Geothermal Energy – how does it stack up in the Future Energy Mix?

Veli Losinj – August -2014

- **For starters - A Look around the World:**
  - How do we fuel our future energy needs?
  - Is the world running out of oil or natural gas?
  - What is the favored form of energy?

World Risks

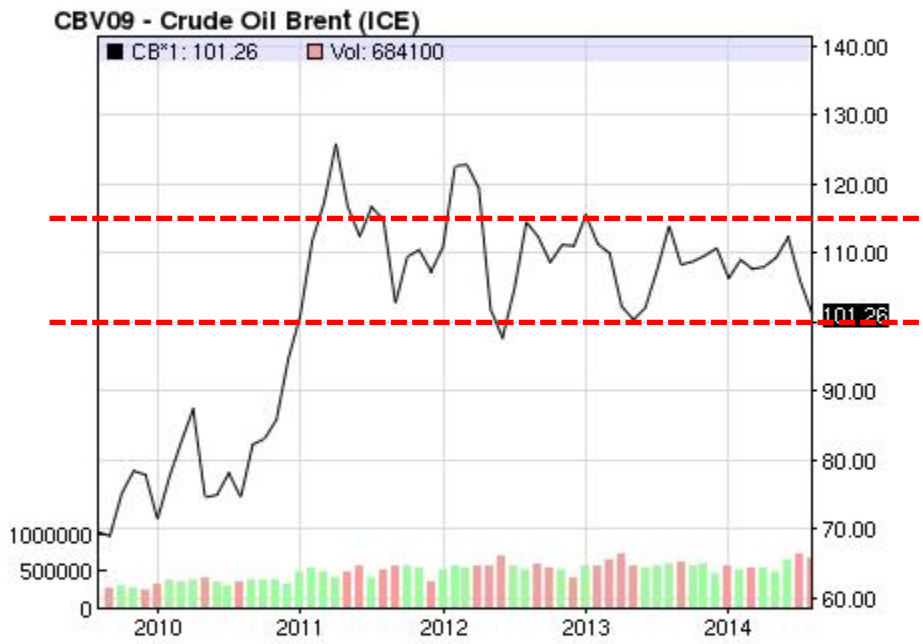
WORLD THREAT MAP
2014
Ukraine-Russia Tensions
Middle East Unrests
Fundmentalist Uprising
Libya Conflicts
Yemen Tribal Conflicts
Argentina Financial Crisis
RESULT GROUP
Global Risk and Crisis Management

World Risks

- How can we secure sufficient, affordable energy supply in a world of economic crisis and political unrest?
- … but is the world really affected by it?

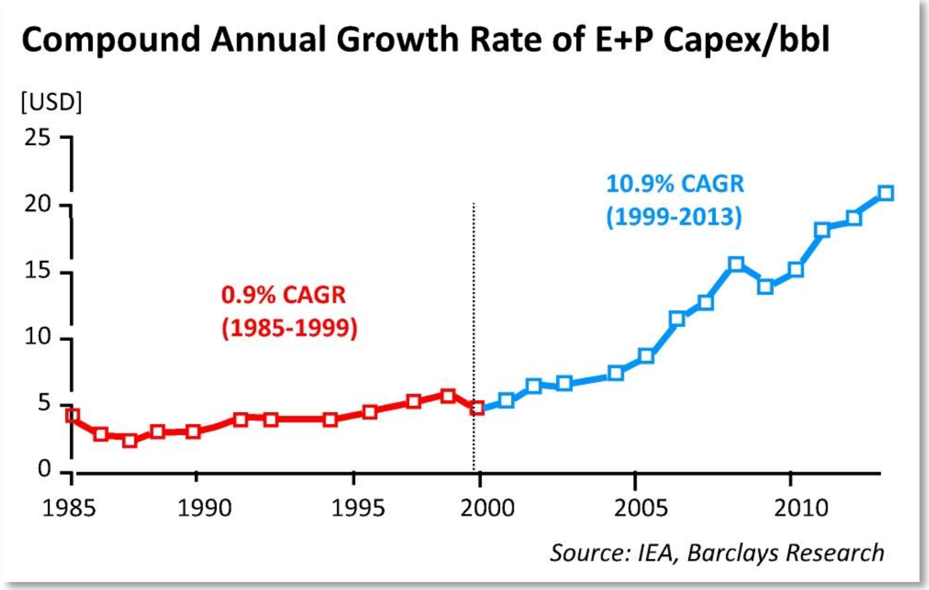
5 Years Brent Oil Price

- Oil prices have been **essentially stable** at around the 100 – 115 USD/bbl bandwidth for the last 5 years
- Major oil price spikes like the one in 2008 **have not reoccurred** as a consequence of past and present political uncertainties



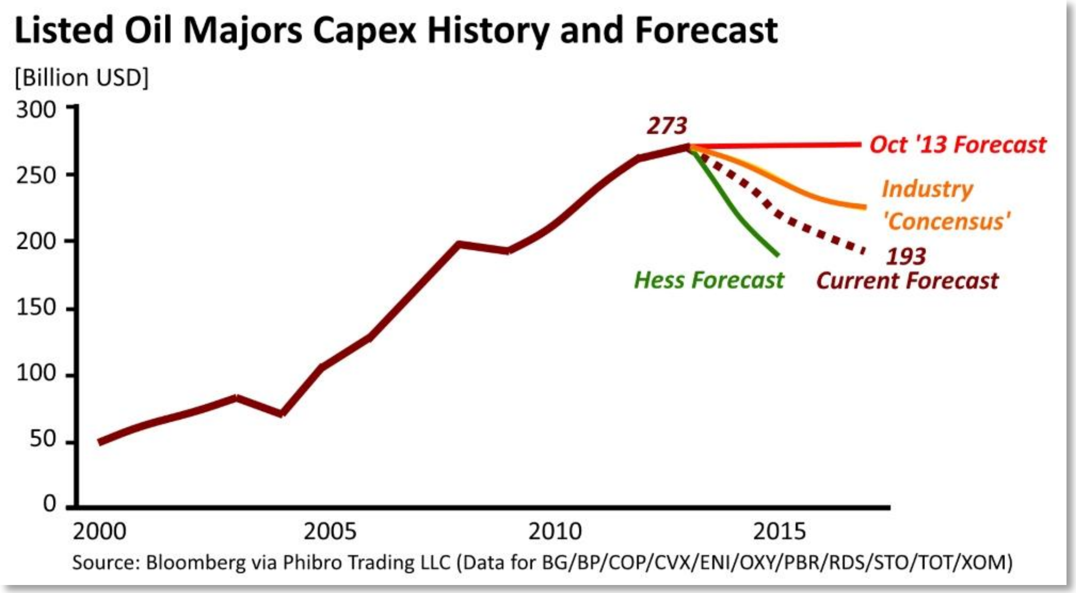
Capex on the rise…

- With oil prices largely flat over the last 5 years, costs are rising faster than revenues
- E+P Capex per barrel are on a 11% p.a. increase
- **A number of projects are consequently deferred, shelved or in for re-assessment**



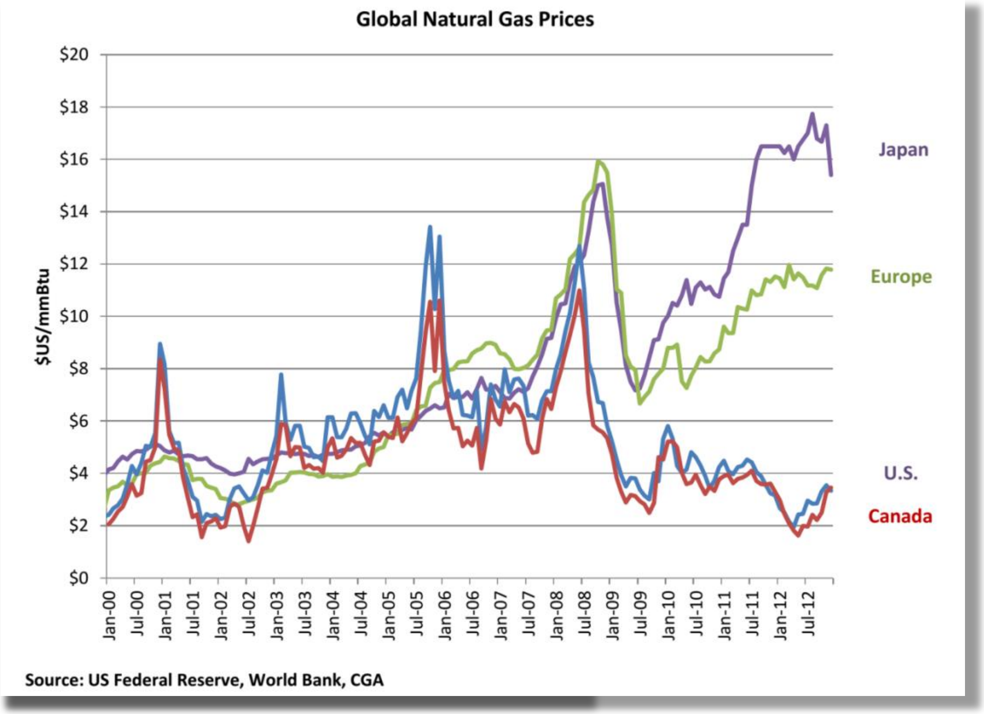
Major oil and gas firms cutting on Capex …

- Capital discipline became now a key issue for Majors
- Cash flow growth supersedes production growth
- Substantial downward revision since Oct-13 outlook
- Oil majors face challenging investment climate
- → **impact obvious: supply shortening!**



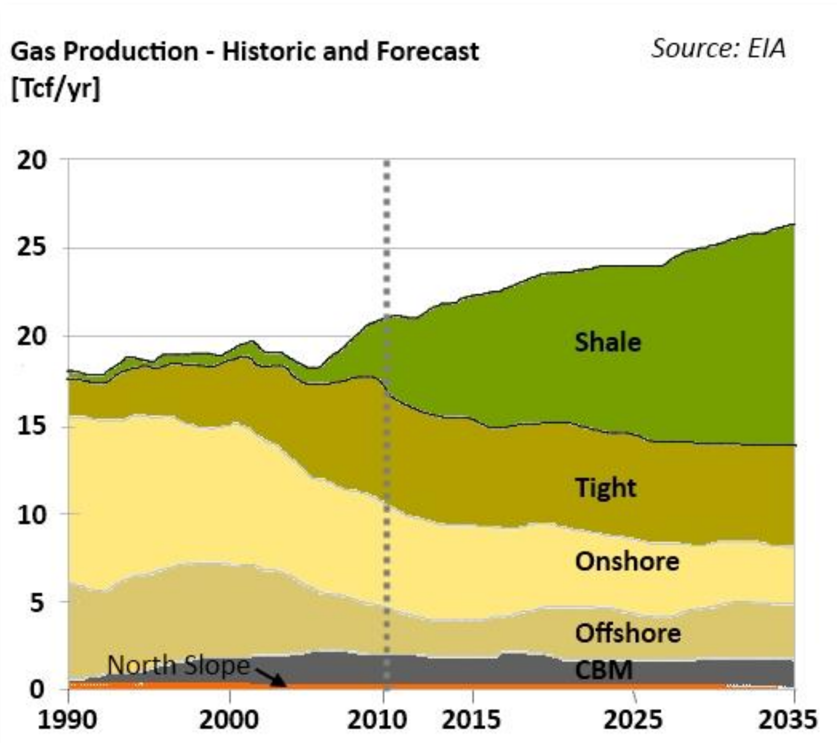
Global gas price developments

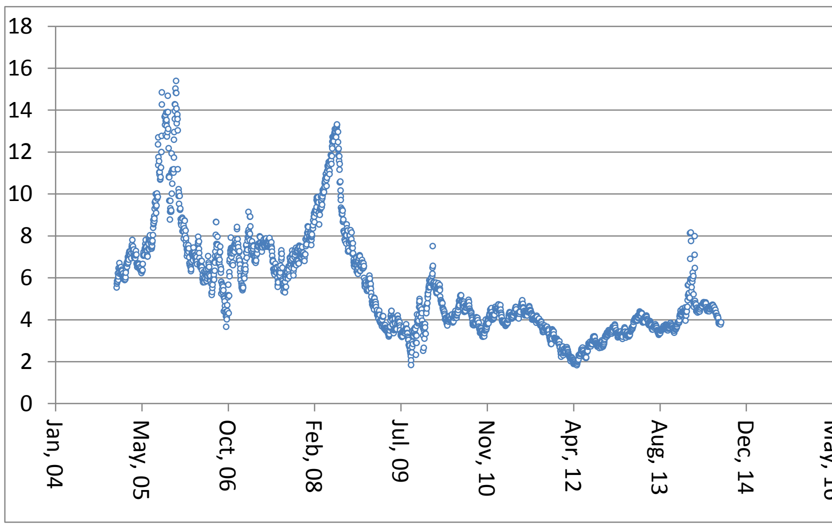
- Over a decade, prices for natural gas markets around the world were essentially following an identical, converging development
- Then, in mid 2008, different markets developed into a large spread between **Japan**'s prices being highest (16 USD/Mcf), closely followed by **Europe** (12 USD/Mcf) and depressed prices in **North America** (4 USD/Mcf at Henry Hub)
- **… what happened?**



