Gas to power for reliabiltiy, de-carbonization policy and market design

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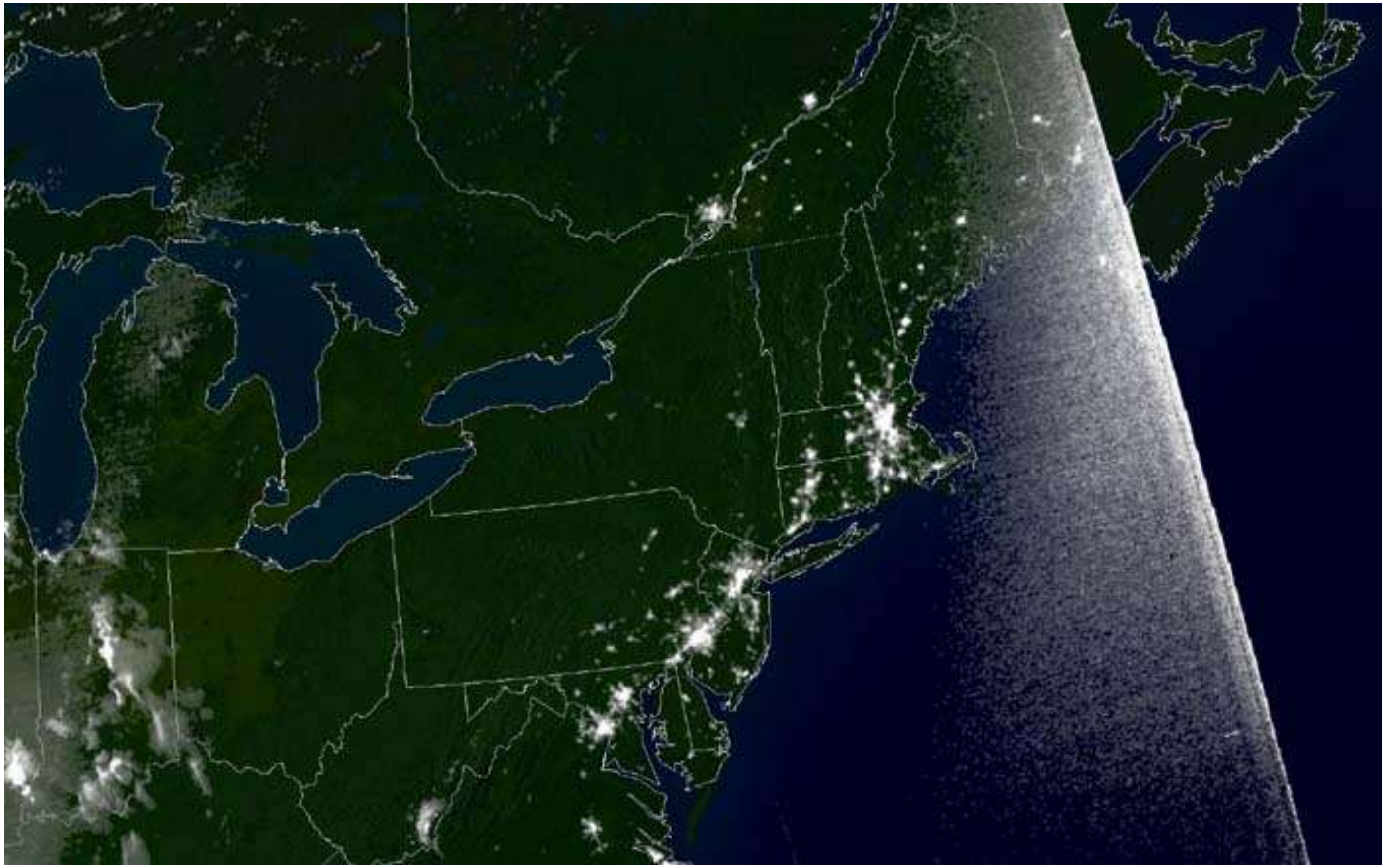
Ralf Dickel
Mobile: + 49 173 713 8976
e-mail: dickel.ralf@t-online.de

Skyline of Toronto Aug. 14, 2003

North East America night of Aug. 14, 2003



Some recent issues affecting reliability

Power capacity:

Germany: Reservekraftwerksverordnung: Cabinet on 27.6.2013

Valid until end 2017, ; look for alternatives as of 2015/16

ensure reliability of power supply, regular analysis by TSOs with BNetzA;

plant closures to be announced to BNetzA, closure can be stopped against cost payment

if needed new capacity can be auctioned under given rules

10 GW announced as of February 2014 for closure

Italy: 10 GW off the grid in 2014 ?

Belgium: unplanned maintenance of nuclear plant in winter 2013/14

UK: Effects of large combustion plant directive, old nuclear plants?

Grid issues:

Taking out nuclear in the south of Germany but also Fessenheim in F

Grid enlargement vs. new power capacity

Cross border flows:

Coal fired power and renewable power from Germanydisplacing other power generation in neighbouring countries (gas in NL)

Effects on GHG emissions

Gas to power, what for? how can it work?

Gas for power to contribute to
- **Reliability of power supply**
- **De-carbonization**

Public goods driven by policy objectives => need policy decisions by public institutions on instrument mix
=> Electricity markets are always political
=> Gas to power: moving from non political burner tip competition to highly political bus bar competition

Reliability:

Concept of VOLL vs. n-1 concept
What role of gas fired power for reliable power supply ?
In general: what market design to ensure reliable power ?

De-carbonization

fuel switch from coal to gas can be a substantial contribution to de-carbonization
an issue of merit order coal vs. gas: coal price to stay low => a political decision on the role of coal vs gas

