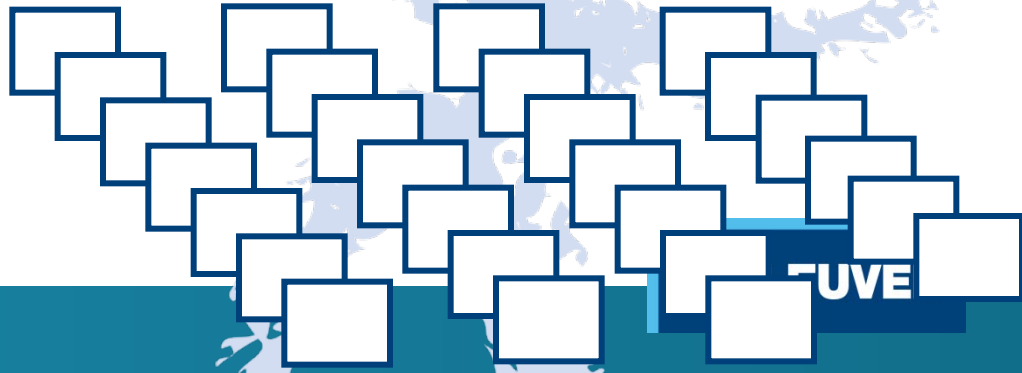
EU ETS

-21% compared to 2005

Non ETS sectors

-10% compared to 2005

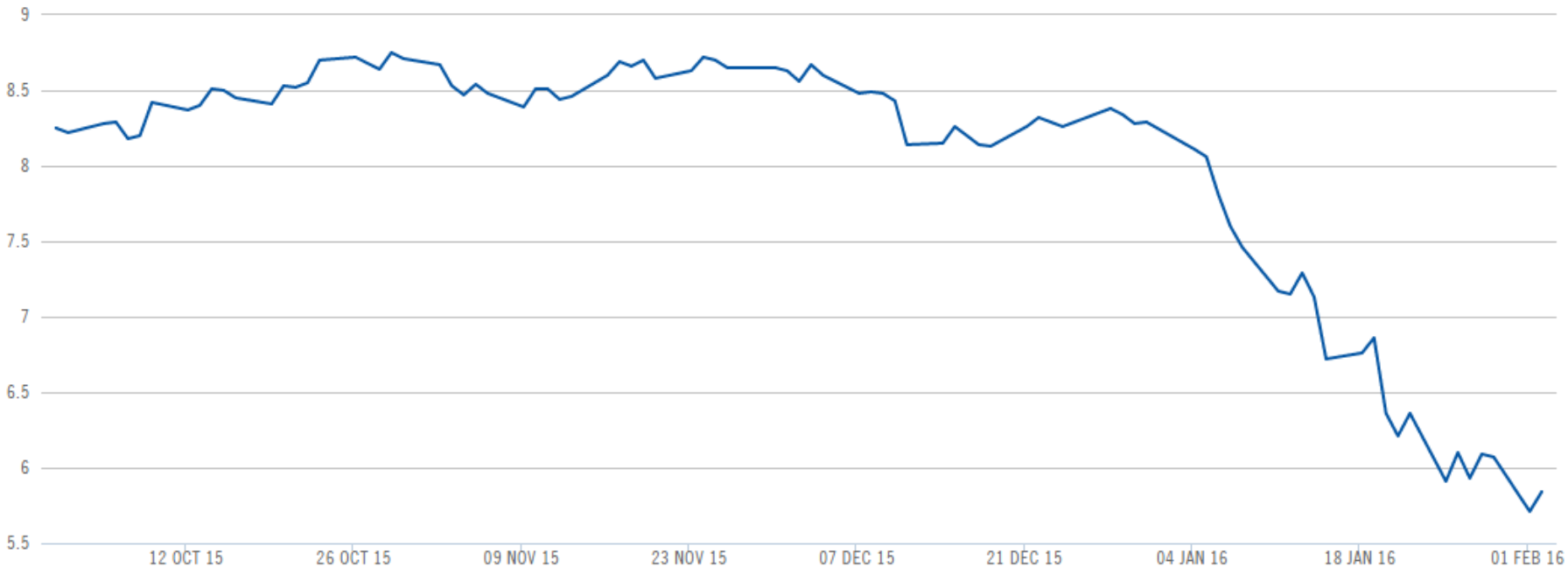
27 Member State targets, stretching from -20% to +20%