US Unconventional Gas

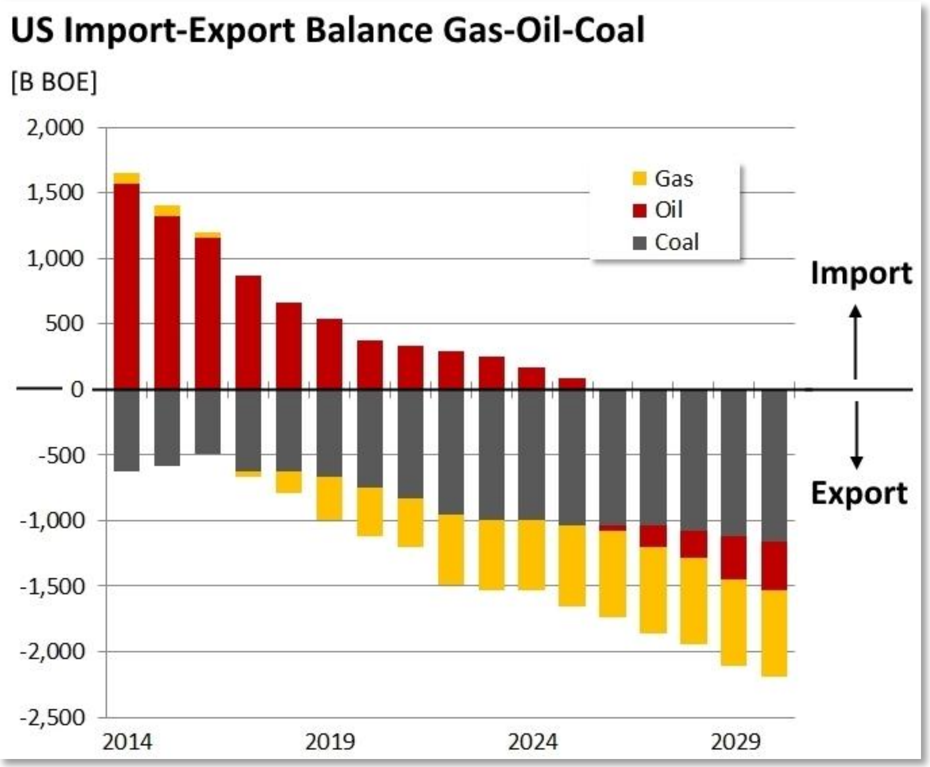
- A rush has set in at ~2008 in the US to develop the resource ‘Tight Gas Sands’ and **‘Shale Gas’**
- While this continues to succeed in the US, other parts of the world have so far not been able to duplicate the story despite large resources are believed to exist elsewhere
- **The downside: prices collapsed in North America** (Henry Hub Spot – USD/Mcf)





US Fossil Fuels Import Export Balance

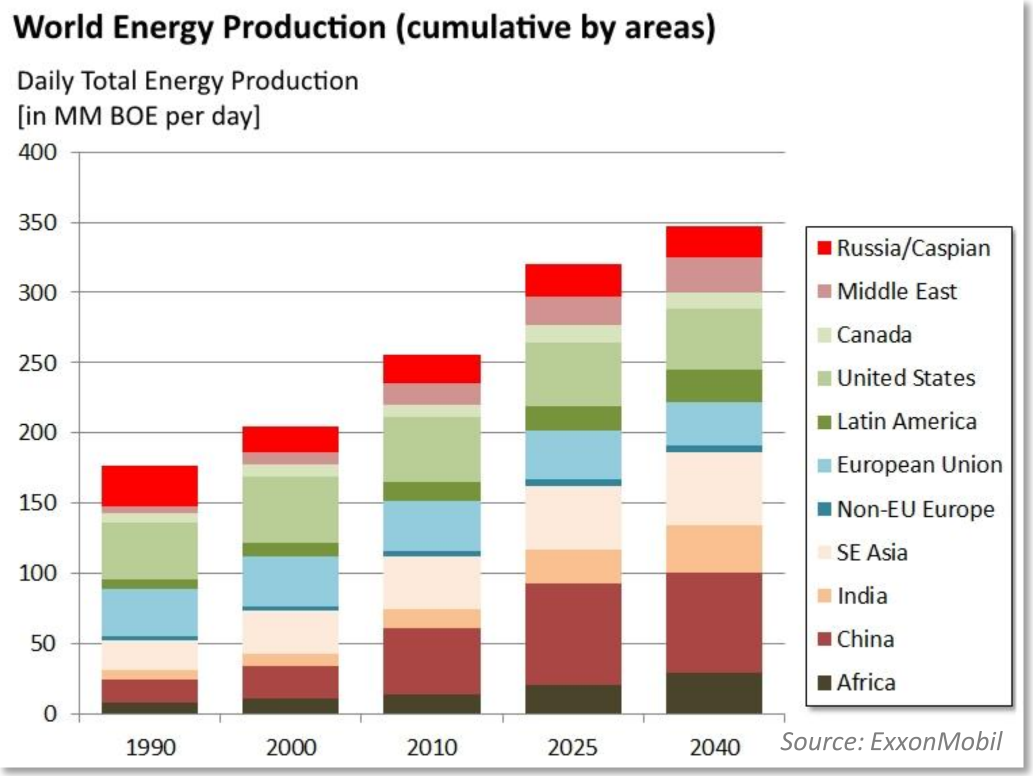
- What first looked too good to be true has meanwhile become a fact, which will make the US not only fossil fuel independent, but will also allow them in future to export natural gas (as LNG) and eventually even crude oil



Source: ExxonMobil

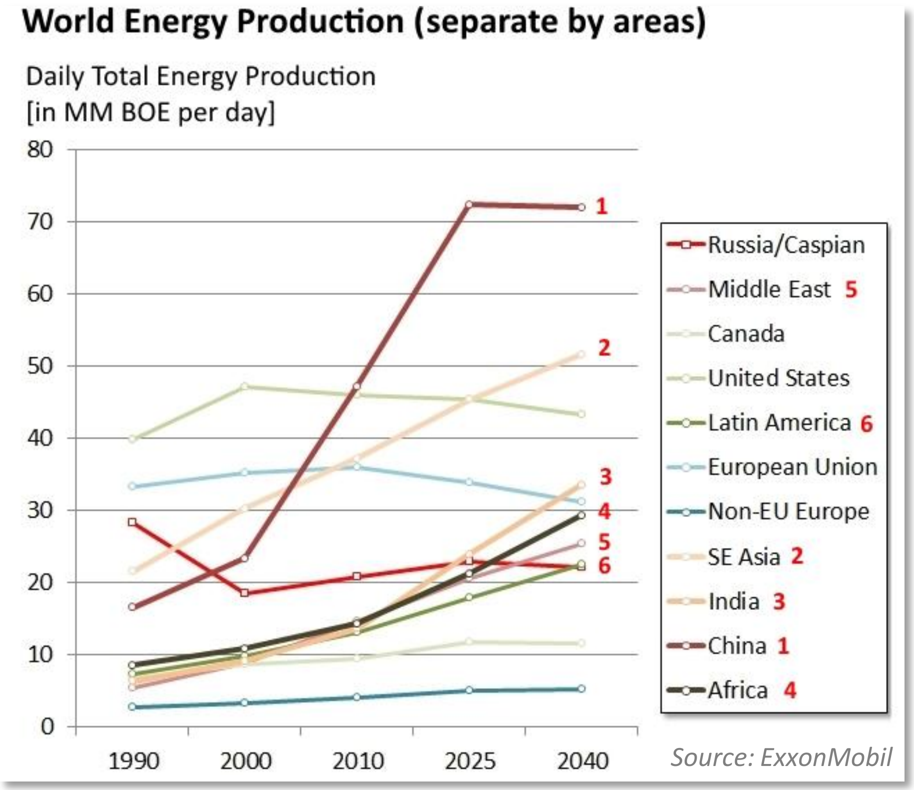
World Production Forecasts

- Including all type of energy (fossil, nuclear and renewables), in a span of 50 years (1990-2040) the world is expected to double its energy production (and demand) from **175 to almost 350 BOE per day**



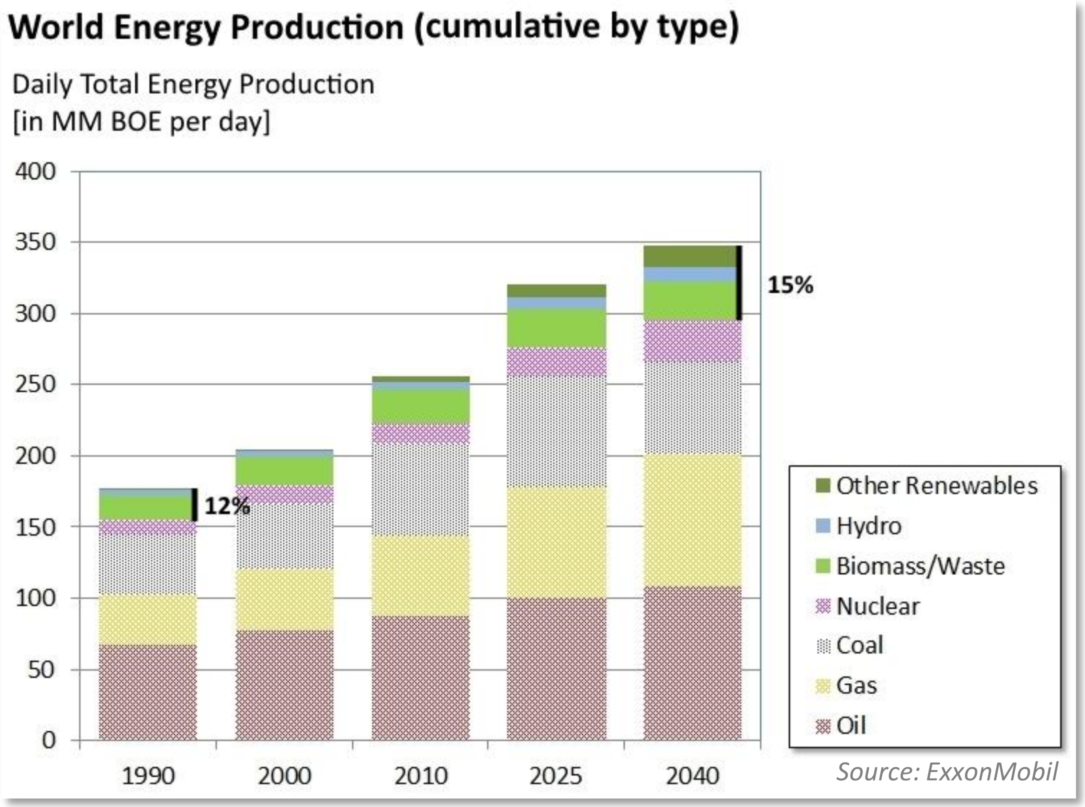
World Production Forecasts (by regions)

- Within these 50 years, the largest energy growth is expected to occur in **Asia (lead by China)**, followed by the **Middle East** and **Africa,** while the OECD countries will have stagnating or dropping energy demands