Reliability

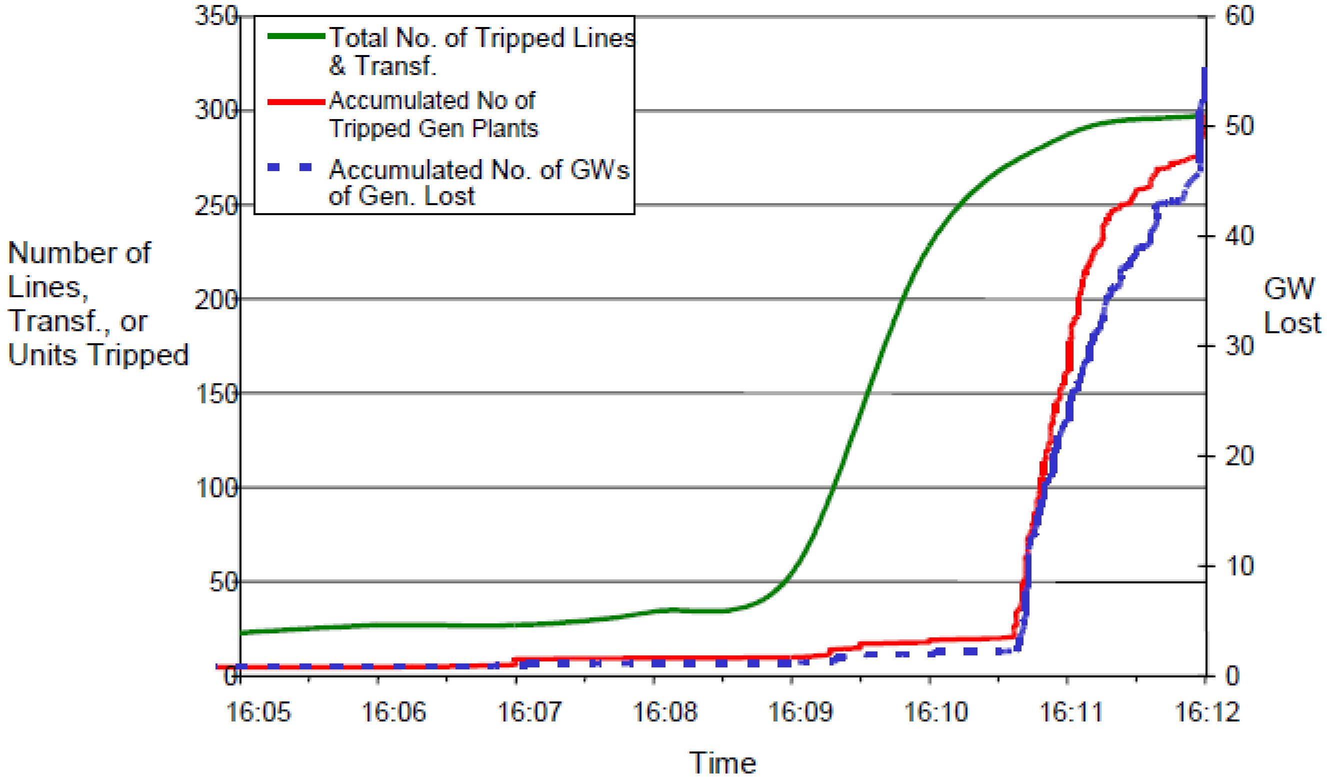
Black outs to remember

France 19 December 1978:	45 Mill. Persons
California 2000/01:	several black outs, PG&E bankrupt
North America 14 August 2003:	50 Mill. Persons
Italy 28 September 2003:	55 Mill. Persons
EU 4 November 2006:	10 Mill. Persons

Learning from California

April 1998	Spot market begins operation
May 2000	Significant rise in energy prices
June 2000	Black outs in San Francisco (100 000)
August 2000	San Diego G&E Comp alleges manipulation
Jan. 17-18. 2001	Black outs affect several 100 000
Jan 17 2001	Governor Davis declares state of emergency
March 19-20, 2001	Black outs affect 1.5 Million customers
April 2001	Pacific Gas & Electric files for bankruptcy
May 7-8, 2001	Black outs affecting 170 000
September 2001	Energy prices normalize
December 2001	ENRON bankrupt, allegations of manipulations
November 13, 2003	Governor Davis ends state of emergency

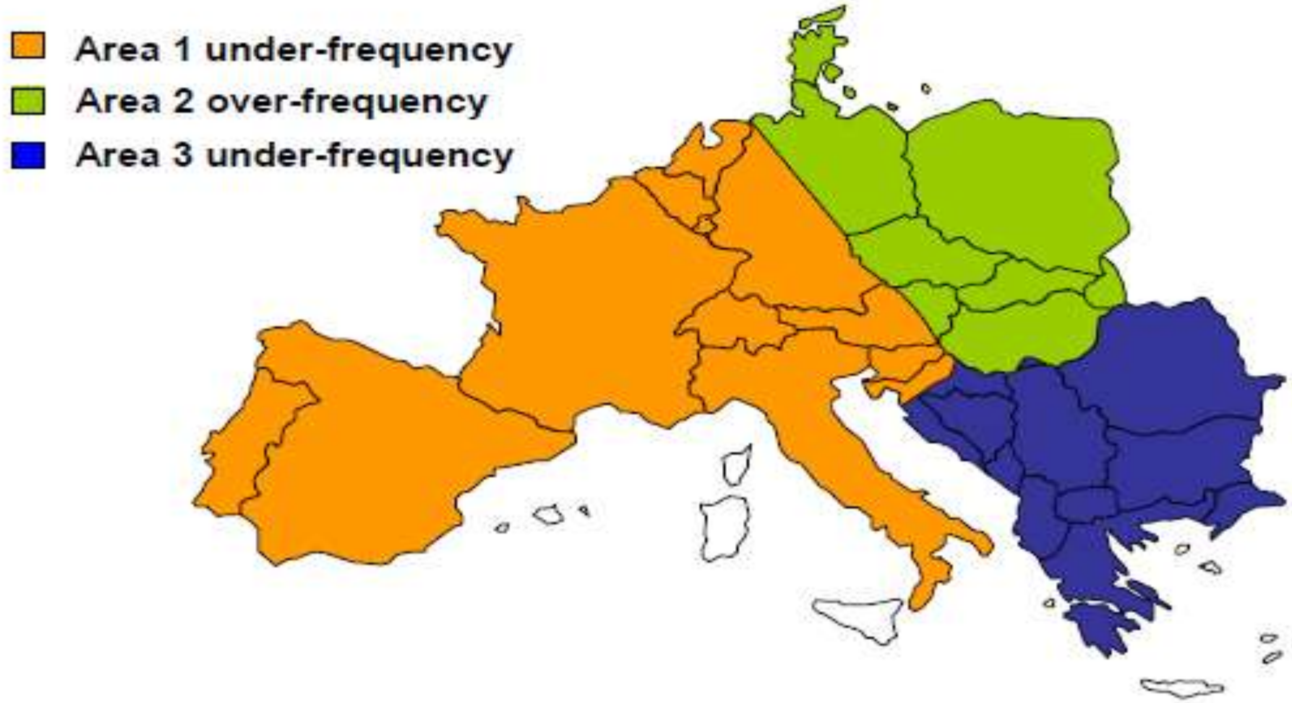
Accumulated line and generator trips during the cascade



Source :NERC: Technical Analysis of the August 14, 2003 Black out, July 2004

Black out in UCTE of 4 November 2006

- Manual disconnection of the line Conneforde-Diele
- Tripping lines of neighbouring TSOs
- Splitting of the whole UCTE system into 3 zones