EU's implementation

Consequences for the CO_2 emissions

Third Phase ...Feb 2016 (latest)



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EU's implementation

Consequences for the CO_2 emissions

- Very low prices for CO_2 emission permits ("allowances")
- Due to
  - **economic crisis** (less CO_2 emissions) in 2008-2014
  - **"banking"** of allowances from phase 2
  - massive injection **RES** with priority access → reduces demand for fossil generation → reduces demand for CO_2 allowances → **lower CO_2 prices**

    *i.e., highly subsidized RES effectively **subsidize cheap coal** by keeping the CO_2 penalties low !!*

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EU's implementation

- Consequences of shale gas in US for CO_2 emissions in DE

- System effect due to low gas prices in USA – shale gas
- Gas extremely cheap in the USA

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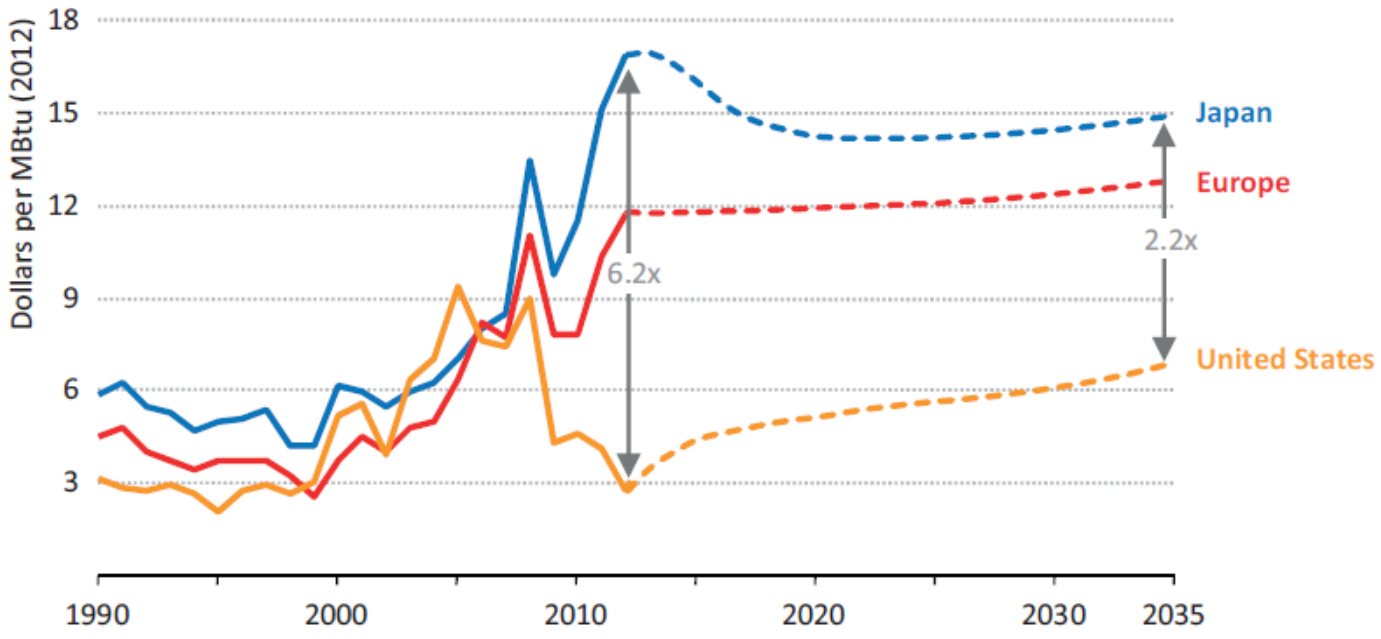
EU's implementation