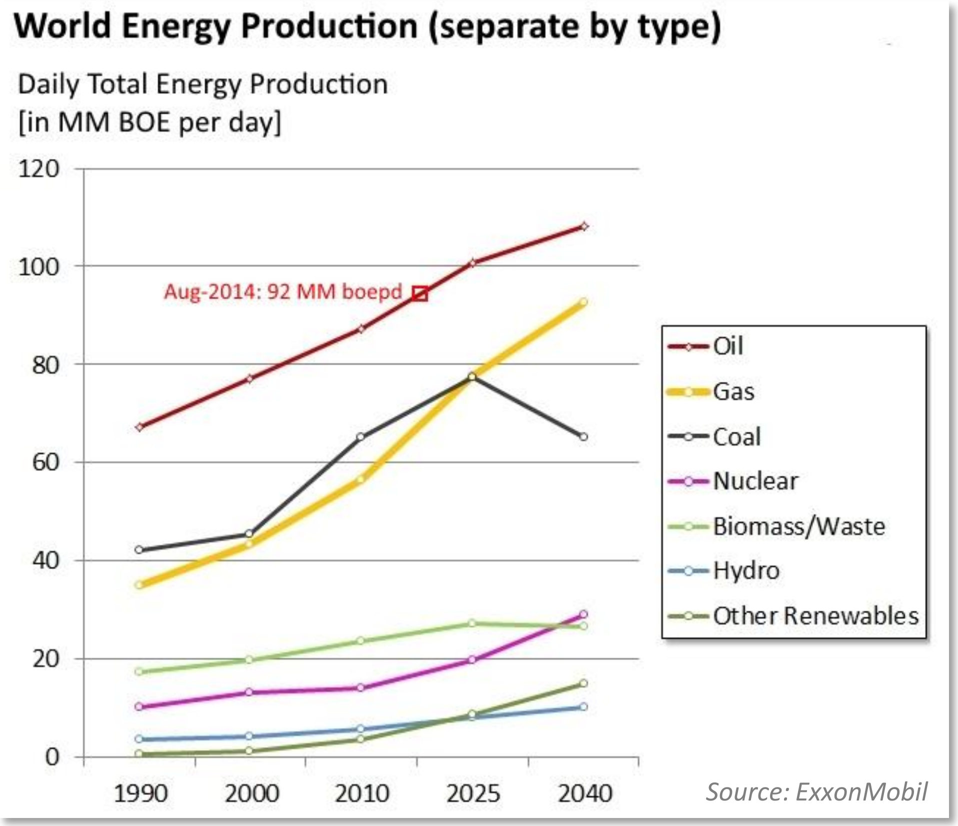
World Production Forecasts

- While fossil fuels will continue to provide the bulk of the energy supply, renewable energies are expected to show only a moderate increase from 12% (1990) to 15% (2040) in the overall energy production



World Production Forecasts (by types)

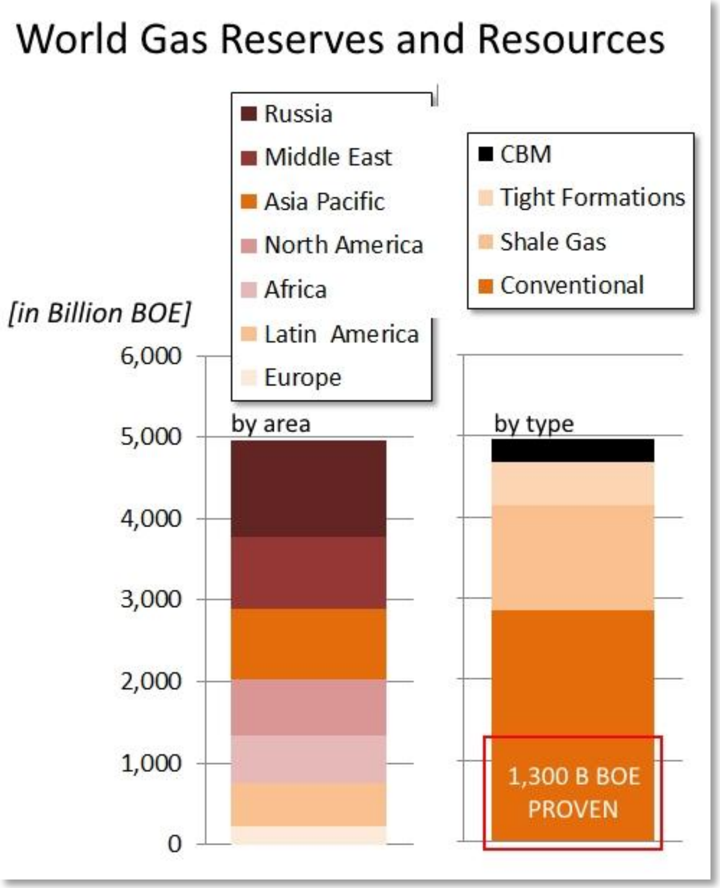
- With crude oil production presently (2014) just shy of the **100 MM boepd**, natural **gas will show the strongest increase** in energy contribution, while coal supply will peak around 2025



World Gas Reserves and Resources

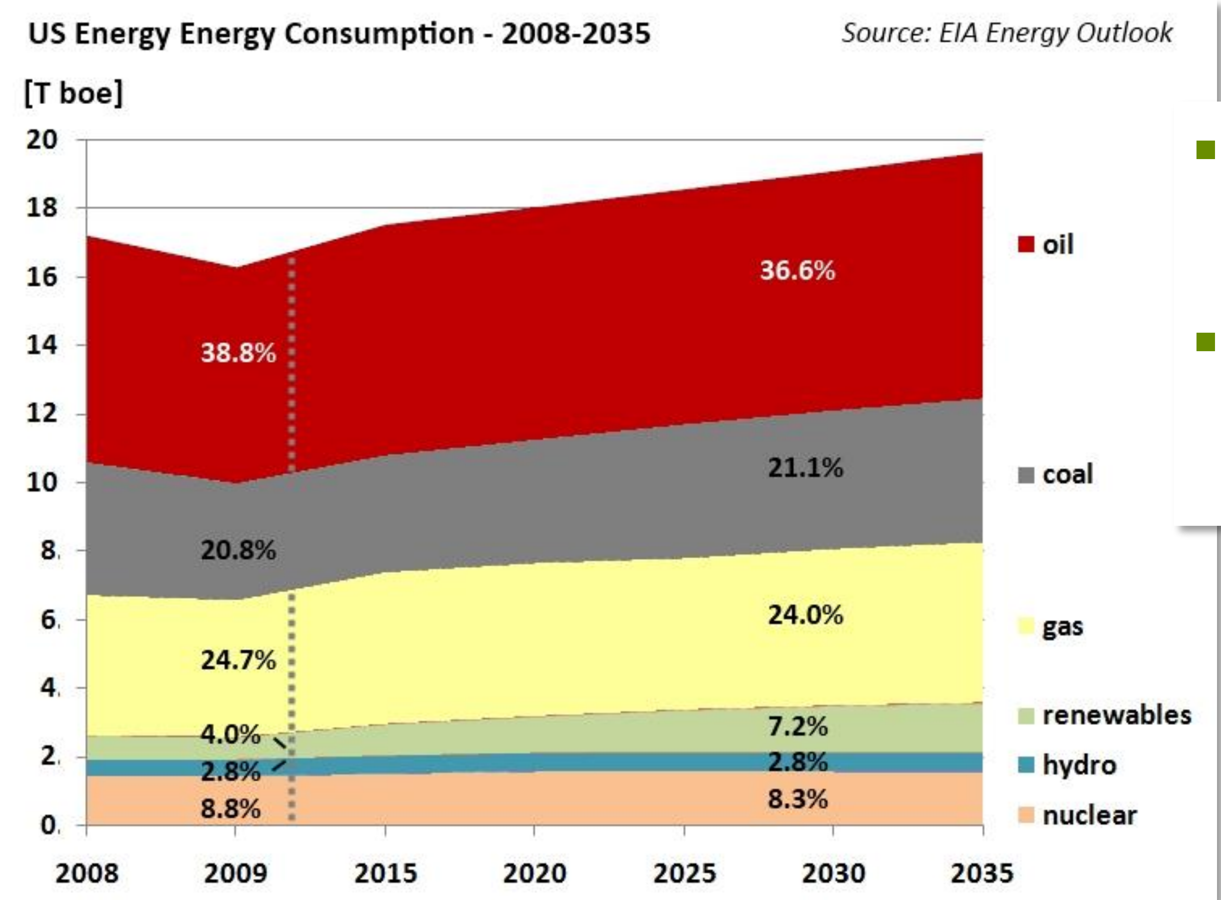
- With **'Peak Oil'** for crude being a myth and Reserves Life Index (RLI) on **gas > 60 years** for Proven Reserves only, their seems no imminent danger of shortage in fossil hydrocarbon fuels

- The before mentioned generalized statements need to be analysed in more granularity for different areas and markets, as North America (US/Canada) and Europe (EU28) behave differently →