Black out in UCTE of 4 November 2006

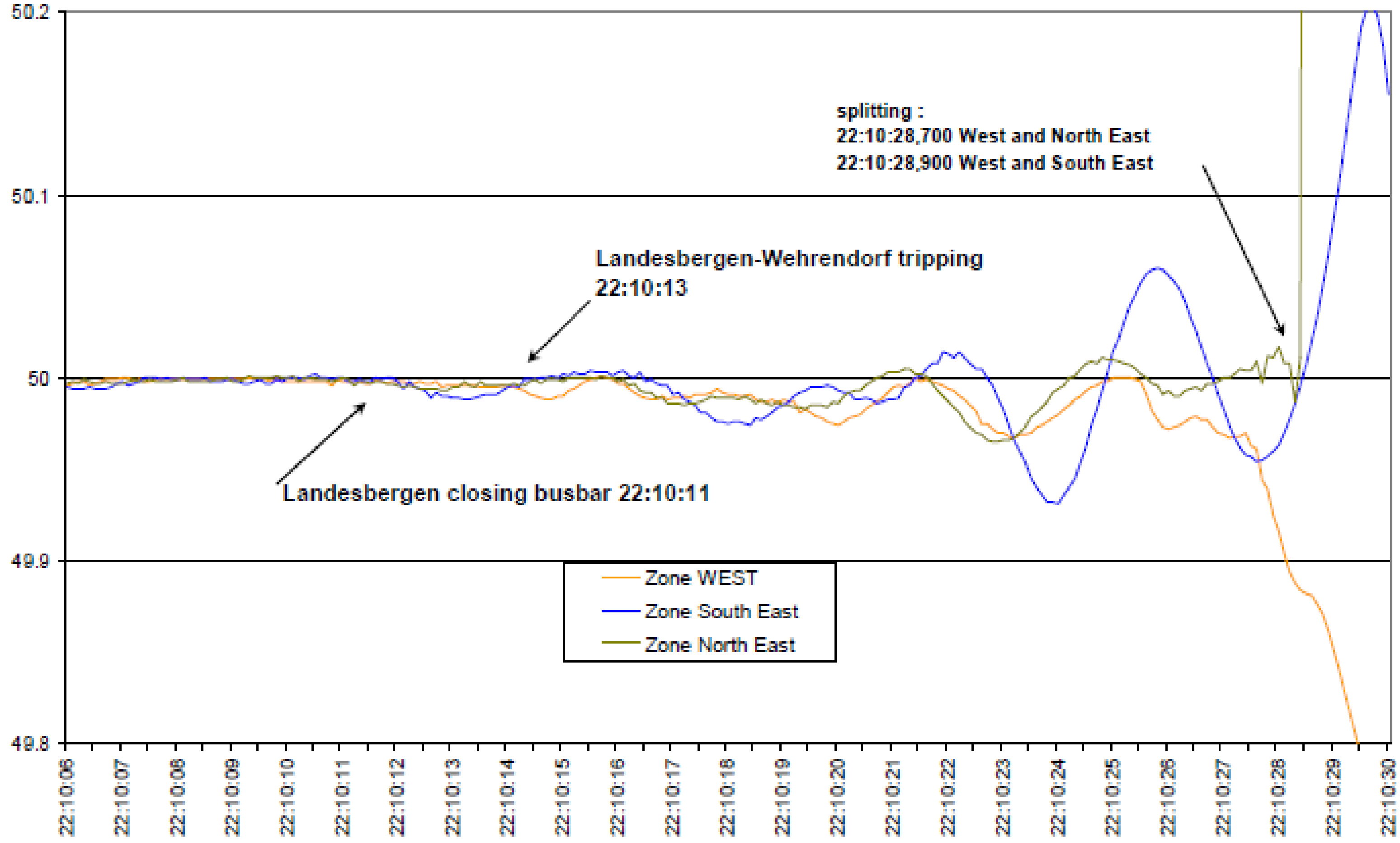


Figure 5: Frequency recordings until area splitting

Figure 6 is presenting frequency recordings as retrieved by Wide Area Measurement Systems (WAMS) in the three areas from 22:09:30 to 22:20:00

Reliability of power supply

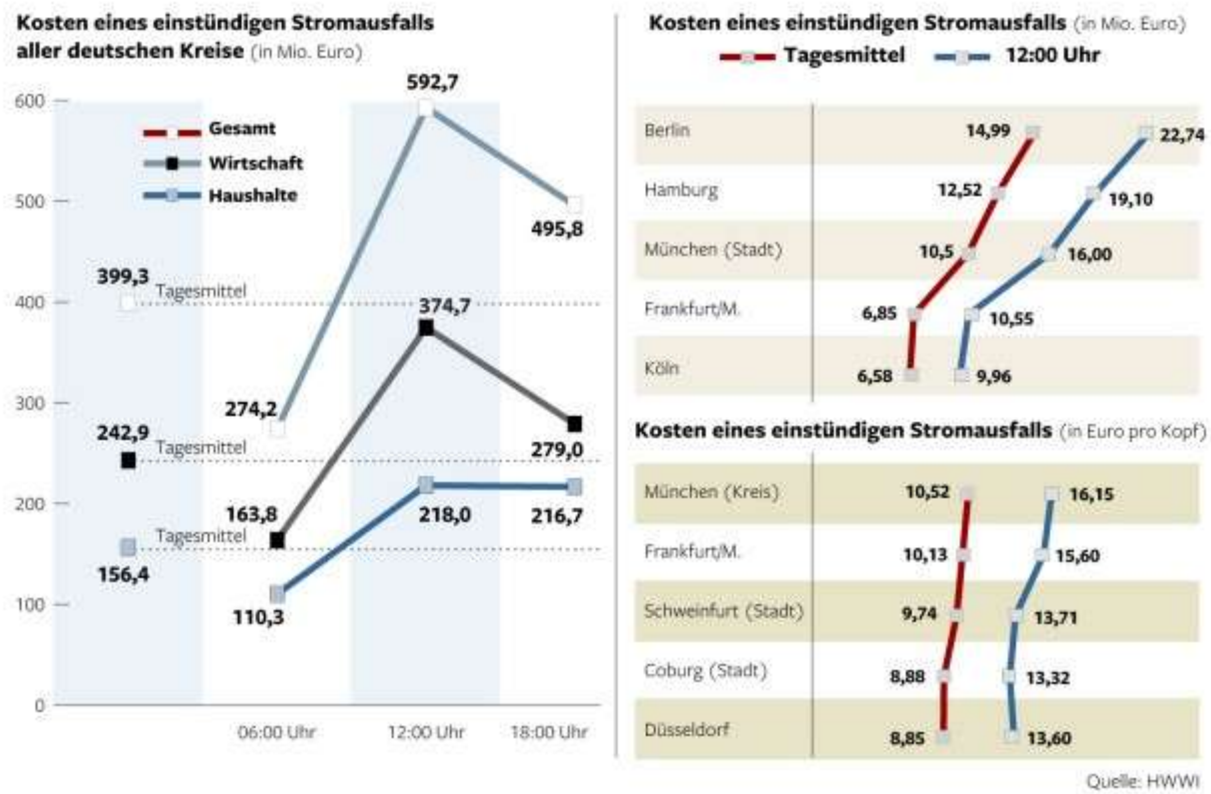
A very technical issue

Two economic approaches:

- Accept the consequences of black outs (VOLL of spontaneous black out and / or rolling black outs) and resulting damages

- If not define and implement reliability => n-1 concept

Costs of a black out in Germany



Source : Report by HWWI as quoted by Die Welt of 28.10.2013

Consequences of loss of power

- No light, no cooling, no heating / warm water
- No traffic; gas stations do not work
- Communication does not work
- Lack of water supply => hygienic problems
- No teller machines, restricted money supply
- Handling of cattle (e.g. milking)=> epidemics
- Fuel for reserve power for critical infrastructure?

Reliability of power supply, n-1 concept

Enough redundancy, which can be mobilized:

i.e. enough capacity at any time to meet demand AND load following (dispatchable) capability to cover variations of supply/ demand (and grid to handle it, and communication capability)

usually gas fired capacity a crucial part of overall capacity installed

- availability of gas for power a question of enough pressure at the plant entry , not of classic security of supply
- on load following : gas fired power has no relevant advantage over other thermal power

=> incentives to maintain and if necessary invest into enough dispatchable power

=> how to recoup full costs (inclusive of adequate profit) ?

=> market design for power?

relevance for gas: maintaining gas fired capacity (and keep a role for gas in power open) BUT this is not creating demand for gas, nor having a GHG effect

Available capacity /reserve margins Germany 2013 (GW)

Peak demand	83
Available dispatchable conventional generation	100
Import capacity, onshore wind	1
Unavailable due to maintenance etc.	8
⇒ Reserve margin	10

Dispatchable capacity:	
Nuclear	12
Gas fired	19
Oil / several energy sources	3/15
Coal / lignite	20/18
Pump storage (for 40 GWh)	9
Hydro / run of river	5
Biomass	6
Intermittent capacity:	
PV	33
Wind	30

Source: IEA Germany 2013 review

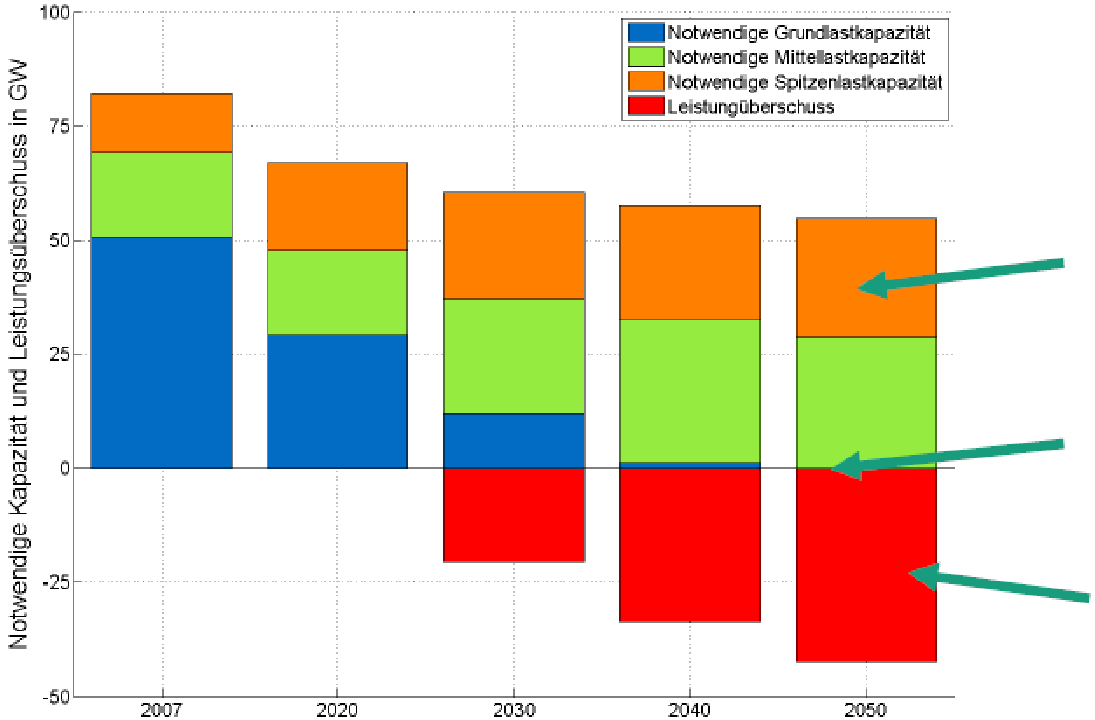
Power plants announced for closure to BNetzA (MW)