Consequences of shale gas in US for CO_2 emissions in DE

Figure 1.3 ▷ Natural gas prices by region in the New Policies Scenario



IEA WEO November 2013

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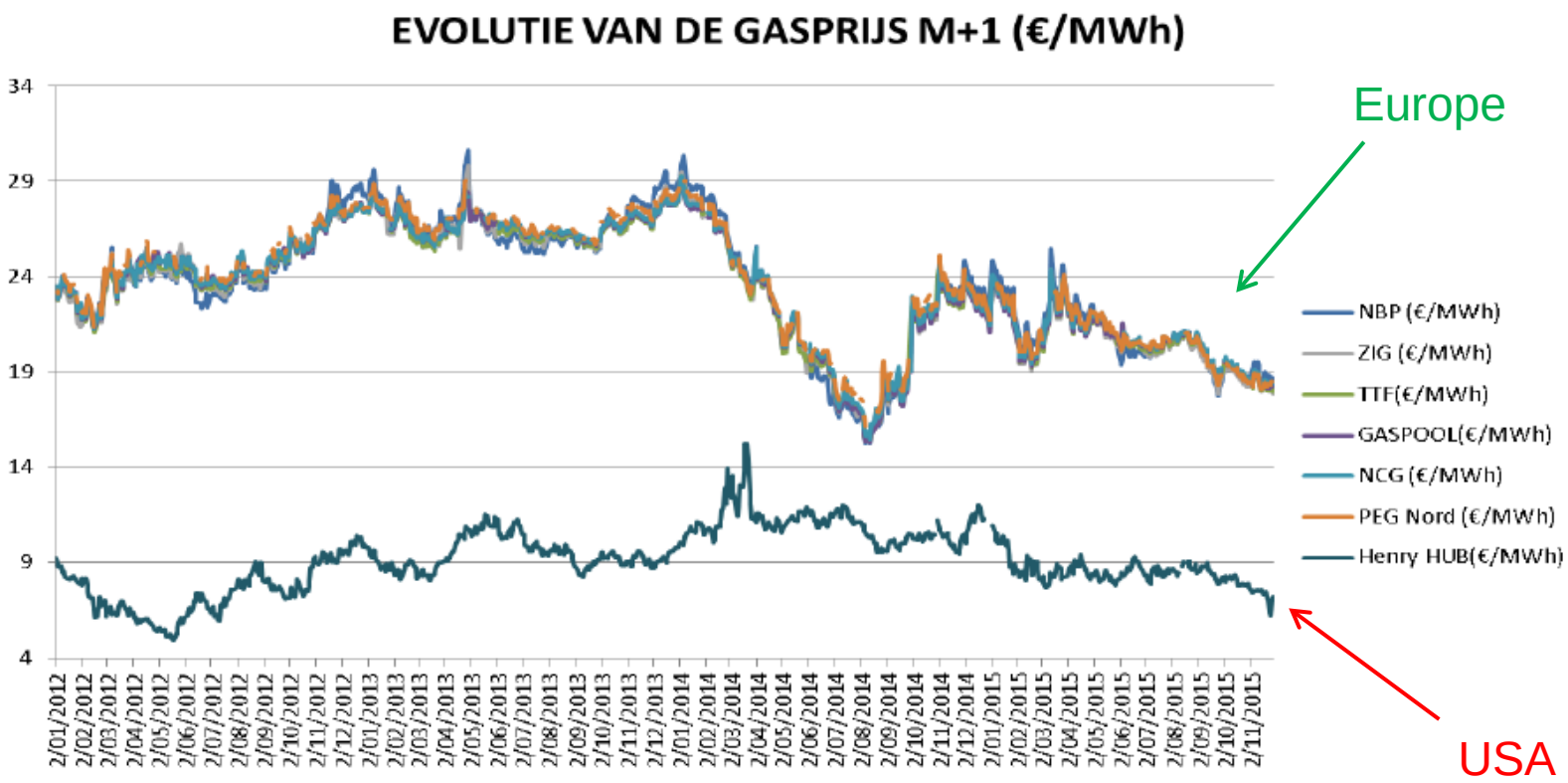
EU's implementation