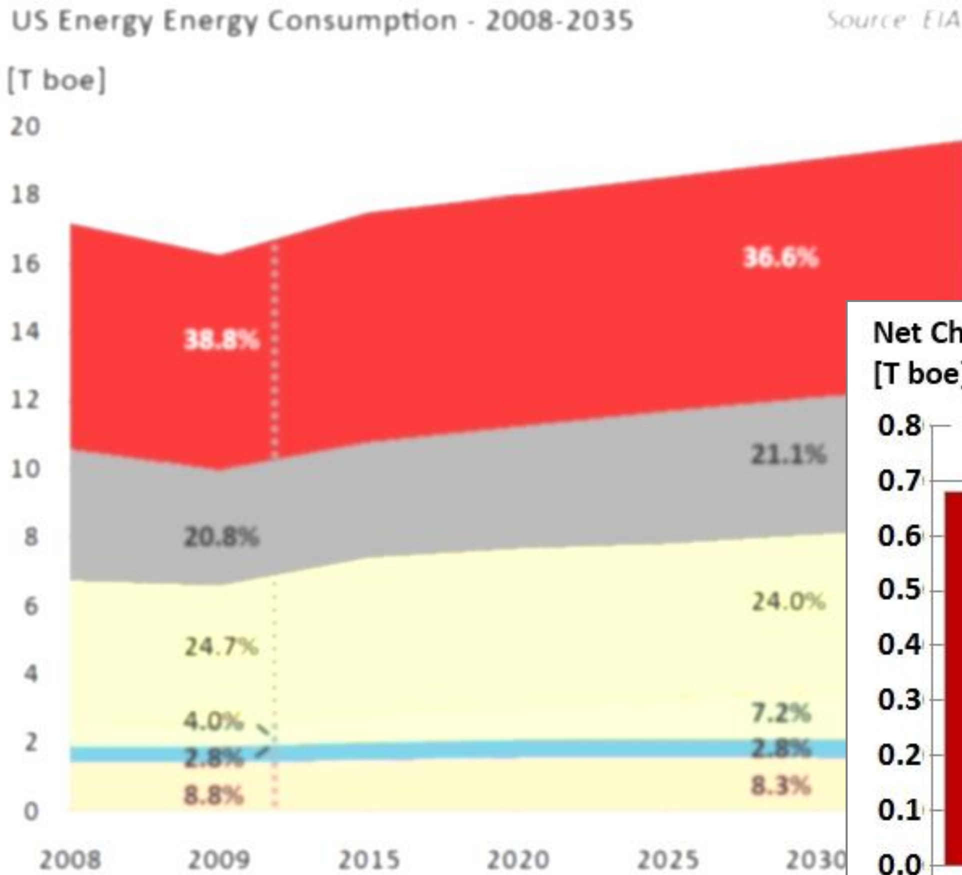
Source: ExxonMobil

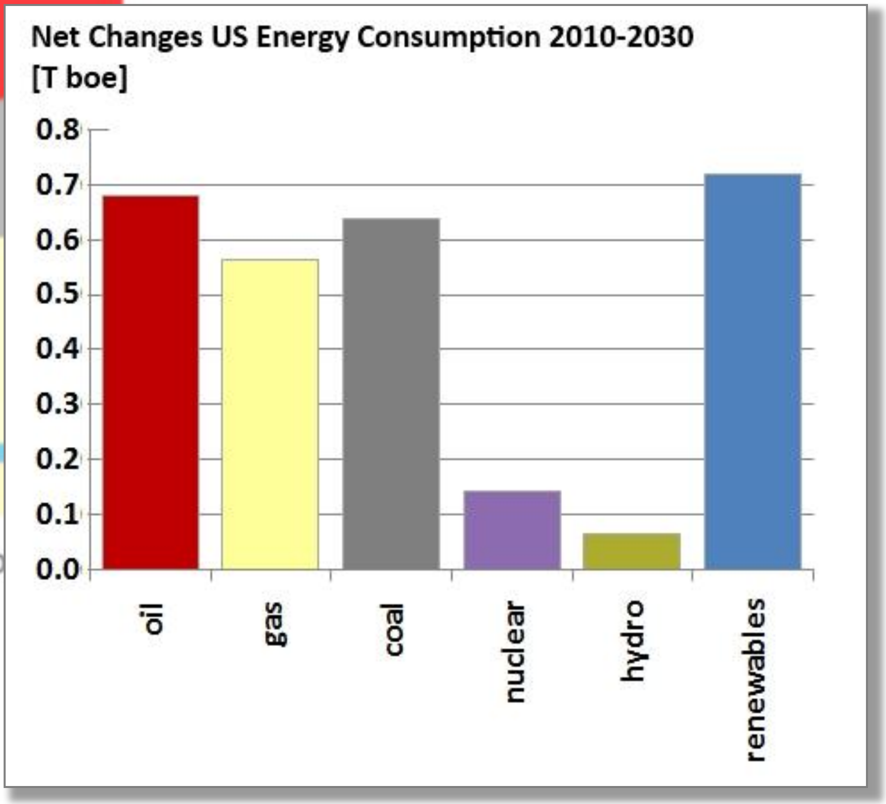
Regional energy mix trends – the USA



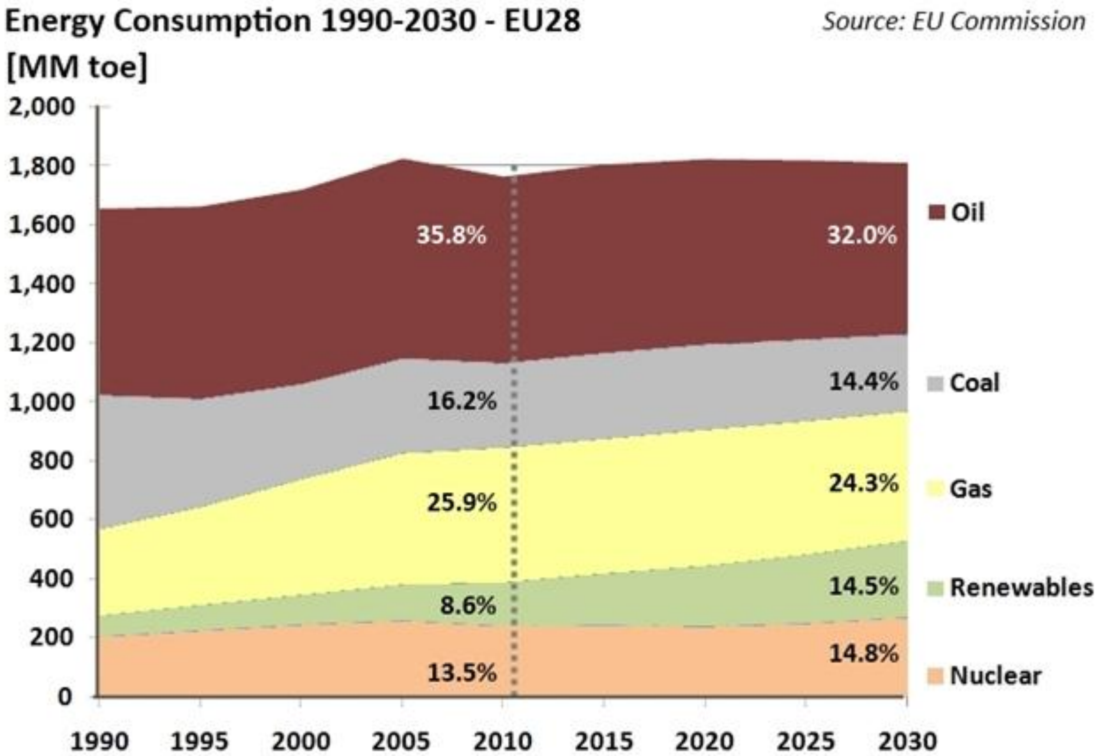
- Even gains across the entire energy mix
- **Growth in nuclear and hydro power are slower**

Oil remains strong in the US



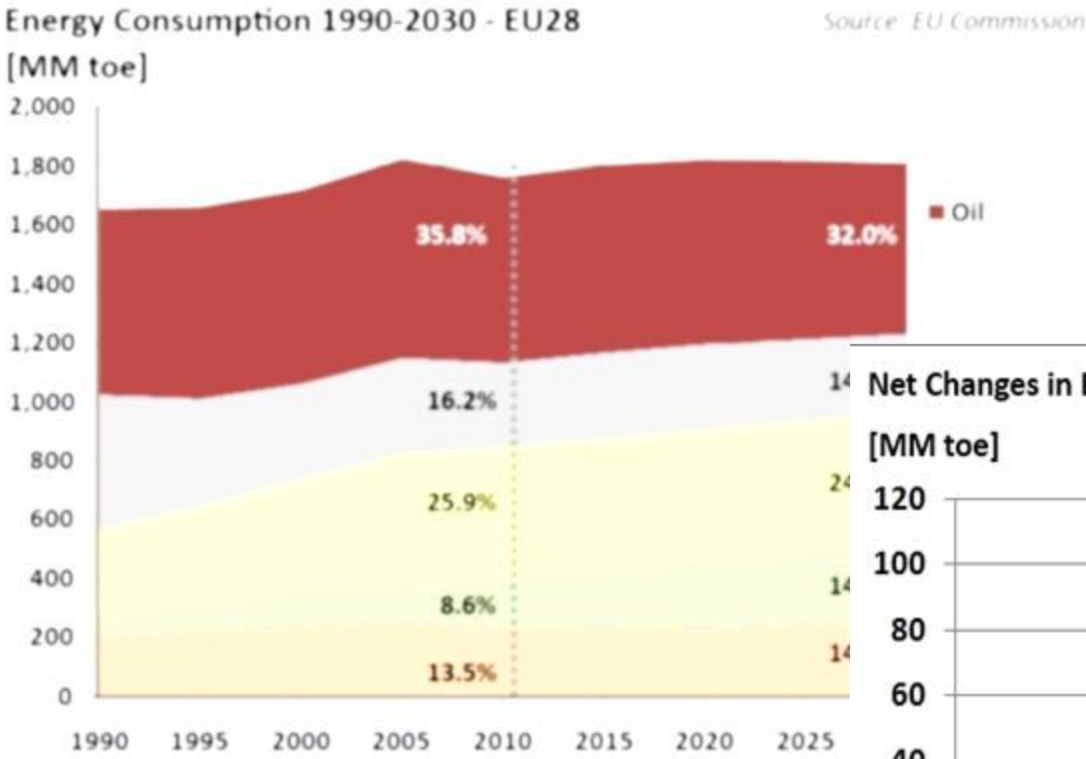


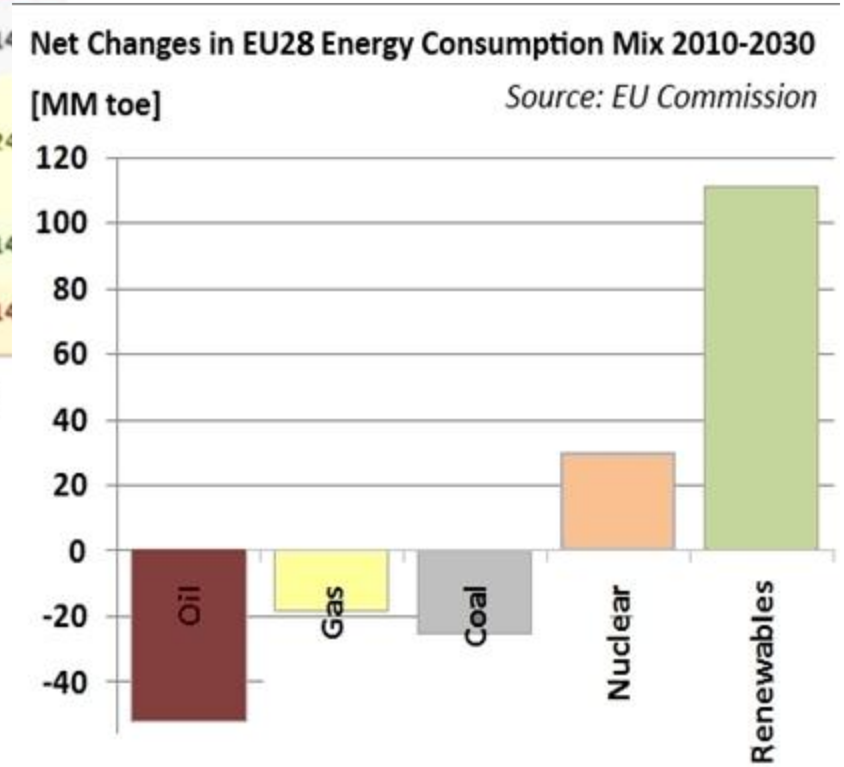
Fossils remain strong in EU28 energy mix



- Fossil fuels strong but are losing
- **Renewable are strongly gaining**
- *(unfortunately, also nuclear rising…)*

… but renewables are on the rise !

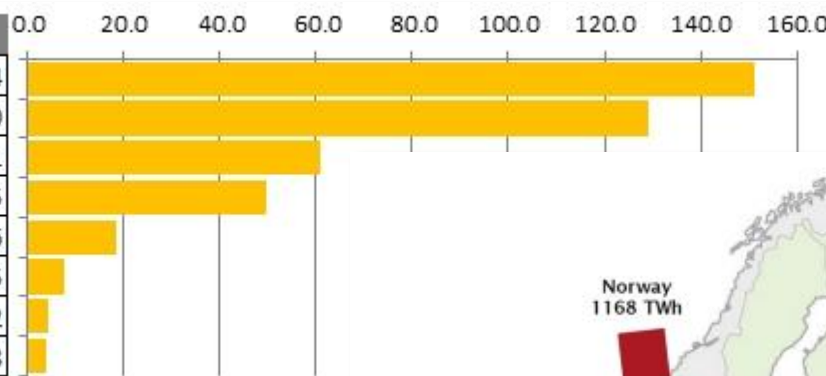


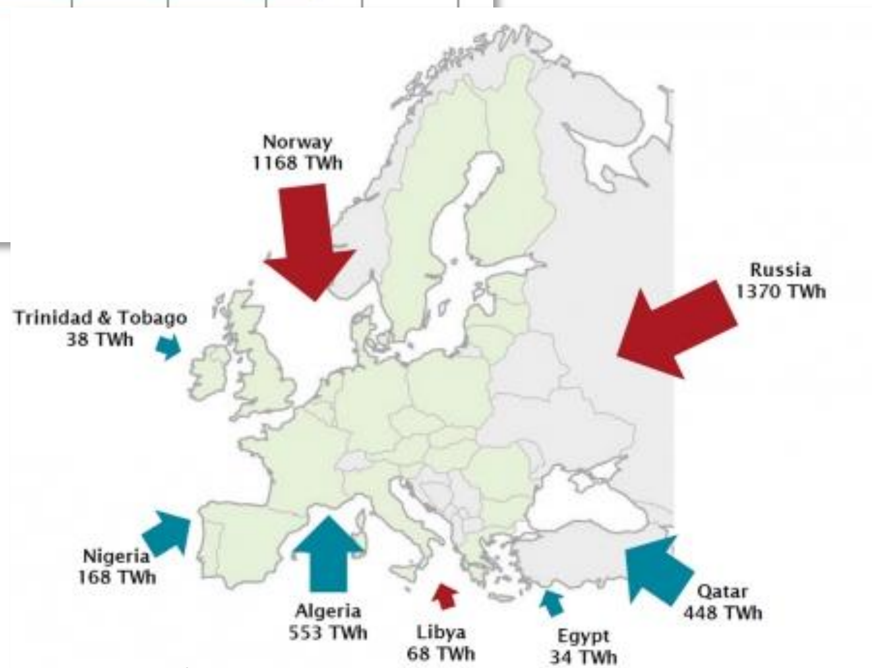


EU28 Gas Supply

- Recent geopolitical events have rekindled the quest for energy independence of Europe
- At present (2014), Russia still provide over 1/3 of the gas supply to EU28
- What are the options for an alternate energy supply for EU28, (if any)?