	RWE	E.on	EnBW	Other	total
Gas	1775	1037	0	2071,5	4883,5
Fuel/gas oil	772	0	424,4	266	1462,4
coal	1711	0	244	1466	3421
other	0	0	0	198	198
total	4258	1037	668,4	4001,5	9964,9

Source: BNetzA KWSAL, as of 4.2.2014

Surplus renewable power,
need for conventional capacity for load management

Benötigter Bedarf an konventioneller Leistung und EE-Überschüsse



- Hoher Spitzen-lastbedarf (25 GW)
- Grundlast „verschwindet“
- Starke Fluktuationen der Überschüsse (40 GW)

Herausforderung: Überschüsse mit Spitzenbedarf übereinbringen

Quelle: Sterner et al., 2010

Fraunhofer IWES

All thermal power plants suitable for load management

Das Potential der heutigen thermischen Kraftwerke

Kraftwerkstyp		Steinkohle	Braunkohle	Gas- und Dampfkraft-werk (GuD)	Gasturbine solo
Lastgradient	$\%P_N$/min	1,5 / <u>4</u> / 6	1 / <u>2,5</u> / 4	2 / <u>4</u> / 8	8 / <u>12</u> / 15
im Bereich	$\%P_N$	40 – 90	50 - 90	40*) - 90	40*) - 90
Minimallast	$\%P_N$	40 / <u>25</u> / 20	60 / <u>50</u> / 40	50 / <u>40</u> / 30	50 / <u>40</u> / 20
Anfahrzeiten:					
Heiß (< 8 h)	h	3 / <u>2,5</u> / 2	6 / <u>4</u> / 2	1,5 / <u>1</u> / 0,5	< 0,1
Kalt (> 48 h)	h	10 / <u>5</u> / 4	10 / <u>8</u> / 6	4 / <u>3</u> / 2	< 0,1

Lesehinweis: heute üblich / <u>Stand der Technik</u> / Optimierungspotential

Anforderungen:

- **Niedrige Minimallast**
- **Hohe Lastgradienten**
- **Kurze Anfahrzeiten**

- Alle thermischen Kraftwerke sind grundsätzlich geeignet zur Lösung der zukünftigen Aufgaben beizutragen

Quelle VDE-Studie 2012: Erneuerbare Energie braucht flexible Kraftwerke

ABB

Translation:

Kraftwerkstyp /Steinkohle / Braunkohle / GuD /Gasturbine solo = Type of power plant / hard coal / lignite / CCGT / turbine alone

Lastgradient / im bereich /Minimallast / Anfahrzeiten / Heiß /Kalt = Capacity gradient / within range / minimal load / start up time / hot / cold

Lesehinweis: heute üblich / <u>Stand der technik /</u> Optimierungspotential = How to read: today´s standard / <u>state of the art</u> / potential optimization

Anforderungen: / Niedriege Minimallast/ Hohe Lastgradieneten / Kurze Anfahrzeiten = Requirements: low minimal load / high capacity gradient / short start up time

The role of gas for reliability

- De facto: existing gas fired capacity important for the capacity balance
- Taking any large amount of capacity out creates deficits violating the n-1 criterion
- Gas turbines quick starter but still slow for emergencies
- No special role of CCGTs in load following
- Linking risks of gas and power grid: an issue of pressure
- For gas to play a role, there must be gas fired capacity (earning full costs) => power sector design matters

Reliability: What design of power sector?

- **In the past: Regional integration**
- **Now energy only market**
- **The future: capacity mechanisms / markets**?

Power sector design: Regional integration

Regional regulated monopolies worked reliably:

- short term optimization by merit order
- long term investment (grid and capacity) optimized according to companies investment criteria
- recuperation of full costs via regulation or contestable pricing
- Customer protection via regulated tariffs for captive customers and via contestability for large customers

⇒ A tendency for higher cost recovery

⇒ Higher dividend or some overinvestment (in reliability of supply, or in higher dividend)

With reliability back on the agenda (lack of investment and renewables):

Re-integration via TSOs / regulator with command of grid and dispatchable (reserve) power

Less and less elements left to the market

Power sector design: Questions on the energy only market

-What protection of inelastic demand ?

-How to recoup fixed costs? If not: model not sustainable

Full costs from scarcity rents? Maybe with a VOLL concept, but hardly with an n-1 reliability concept : From the differential to marginal costs of next plants in the merit order? Reserve unit will limit scarcity rent.

-How to prevent gaming? By threat of competition authority? Force to bid in? Maintenance and repair?

-Incentives for new / adequate investment? What if they do not work (e.g. UK) ?

-Why making fixed costs a gamble for commercial success and power reliability?

Power sector design:
Questions on capacity mechanism/ markets

-Must be coherent across neighbouring markets / EU and with other power markets (futures etc.) (California lesson)

-Price for written off vs new investment (golden end problem) ?

-How to define demand for reliable capacity (public good) by the market? How to avoid free rider effect? Bottom up approach: In practice cutting off customers without booked capacity? How to allocate (force majeure)lack of capacity?

-Any supply of capacity short of the total capacity needed: zero value to avoid spontaneous black outs; ok for defining rolling black outs