Consequences of shale gas in US for CO_2 emissions in DE



Source: CREG, Dec 2015

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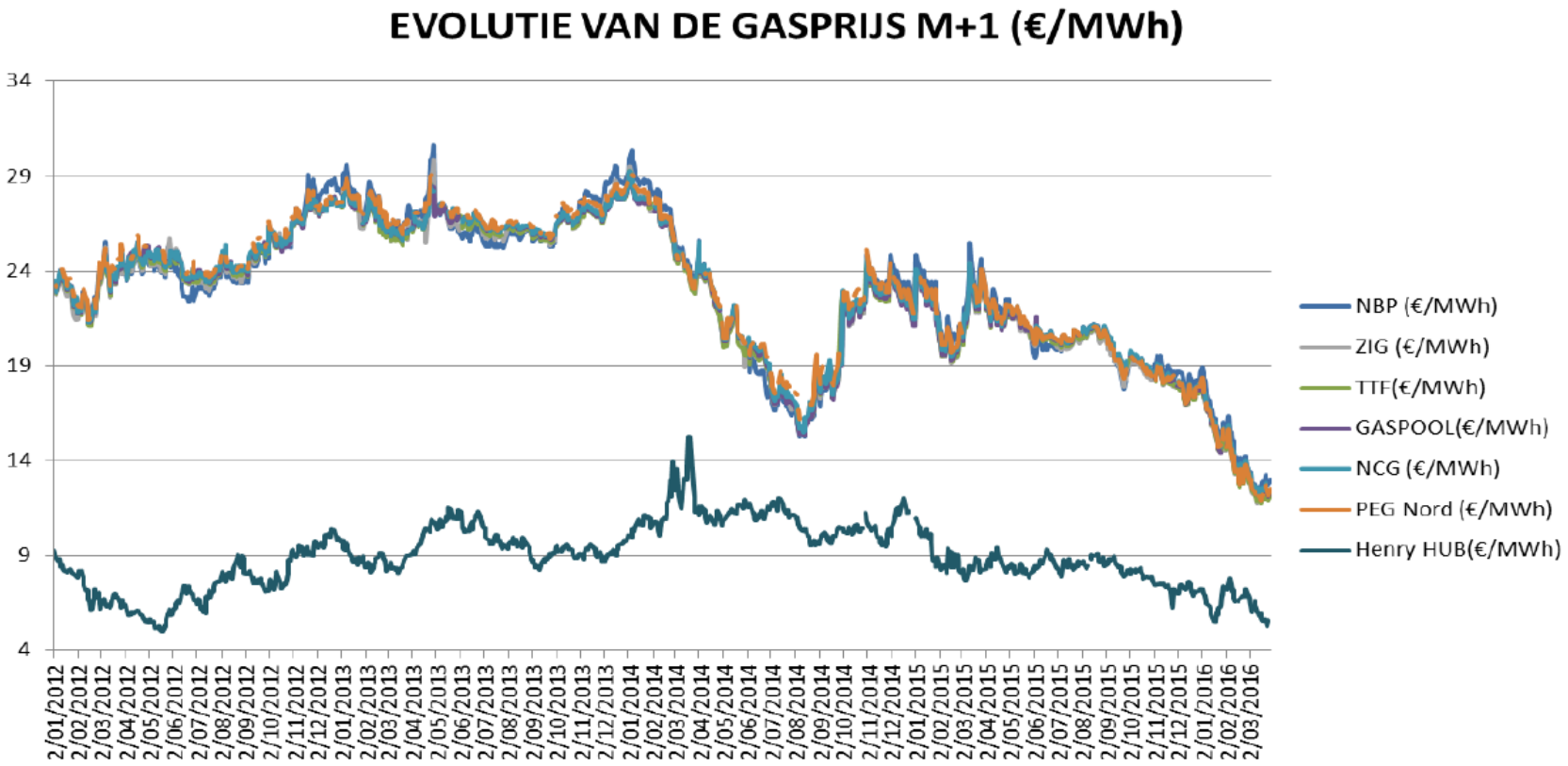
EU's implementation

Consequences of shale gas in US for CO_2 emissions in DE



Source: CREG, May 2016

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EU's implementation

Consequences of shale gas in US for CO_2 emissions in DE

- System effect due to low gas prices in USA – shale gas
- Gas extremely cheap in the USA
- Gas pushes coal out of merit order in USA
- US coal demand decreased
- Lower coal prices
- USA coal offered to world market ... shipped to Germany
- Cheap US coal used in German coal fired plants

→ CO_2 emissions electricity generation have gone up!