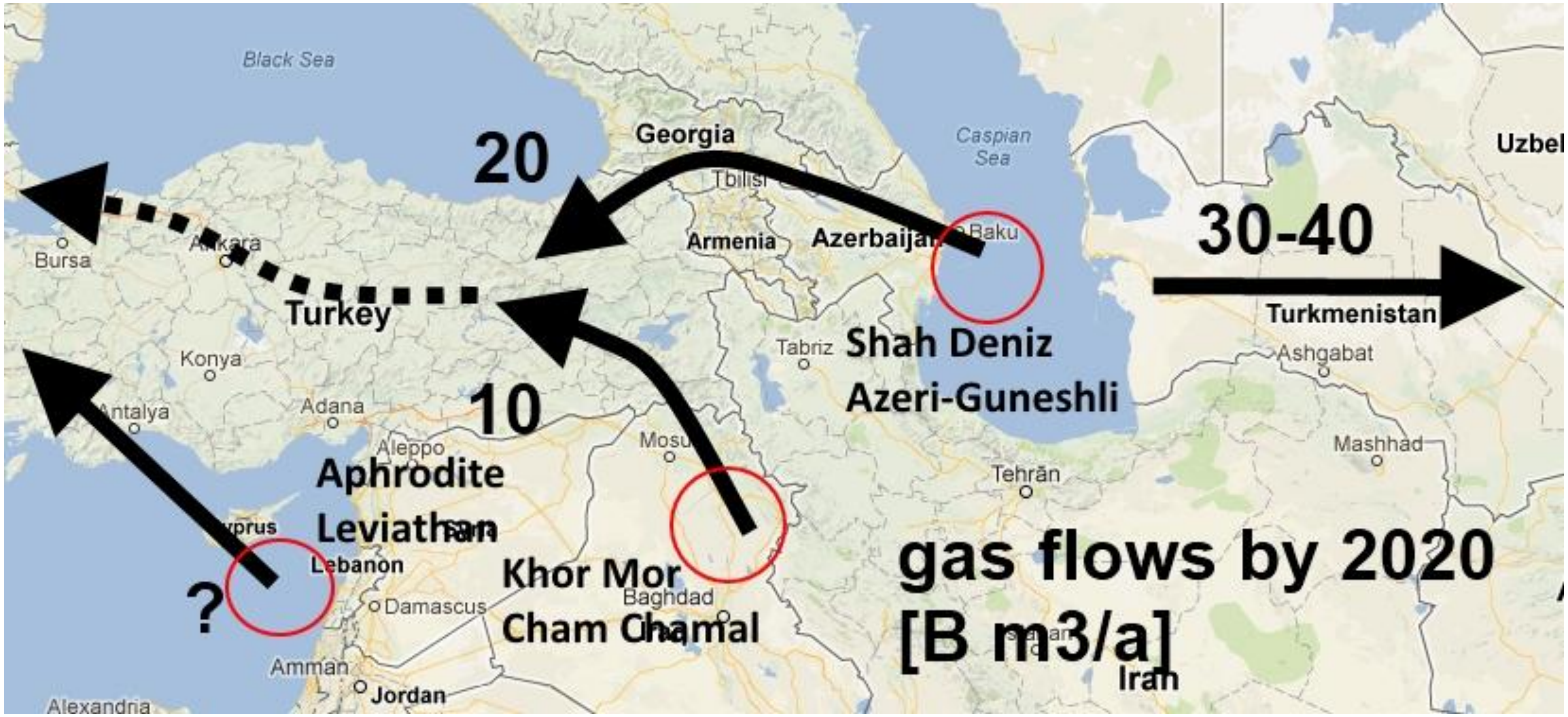
Country	[%]	[B m3]
Russia	35.6%	151.4
Norway	30.4%	129.0
Algeria	14.4%	61.1
Qatar	11.6%	49.5
Nigeria	4.4%	18.6
Libya	1.8%	7.5
Trinidad	1.0%	4.2
Egypt	0.9%	3.8





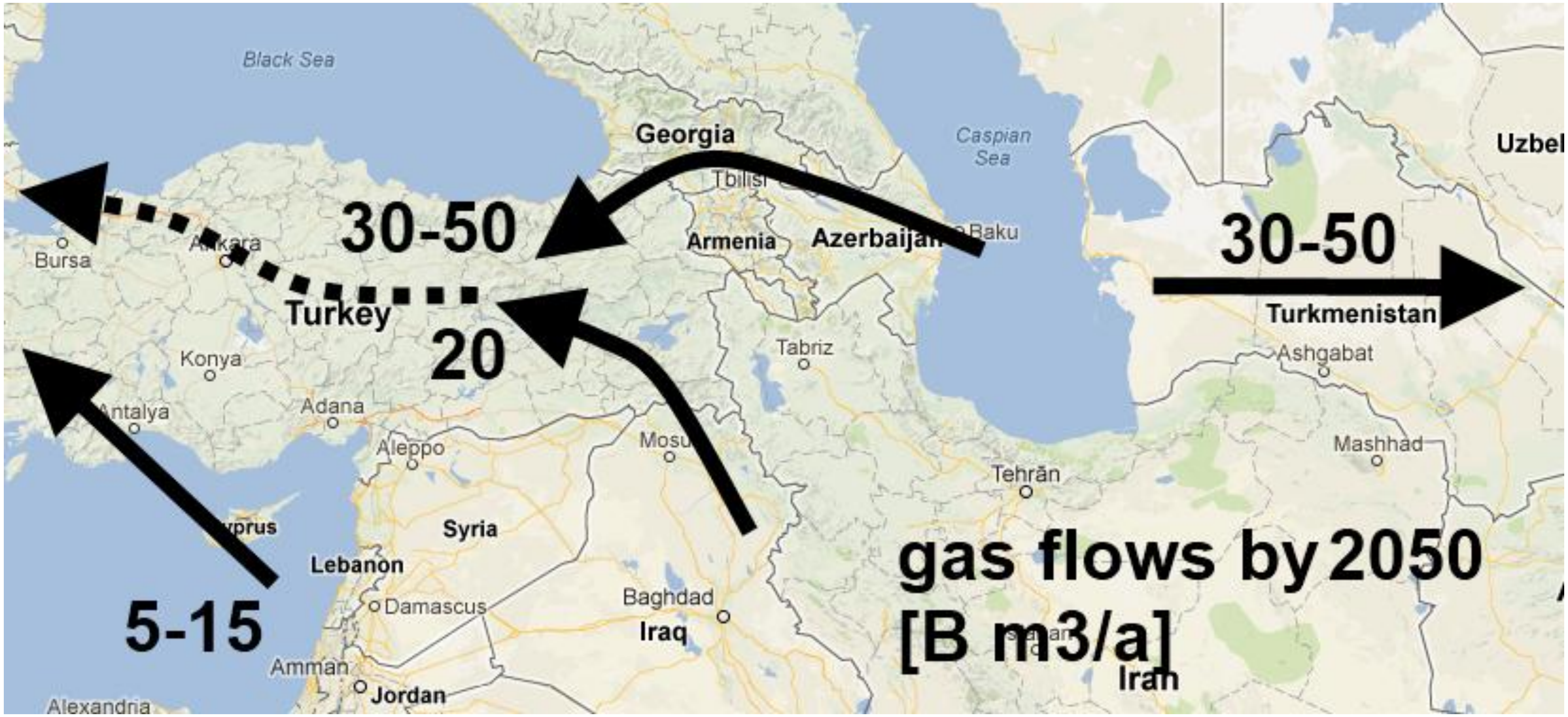
Source: WoodMacKenzie

Central Asian Gas for Europe?



- 30+ B m3/yr will try to get to Western markets by 2020

Central Asian Gas for Europe?



- By 2050, it will be 60-80 B m3/yr
- Turkmen gas will go East – not West!
- With EU28 importing 150 B m3/a from Russia (2014), the gap is 70 B m3/a…

World Energy Supply and Renewables

- So much about the **Energy Supply to the World** (which is obviously not yet running out of fossil fuels)
- But how do the **Renewable Energies** perform in this competition?

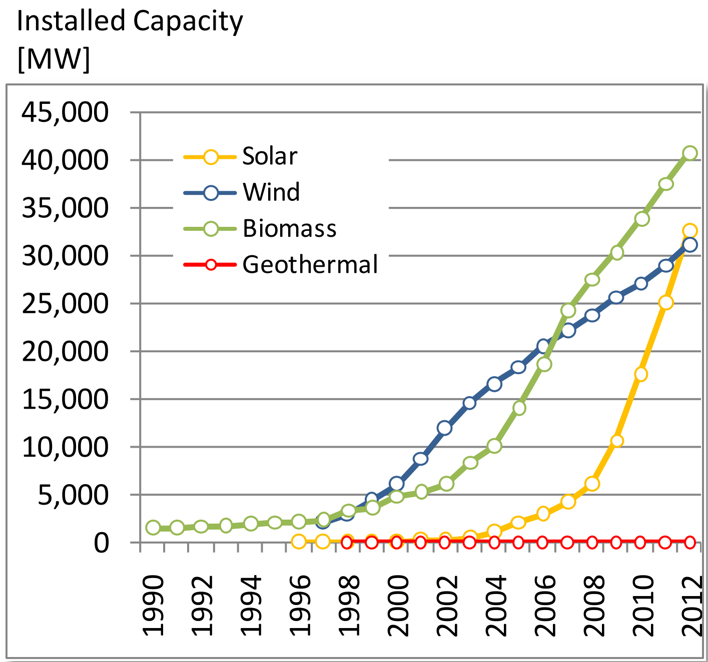
Germany on track for a new record in 2014

Press Release 12-Aug-2014:

- **Germany's renewable energy sector touched a new record in the first half of 2014, according to the Fraunhofer institute.**
- Renewable energy sources generated 81 TWh in the first half of 2014, accounting for **31% of the nation's electricity**. Solar and wind power had a contribution of 45 TWh or 17%, spurring production by 28% respectively 19%. The again happening record in Germany's renewables proves the incredible success of Germany's EEG legislation. In total, renewable energy production certainly surpassed power production from lignite (69.7 TWh), the single most important energy source. Electricity exports increase one more time by 27% to 18.3 TWh. If this trend is continuing, Germany would hit the third electricity export record in 2014 after already touching records in 2012 and 2013. Its main customers have been the Netherlands, followed by Austria, Switzerland, and Poland.