De -carbonization

Carbon price and merit order

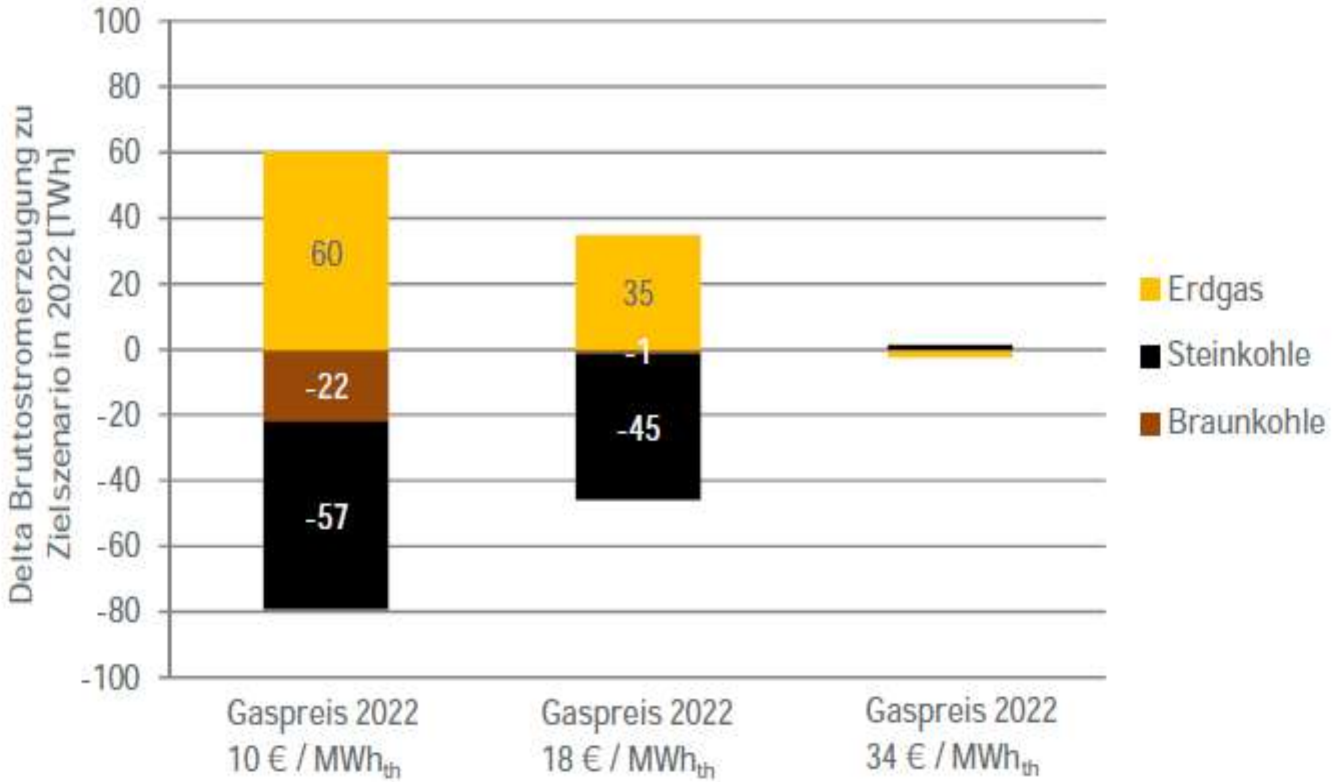
- Very little effect as long as short of fuel switching
- Effects within fuel:
  - Merit order given by fuel efficiency driven by variable costs i.e. costs of fuel which are inverse proportionate to efficiency
  - Pricing carbon does not change the merit order within a fuel
- Fuel switching:
  - Threshold price level
  - Change in CO2 emissions happens with fuel switching (ex US, UK)
  - Immediate fuel switching possibilities given by existing coal/gas power capacity
- Electricity saving: Rather driven by overall price level for final consumers having major other components (taxes etc)
- Dilemma: low Carbon prices have little effect, high carbon prices drive out the non power industry

Price of carbon to make power from CCGT competitive as a function of gas price at 100$/t coal

Gas Price	Carbon Price needed
($/MMBTU)	(€/tCO2)
5	-0,23
6	10,66
7	21,55
8	32,44
9	43,34
10	54,23
11	65,12
12	76,01

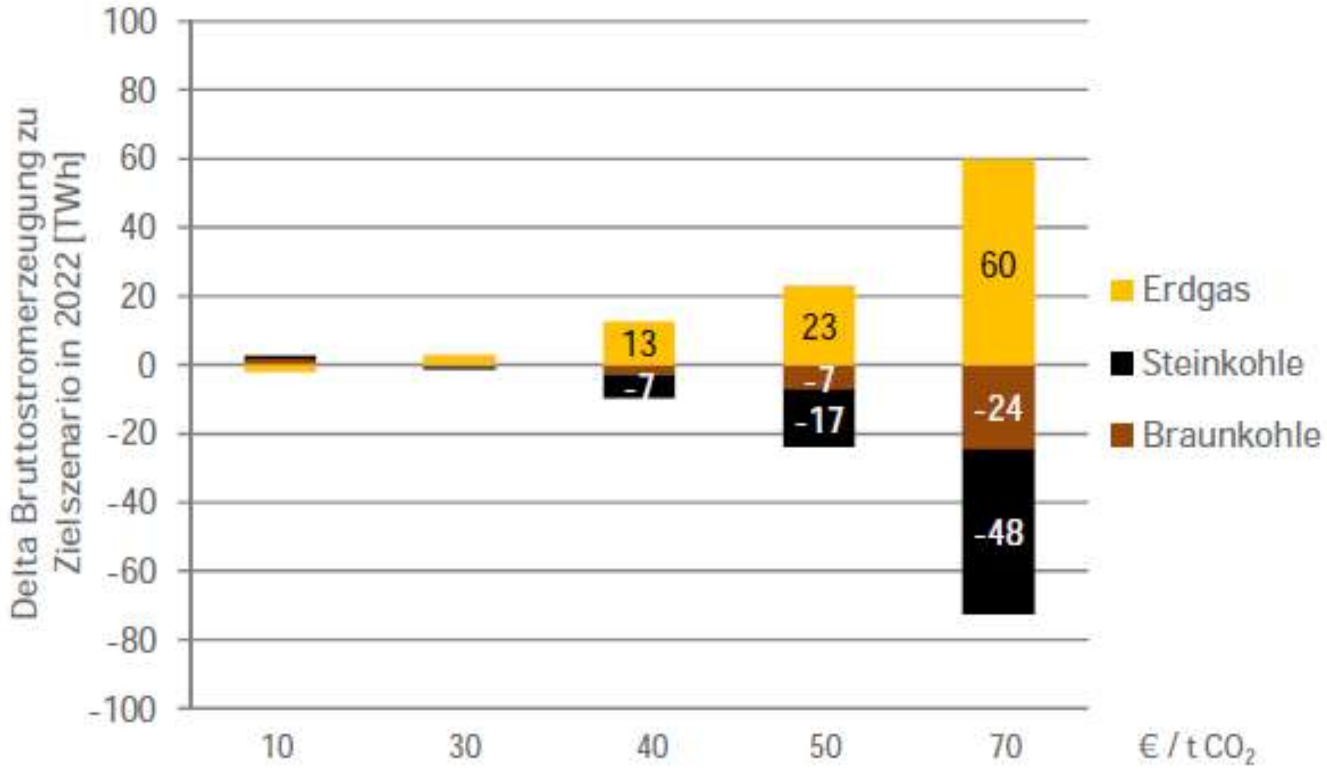
based on coal price 100$/t ; €=1,30$; CO_2 emission factors ; gas: 55tCO_2/TJ coal:92tCO_2/TJ; electric efficiency coal: 0,43 gas: 0,57 , extra op costs coal:0,15 cts/kWh