- But does not matter in EU since ETS, only price increase EUAs
- **In mean time: world emissions CO_2 up up up**

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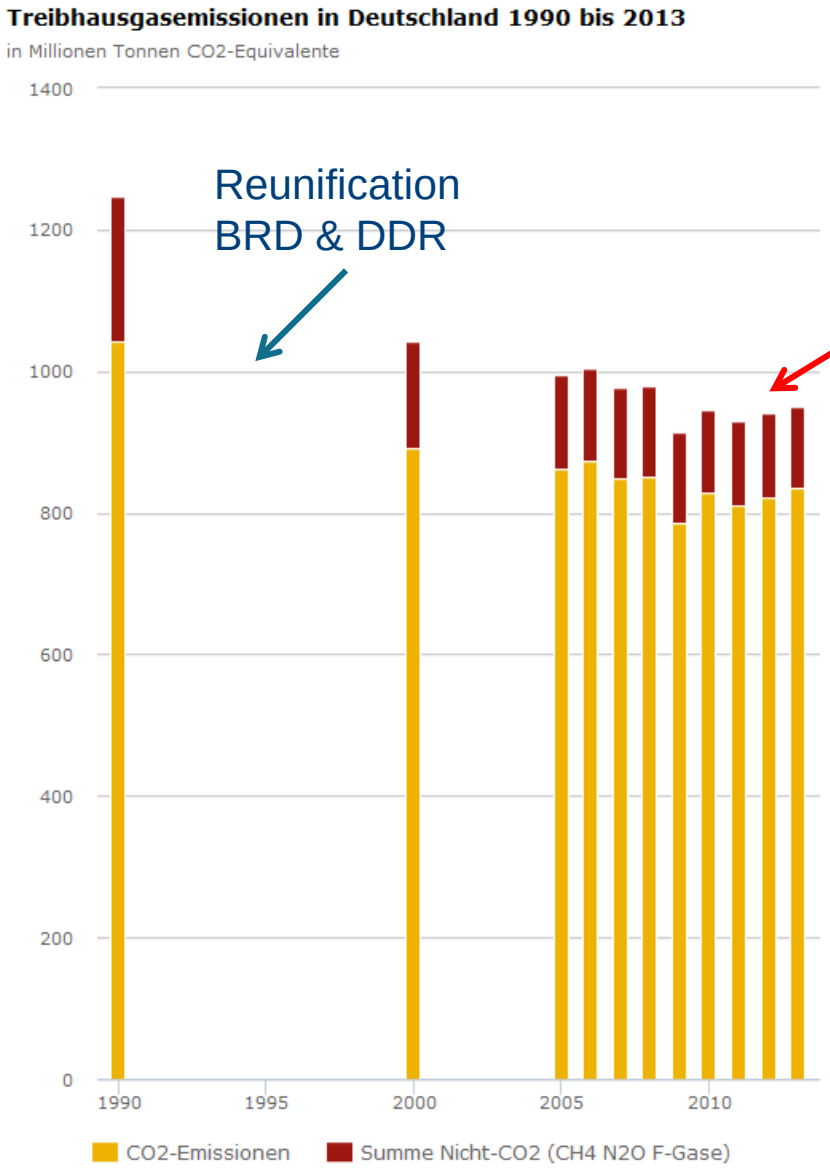
EU's implementation



CO_2 emissions Germany

(Ref. Der Speigel Energiewende)

Increase CO_2 emissions in DE !!