Effect and Efficiency of FITs - Germany

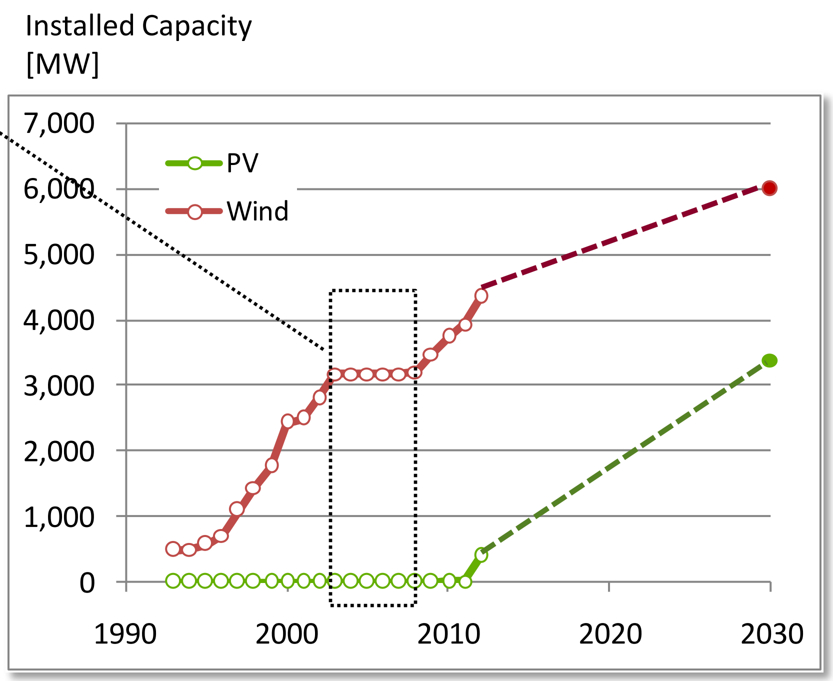
- **The Rise and Rise**
- After the adoption of Feed-In Tariffs (FIT) including their revisions the Renewable Power Industry is increasingly investing and will soon exceed 100,000 MW installed capacity;
- Germany produces some 32% of its energy demand from renewable sources; over 300,000 people are employed in the renewables industry which has an annual turnover of ~40 Billion EUR.
- The Nuclear Exit strategy has provided a large boost to renewables, although coal power generation plants were also on the comeback



Source: BP Statistical Review of World Energy 2013

Effect and Efficiency of FITs - Denmark

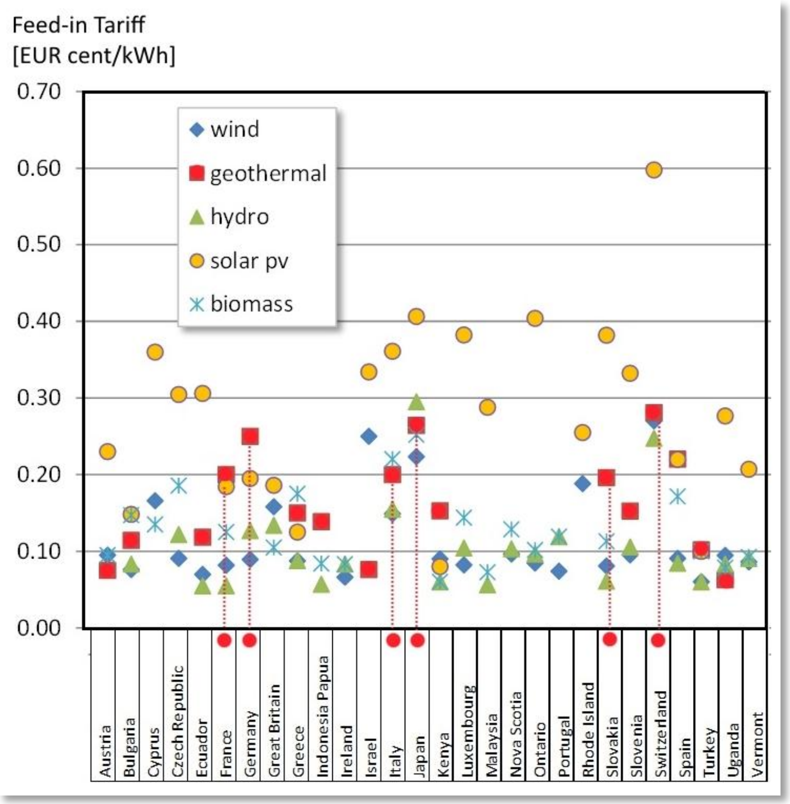
- **The Rise, Fall… and Rise**
- Development of Feed-In Tariffs (FIT) helped the Renewable Power Industry to progressively invest into over 3,200 MW installed production capacity; with the abolishment of the FIT in 2004 *(due to changes in the political landscape)*, investment stagnated… as adverse developments were obvious, policy was revised, causing revival of investments
- Denmark supplies 28% of its energy from renewable sources; 21,000 people are employed in this industry which has an annual turnover of 37 Billion USD.
- For 2030, Denmarks plans installation of 10,000 MW PV+Wind plants



Source: John Farrell (2009)
'Feed-In Tariffs in Amerika'
Heinrich Böll Foundation

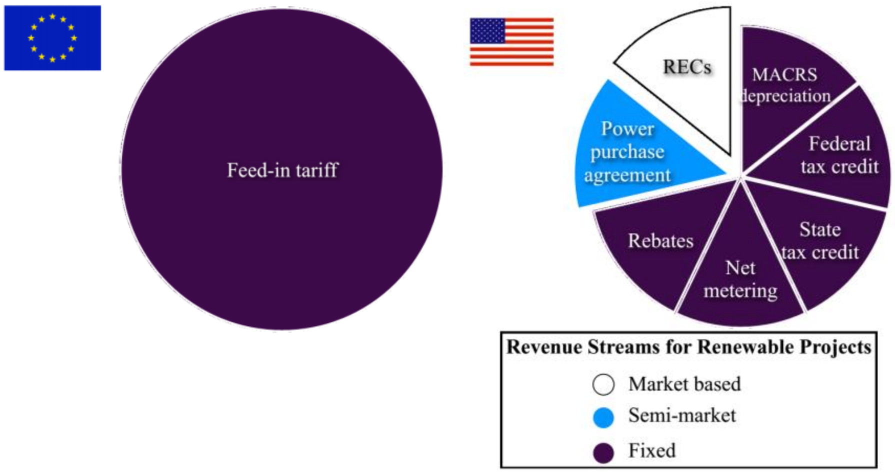
Selected Feed In Tariffs

- After unsuccessfully toying with tax cuts, grants and subsidies, many countries around the world have adopted **Feed-In Tariff (FIT)** systems to entice small Private Power Plants (PPPs) and renewable energy generation
- Solar (photovoltaic) seems to be favoured with high FITs while geothermal remains at an average *(except in few countries, where indicated)*



Feed-In (FIT) vs Renewabe Electricity Standard (RES)

- **Europe (FIT) and USA (RES)**
- A single source of revenue for energy makes the financing of renewable energy projects in Europe much simpler:

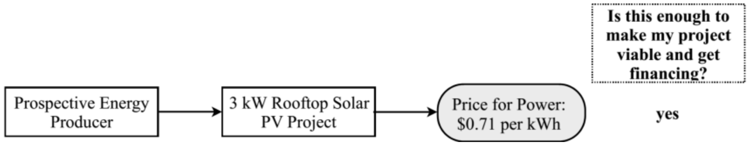


Source: John Farrell (2009) 'Feed-In Tariffs in Amerika' Heinrich Böll Foundation

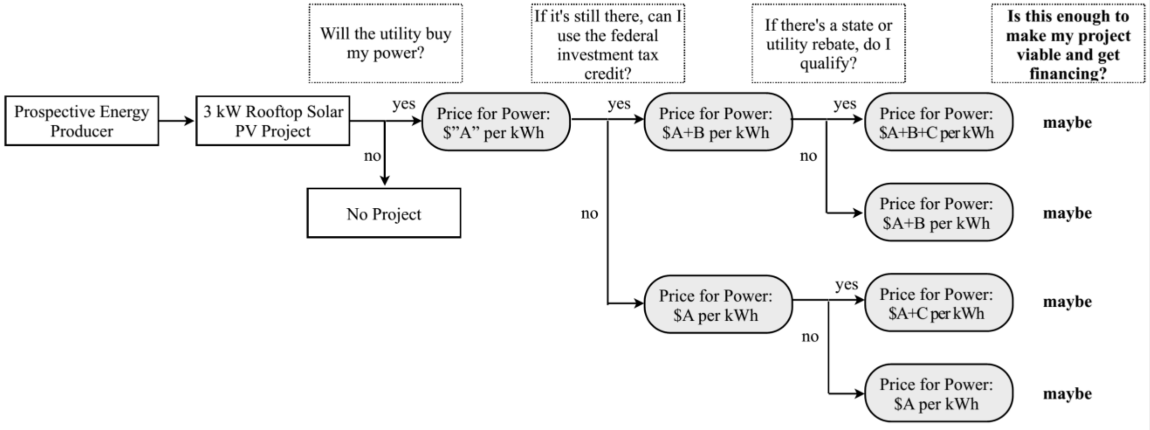
- A typical energy sales and purchases contract between an industrial power provider and a utility company has 85 pages in the US – in Germany, it has between 2 and 4…

Feed-In (FIT) vs Renewabe Electricity Standard (RES)

- **Project Financing and Economics**
- An FIT based project is much simpler to finance and decision making is straight forward – the paper trail for other cases is quite complex:
- Feed-In Tariff (FIT):



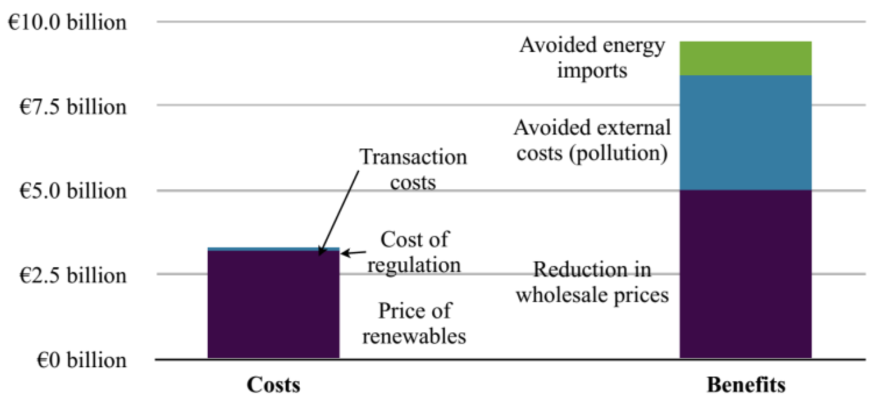
- Renewable Electricity Standard (RES):



Source: John Farrell (2009) 'Feed-In Tariffs in Amerika' Heinrich Böll Foundation

Feed-In (FIT) vs Renewabe Electricity Standard (RES)

- **Cost - Benefit**
- FIT based energy supply shows a very robust cost vs benefit ratio: Germany benefits from the continued support of renewable energy producer with a net benefit by a factor of 3



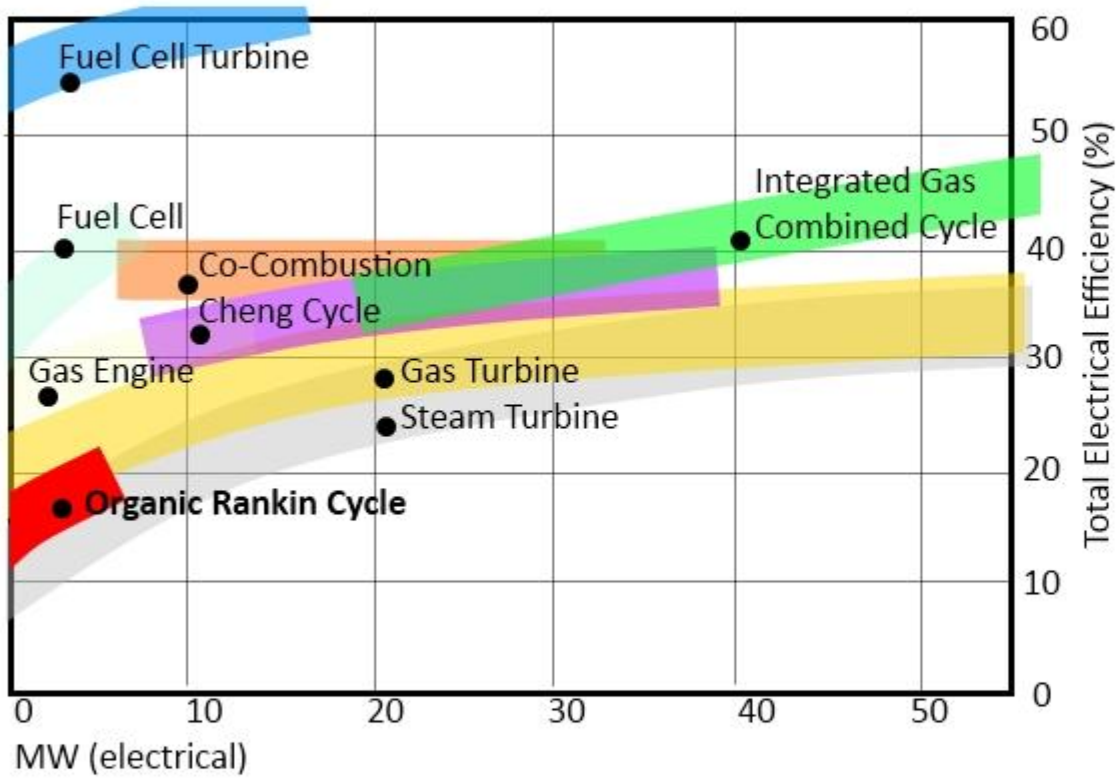
Source: John Farrell (2009)
'Feed-In Tariffs in Amerika'
Heinrich Böll Foundation