Power generation as a function of gas price



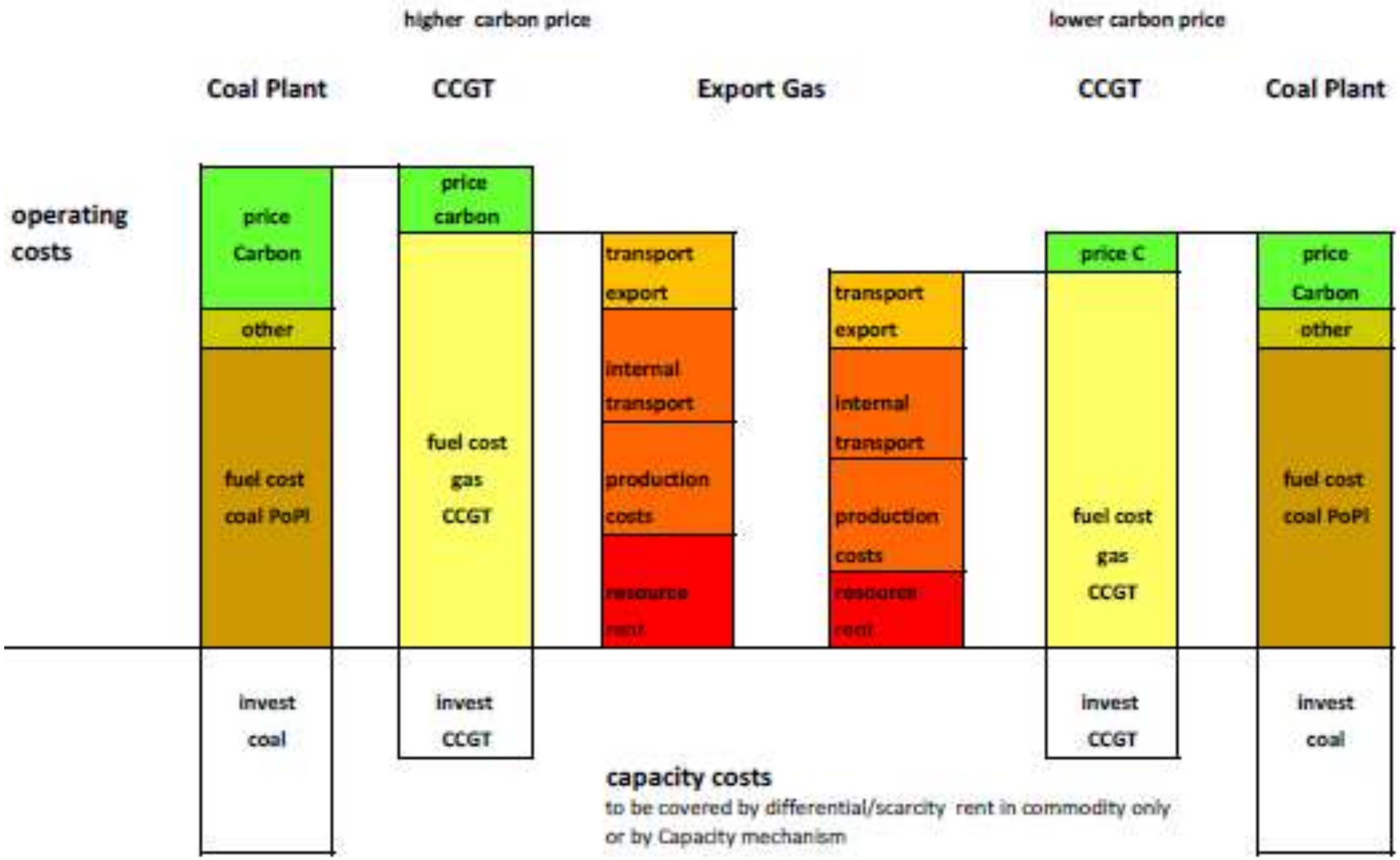
Source . EWI 2013: Trendstudie Strom 2022

Power generation as a function of CO_2 price



Source . EWI 2013: Trendstudie Strom 2022

Carbon Price and Resource Rent



Why US Sulphur cap and trade works

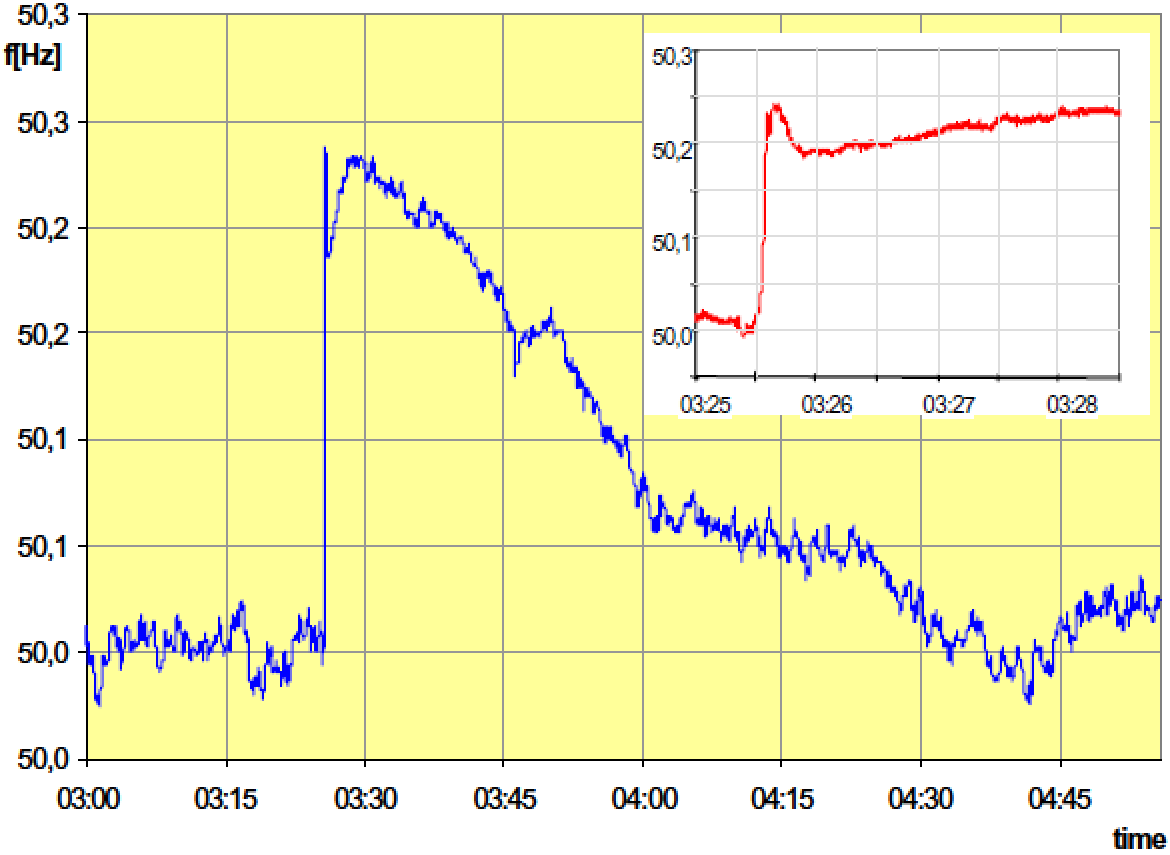
- Applicable to only one sector (power)
- Instruments to meet Sulphur emission levels at calculable costs:
  - use low sulphur coal from Wyoming
  - use more natural gas
  - invest in de-sulfurization of power plants
- Limits set as a trade off between local externalities and economic costs (cost-benefit to economy close to 0)
- Sulphur not an essential part of the process, de-sulfurisation not critical to overall economy