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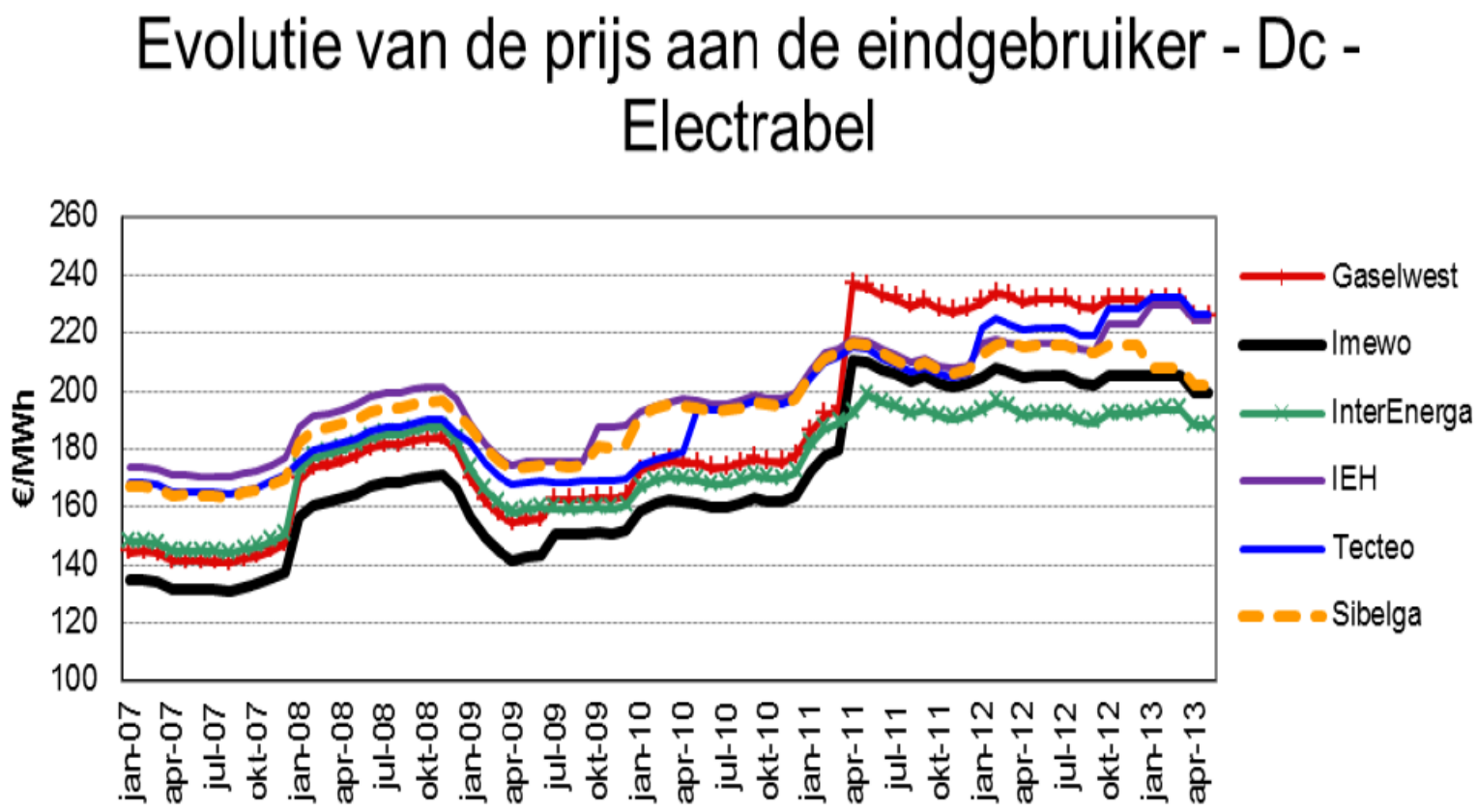
EU's implementation

Issues / challenges / problems in the EU market

- Technical challenges
- Market-integration problems
- Consequences for the CO_2 emissions
- End-electricity prices for end consumers