Energy Market Access – FIT vs RES

- Feed-in Tariffs : (FIT) — prices are **politically** determined; quantities are **market** determined
- Renewable Electricity Standard: (RES) — prices are **market** determined; quantities are **politically** determined
- → **purely market oriented contracting is a myth!**
  Neither the FITs nor the Green Certificate/Renewable Electricity Standard (RES) approach are inherently more "market oriented"
- **However:**
  The Green Certificates/RES approach favors corporate ownership structures, which may lead to NIMBYism (or even BANANA) *)
-

*) *NIMBY = not in my back yard*
BANANA = build absolutely nothing anywhere near anyone

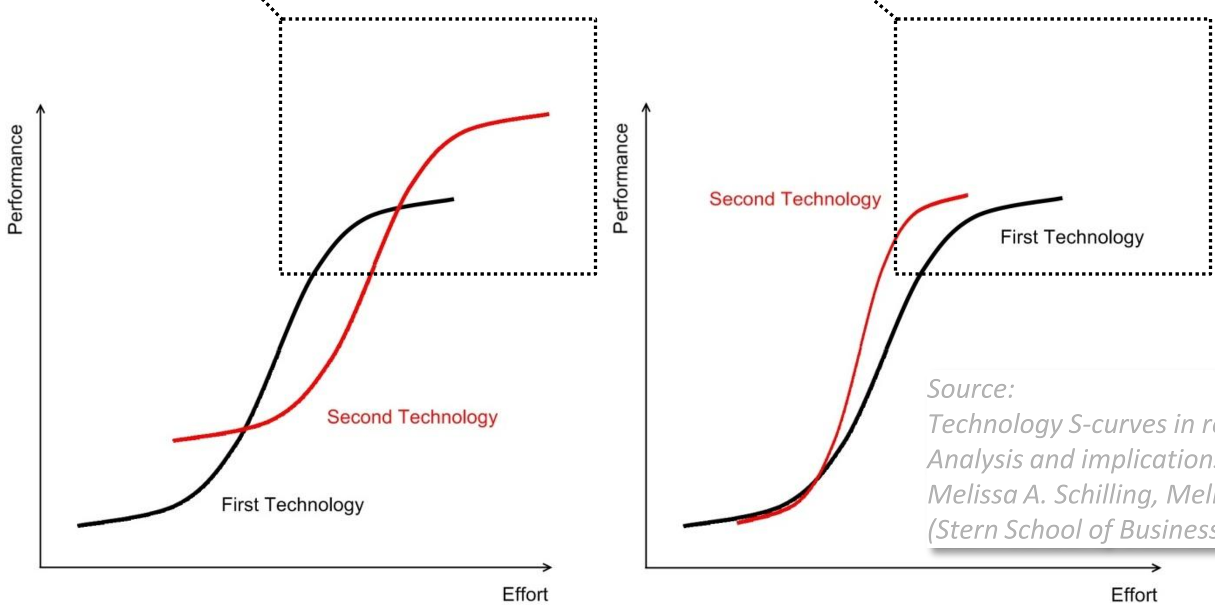
Geothermal vs Other Power Generation Systems



- at present, only **small plant sizes** possible (limited by mass flow)
- electrical efficiency **still low** but in range of small steam turbines
- ***Technical Improvements? → Technology S-Curves...***

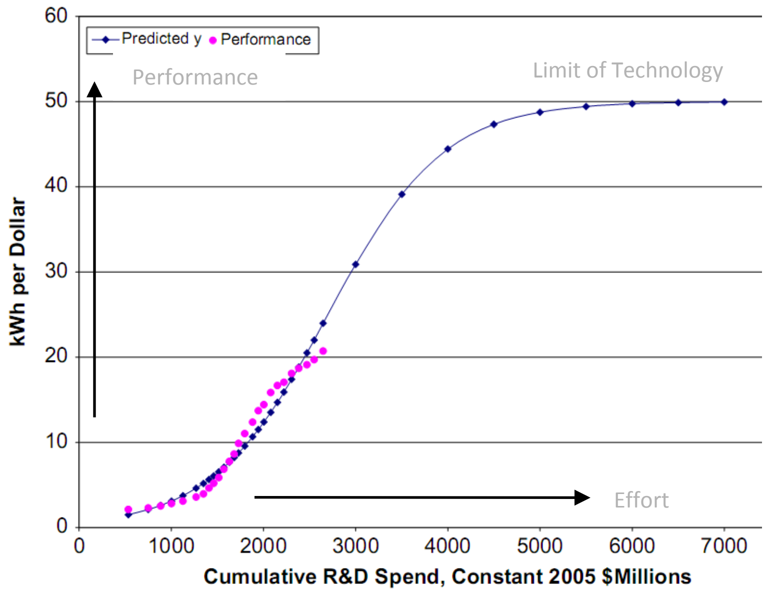
Technology S-Curves (theory)

- Technology S-Curves represent the “learning curve” of an industry
- **Effort** *(=cumulative expenditure)* is plotted vs a **Performance** Indicator *(=efficiency, cost per unit produced, etc.)*
- Deviations from the S-Shape can be caused by onset of a Second (Generation) Technology indicated either by
  - *an offset, similar shaped S-curve with an improved final performance or*
  - *a steeper inclination of the S-curve (faster “learning”, less effort)*

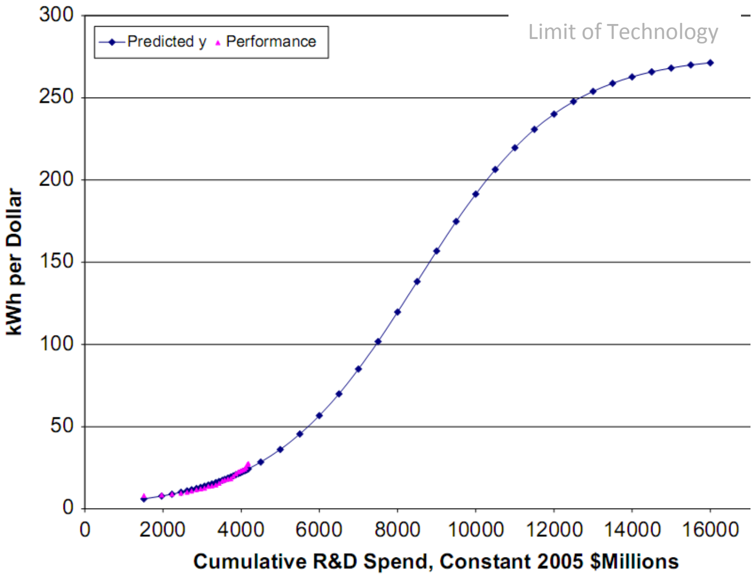


Source:
Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government
Melissa A. Schilling, Melissa Esmundo
(Stern School of Business – Feb-2009)

Technology S-Curves in Renewable Energy



Wind Energy



Geothermal Energy

Source:
Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government
Melissa A. Schilling, Melissa Esmundo
(Stern School of Business – Feb-2009)

Geothermal energy has **largest potential** of all renewable energies for fast and further improvement of technological efficiency

Valuation of Geothermal Projects

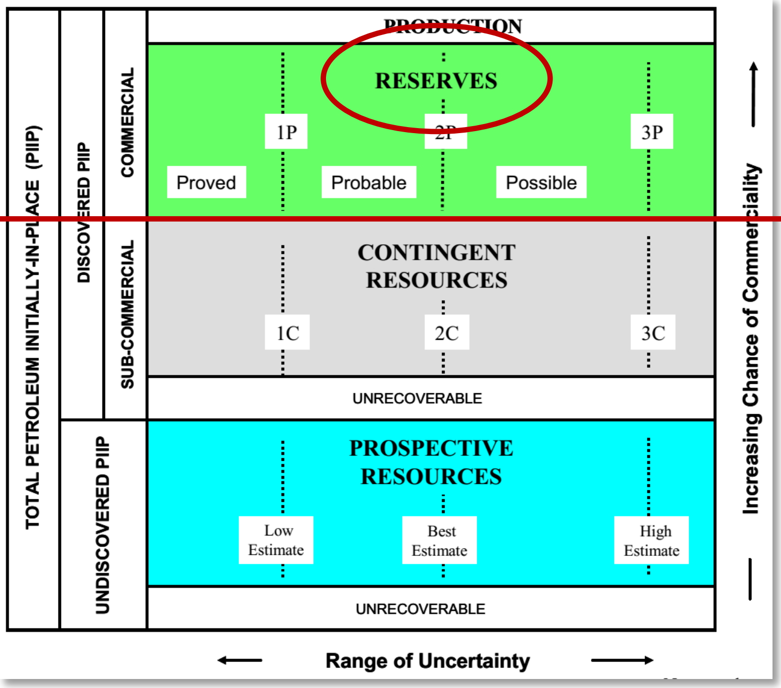
- A **risked valuation** of (geothermal) projects provides a method to
  - model contractual conditions
  - valuate reserves
  - assess risks expressed as economic indicators (NPV, PO, ROR, etc)
- Proven and Probable Reserves can be **valued and financed**
- Possible Reserves and Resources can be **valued but <u>not</u> financed**

Reserves and Resources Definition

- Society of Petroleum Engineers (SPE) has developed a Hydrocarbon **Reserves and Resource Classification**, which is meanwhile globally adopted by the industry, banks and stock exchanges
- It is suggested, that the Geothermal Industry should adopt a similar classification for its Geothermal Reserves and Resource base

commercial

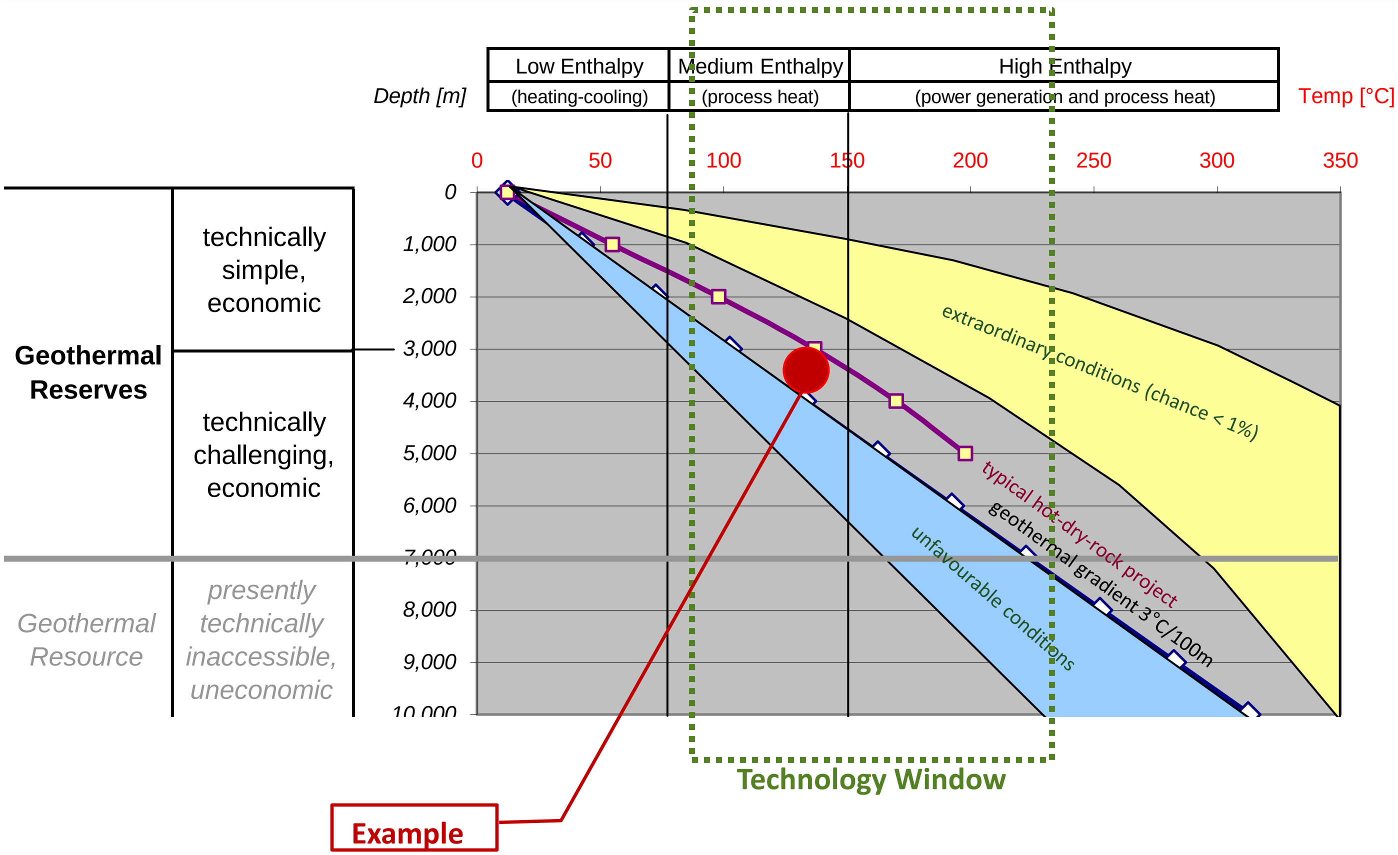
non-commercial



Source: SPE - Guidelines for Application of the Petroleum Resources Management System November 2011