Using gas for de-carbonization in power

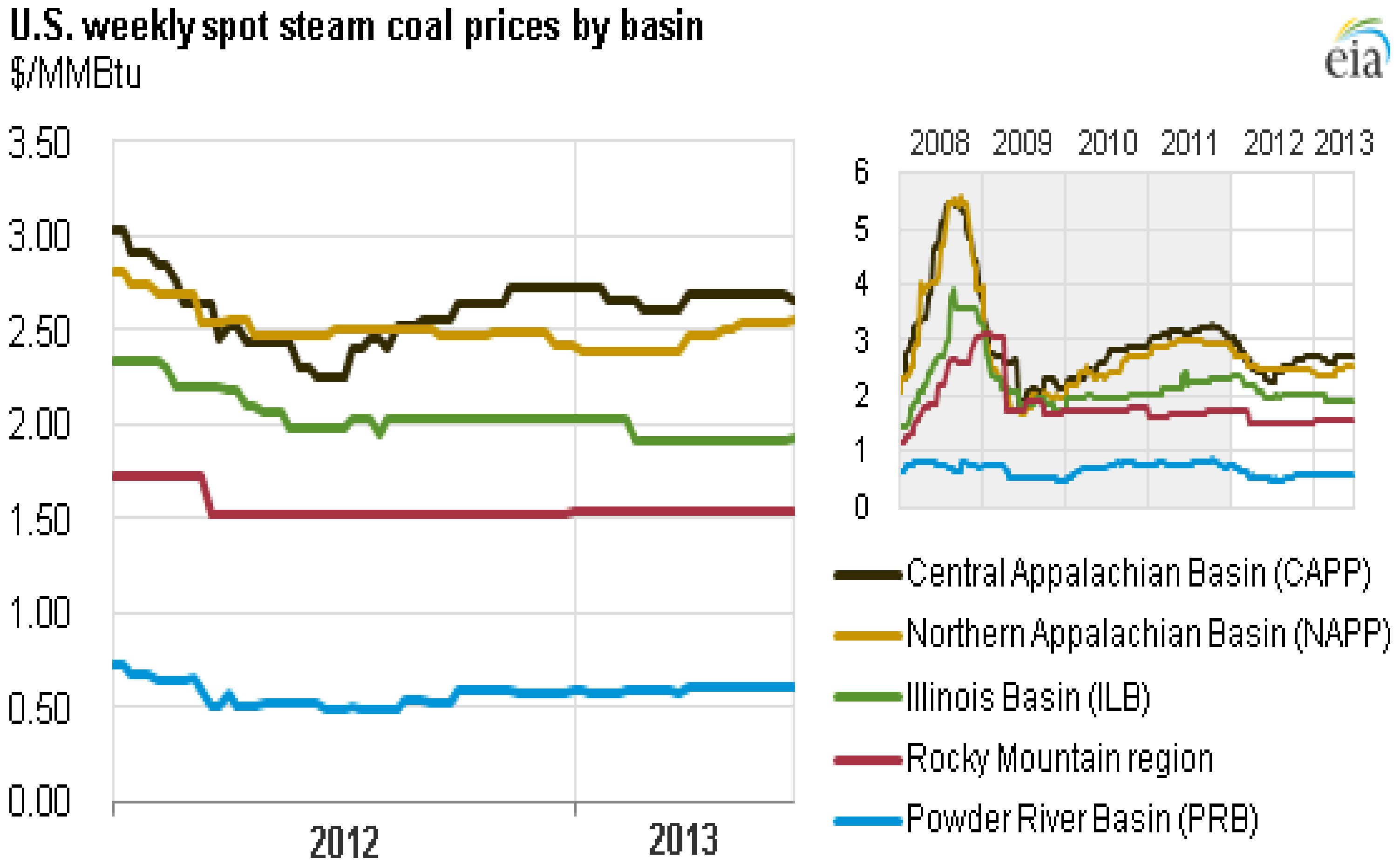
- A question of volumes, not capacity per se
- Needs gas fired capacity which can be used
- Could be interruptible basis (no security of supply issue)
- Defined by merit order vs coal, lignite
- **An issue of political will to favour gas over coal** for GHG reasons: Merit order could be changed various instruments:
  - Power specific CO_2 regime
  - Coal specific CO_2 volume restrictions
  - Coal specific taxation (maybe with phase out aids for EU coal producers)
  - Emission standards like proposed by EPA
- What would make (interruptible) gas sales to power attractive for gas producers?

Reserve charts

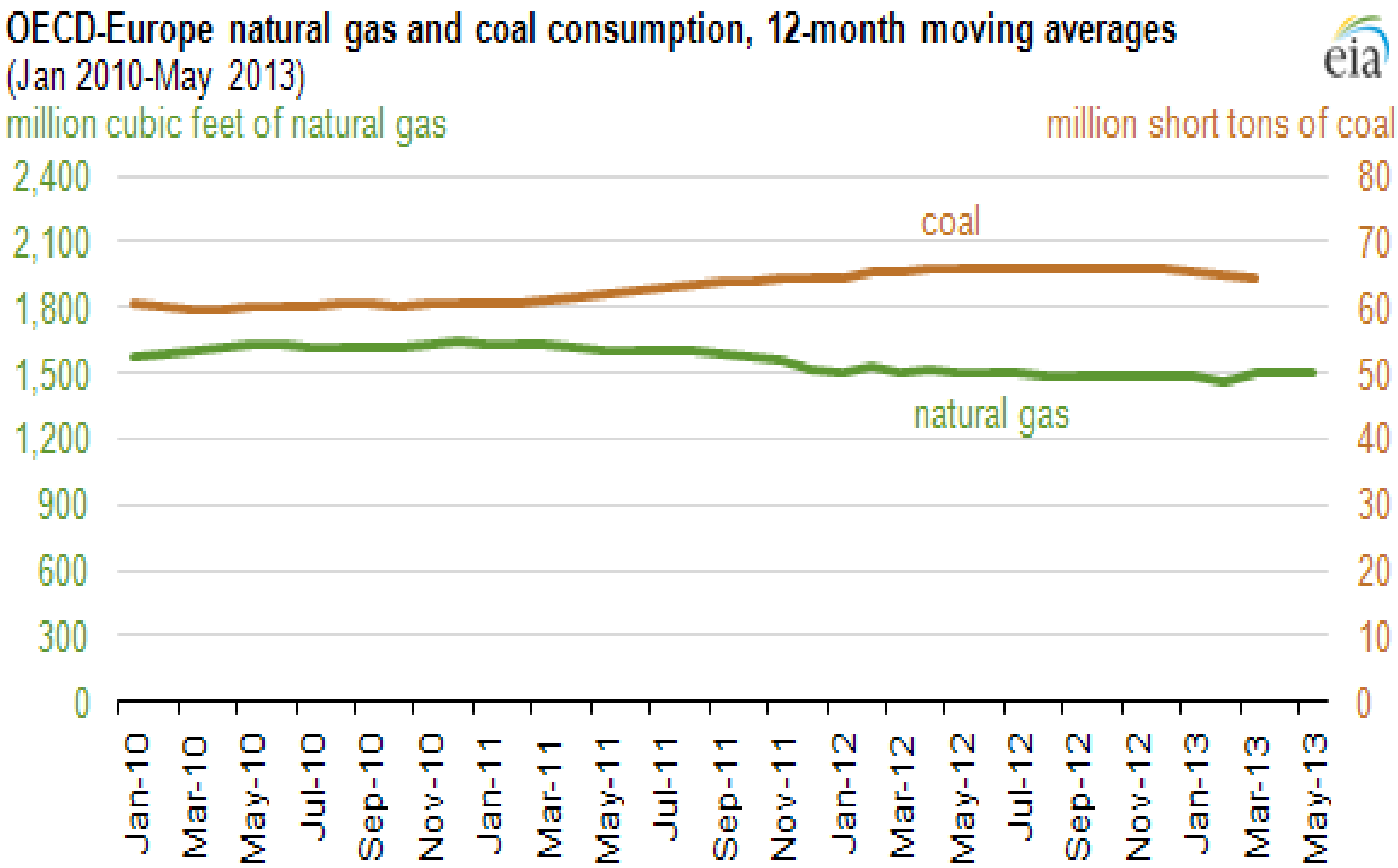
Frequency in UCTE 1st Zone, 28 Sept. 2003