Decomposition of energy retail prices
Electricity

- Evolution of final price – domestic consumer



Source: CREG, 2013

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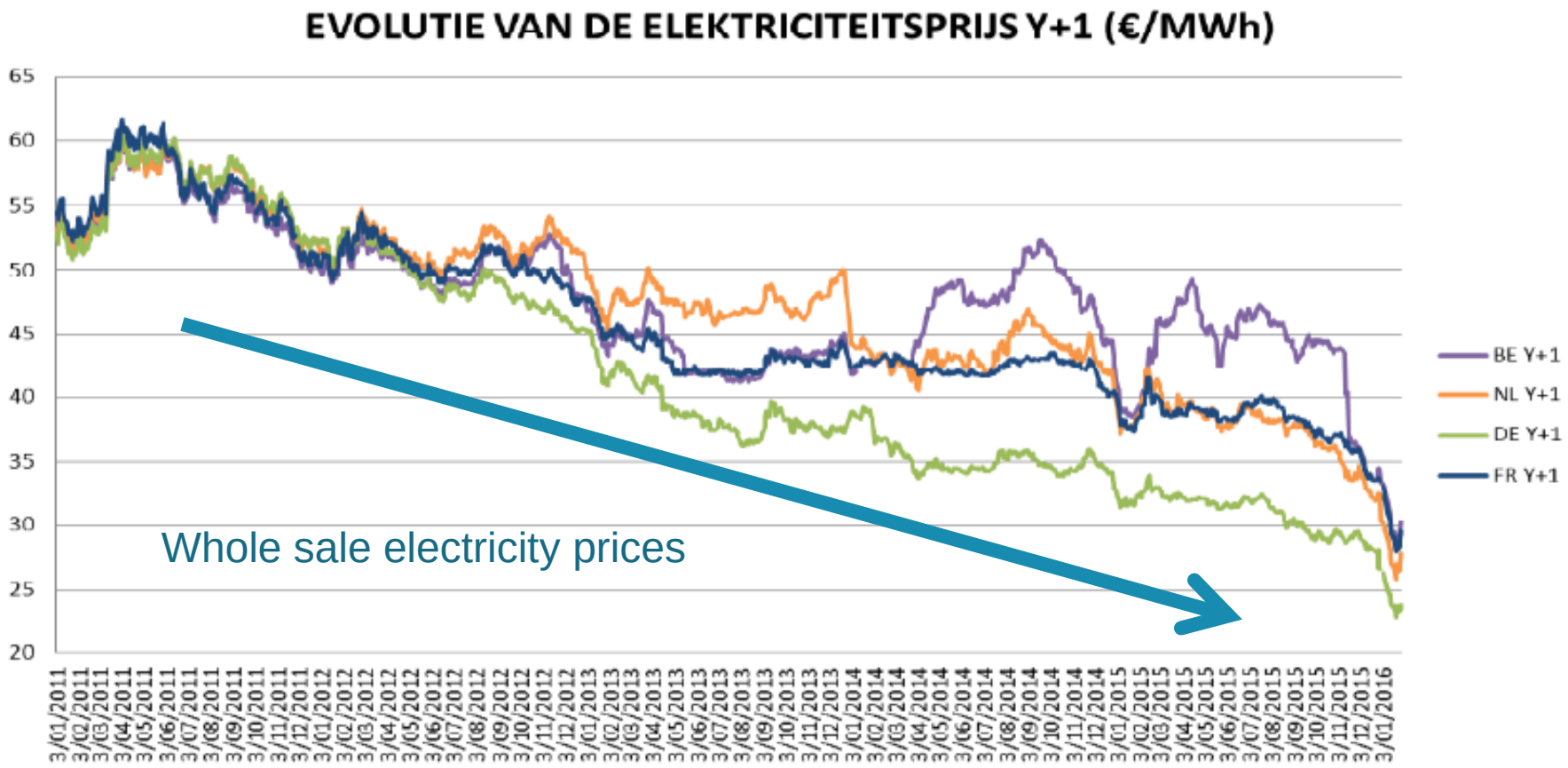
Example dichotomy electricity prices



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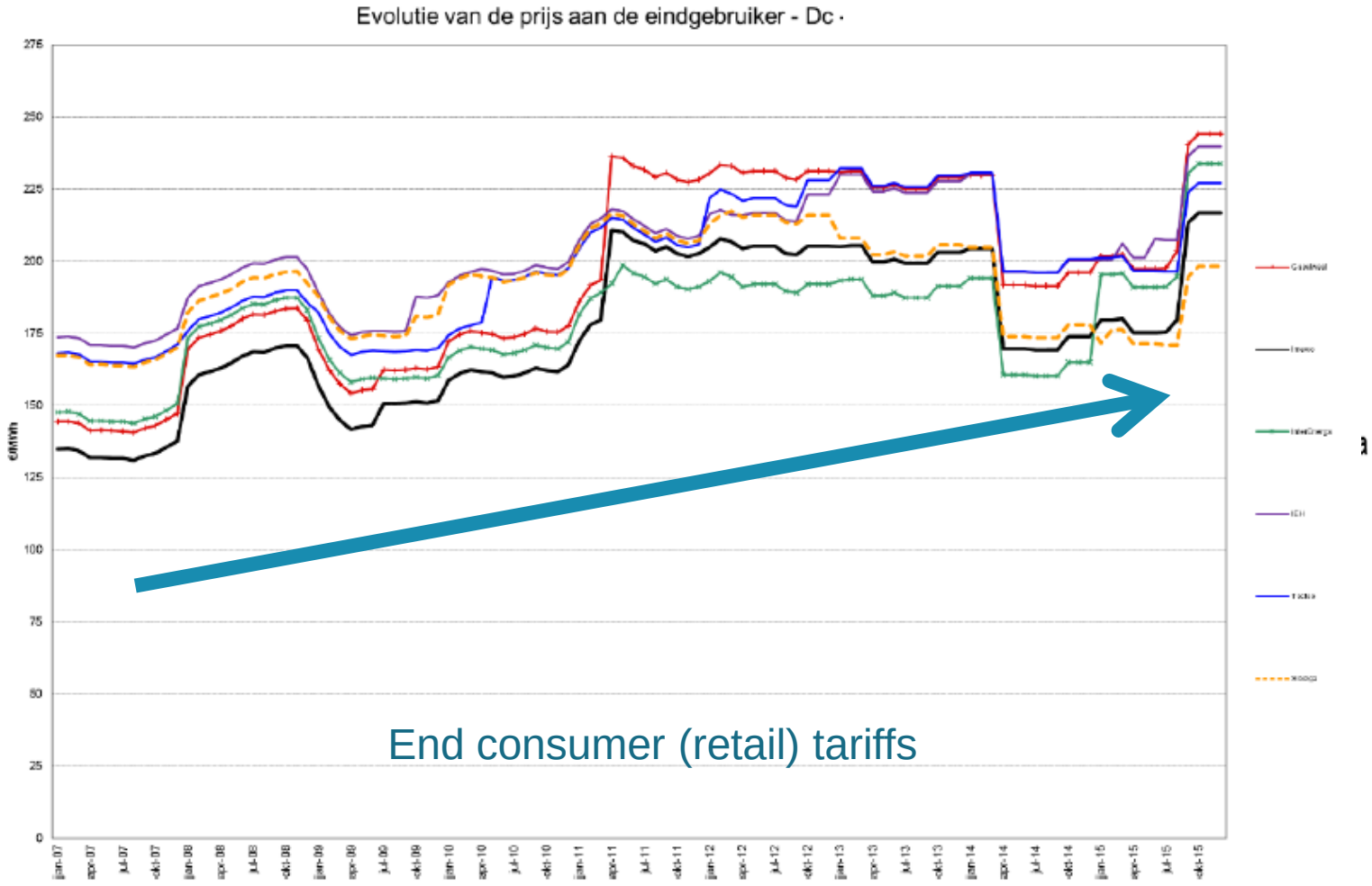
Example dichotomy electricity prices



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Far-Future Challenges

- Zero marginal cost → pricing?
- More RES piling up at same moment? Superfluous... Storage or ESI (heat, transport, P2fuel)
- Concern: more self consumption – emergency pricing?

Conclusions

- EU policy makers picture a rosy situation. But...
- European electricity system is in crisis
  - Many distortions
  - System cost grossly underestimated
  - To be paid for by consumers, tax payers or share holders (pension funds...)
- Energy issue is very complicated because interactions

  → more need to study the system effects
- Now, must keep all options open:
  - Need stable & simple regulatory environment
  - Give freedom to market players to provide services: ESCOs, Aggregators...
- Far future daunting challenges!

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