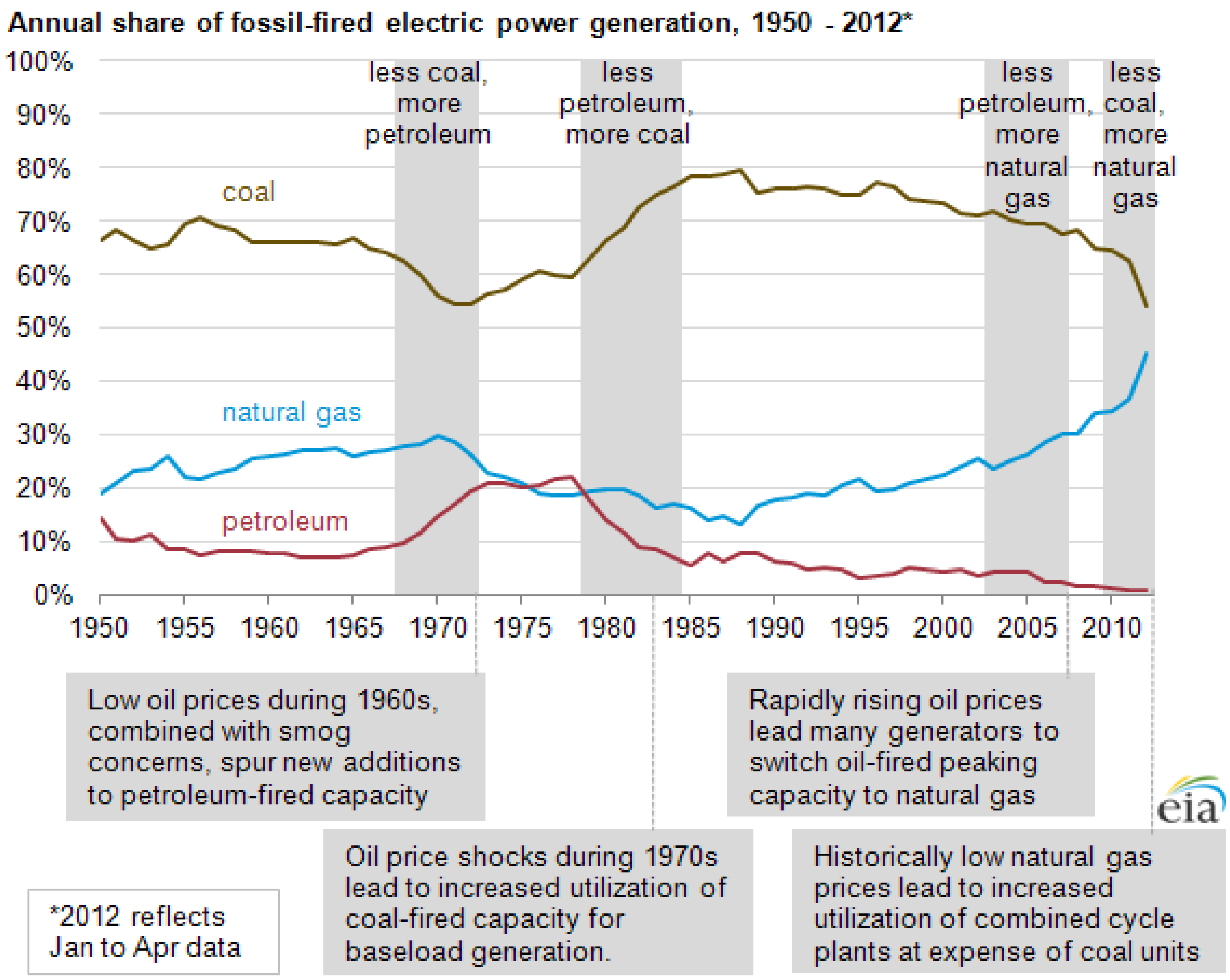
Source: UCTE, Final report on the 28 September 2003 Blackout in Italy



Source: EIA Jjuly 2013



Source: EIA September 2013


Annual share of fossil-fired electric power generation, 1950 - 2012*
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
coal
natural gas
petroleum
less coal, more petroleum
less petroleum, more coal
less petroleum, more natural gas
less coal, more natural gas
Low oil prices during 1960s, combined with smog concerns, spur new additions to petroleum-fired capacity
Oil price shocks during 1970s lead to increased utilization of coal-fired capacity for baseload generation.
Rapidly rising oil prices lead many generators to switch oil-fired peaking capacity to natural gas
Historically low natural gas prices lead to increased utilization of combined cycle plants at expense of coal units
*2012 reflects Jan to Apr data
eia

U.S. carbon dioxide (CO_2) emissions resulting from energy use during the first quarter of 2012 were the lowest in two decades for any January-March period. Normally, CO_2 emissions during the year are highest in the first quarter because of strong demand for heat produced by fossil fuels. However, CO_2 emissions during January-March 2012 were low due to a combination of three factors:

A mild winter that reduced household heating demand and therefore energy use

A decline in coal-fired electricity generation, due largely to historically low natural gas prices

Reduced gasoline demand

U.S. CO_2 emissions from energy consumption totaled 1,340 million metric tons during the first quarter of 2012, down nearly 8% from a year earlier and the lowest for the January-March period since 1992, according to the U.S. Energy Information Administration's June Monthly Energy Review. July 2012

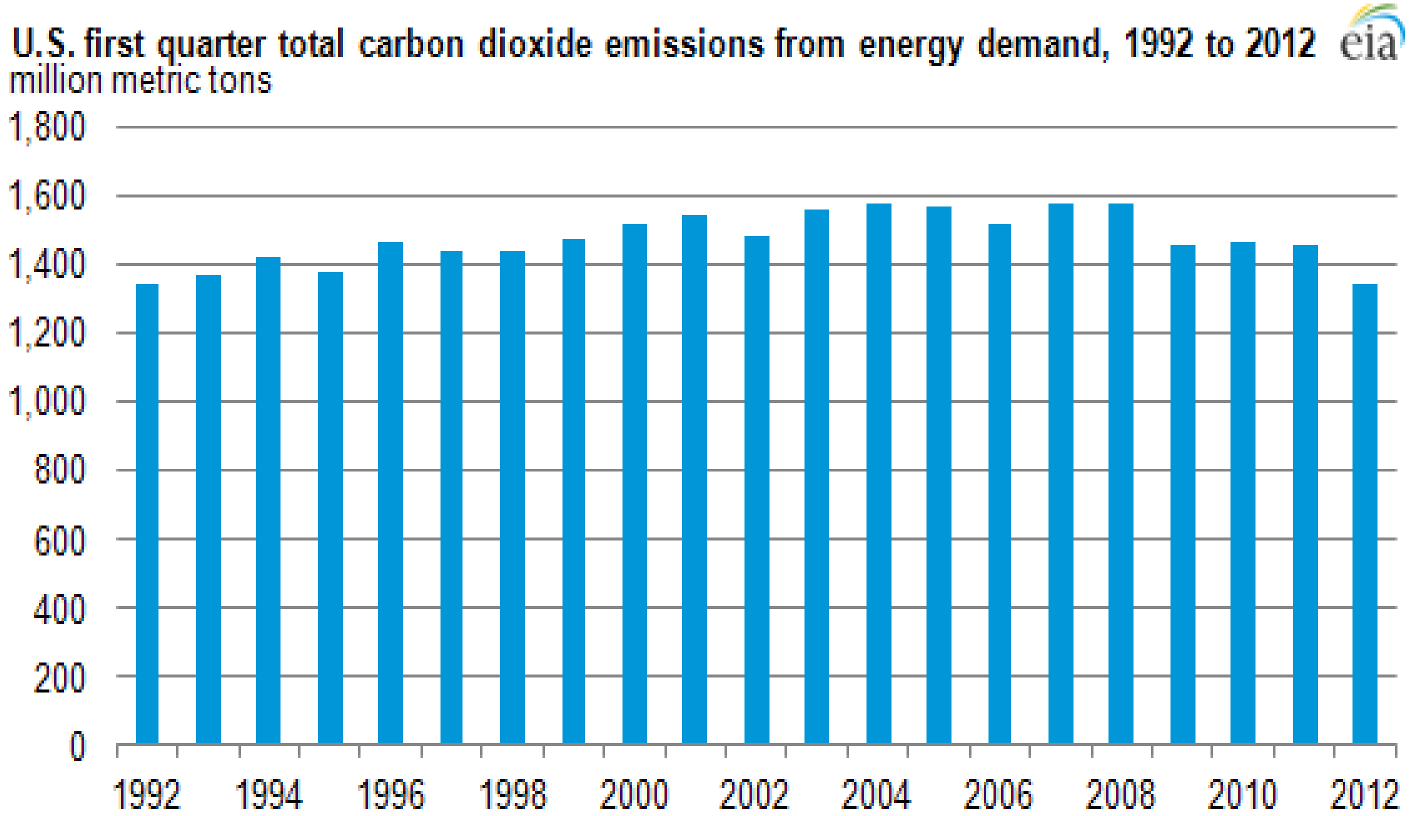


Illustration:
Variable costs of coal / gas fired power as function of carbon price