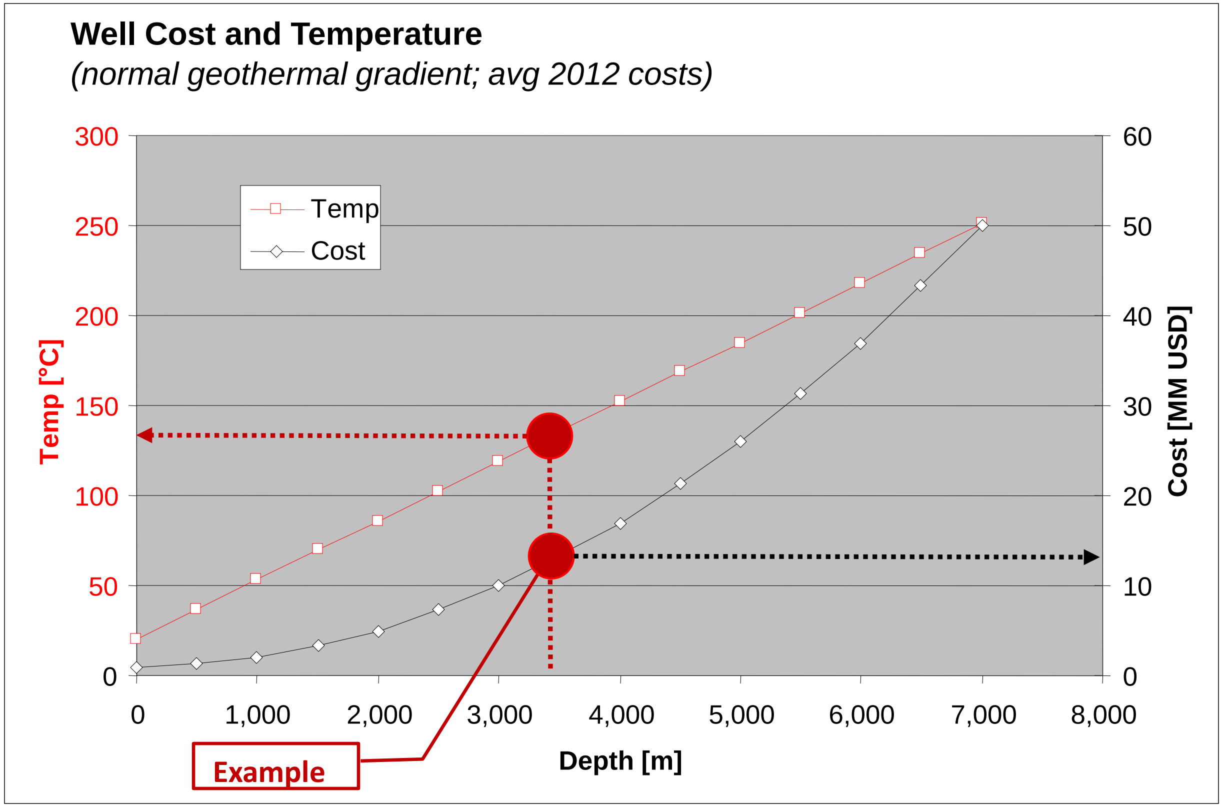
Reserves and Resources - Example

- Drilling technology and costs largely dictate cut-off between Geothermal **Reserves** and **Resources** (presently at +/- 7,000 m). Changes in energy cost environment shift limits up or down!



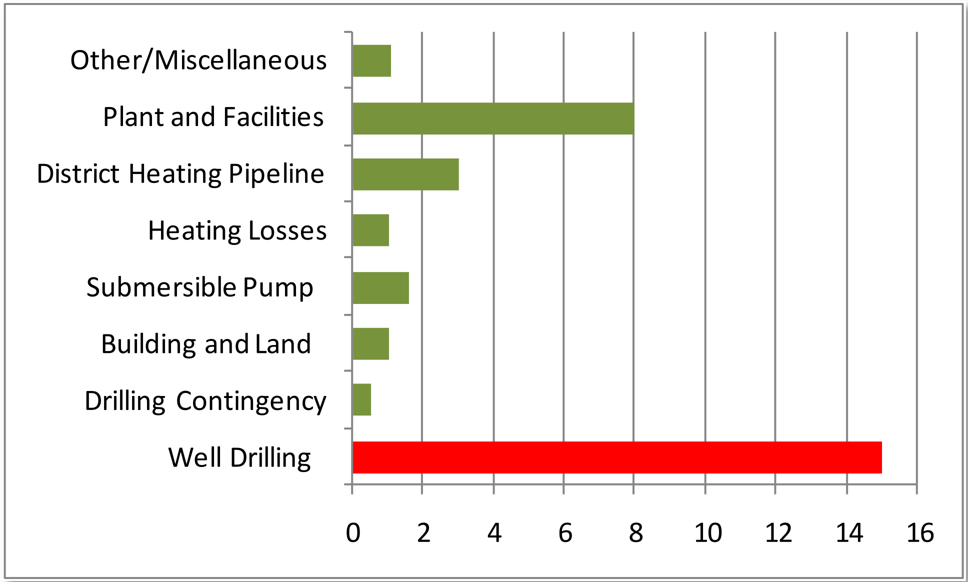
Example - Well Costs and Resource Temperature

- Estimate of Well Costs
- Depending on depth, wells represent ~50% of CAPEX…



Well Costs and Other Project Costs Assumptions

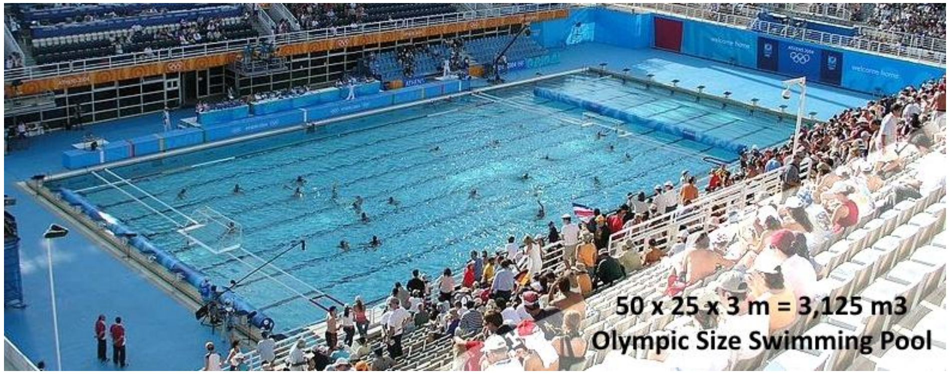
- Well Costs are **dominating cost element** (~50%)
- Capital Expenditures will vary with project type, location
- Used example is for an average geothermal power project with well depths at ~3,500 m well



Geothermal Project Economics – Assumptions (1)

Base Assumptions		Fill in value
Parameter		Calculated
Depth of the well	3,500	*[m]*
Geothermal gradient	0.038	*[K/m]*
Reservoir temperature	133.0	*[°C]*
Flow of the well	115.0	*[l/s]*
Well head temperature	128.1	*[°C]*
Reinjection temperature	55.1	*[°C]*
Conversion efficiency thermal power	96.0	*[%]*
Full load hours per year	8,000	*[h]*
Thermal Power	33.7	*[MW]*
Thermal Energy	269.8	*[GWh]*
Heating hours per year	3,200	*[h]*
Heating energy per year	107.9	*[GWh]*
Annual growth heat sales	2.0	*[%p.a.]*
District heating wholesale price per MWh	55.0	*[EUR]*
Electricity per year	19.4	*[GWh]*
Received price per MWh electricity sold	190.0	*[EUR]*
Size of electric power station	3.5	*[MW]*
Total Investment	31.2	*[MM EUR]*
Conversion efficiency electric power	12.0	*[%]*
Price increase for electricity bought	4.0	*[%p.a.]*
Price increase general costs	3.0	*[%p.a.]*
Price of CO_2 Emission	5.0	*[EUR]*
Capacity of 1 W =	1.16222	*[kcal/h]*

	115	[l/sec]
	6,900	[l/min]
	414,000	[l/h]
	9,936,000	[l/d]
	67,592	[bwpd]
	9,936	[m3/d]
Olympic Pool	**3,125**	**[m3]**



Geothermal Project Economics – Assumptions (2)

CAPEX

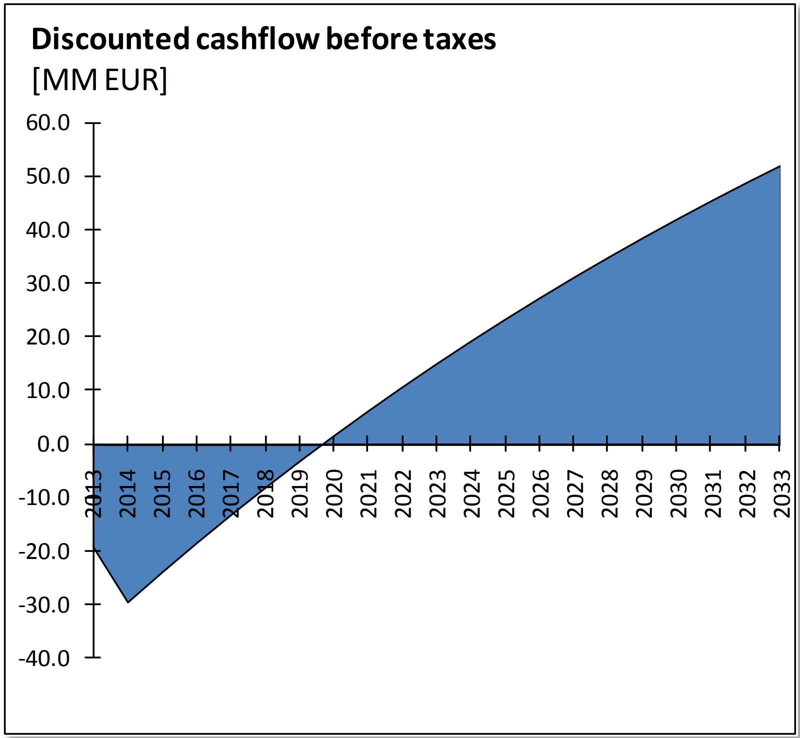
Parameter			*Depreciation*	
Drilling	15.0	*[MM EUR]*	30	*[yrs]*
Drilling reserve	0.5	*[MM EUR]*	30	*[yrs]*
Building & land	1.0	*[MM EUR]*	15	*[yrs]*
Pump	1.6	*[MM EUR]*	5	*[yrs]*
Heating redundancy	1.0	*[MM EUR]*	5	*[yrs]*
Heating pipeline	3.0	*[MM EUR]*	30	*[yrs]*
Electric power station	8.0	*[MM EUR]*	20	*[yrs]*
Other	1.1	*[MM EUR]*	5	*[yrs]*
Total CAPEX € million	**31.2**	*[MM EUR]*		

OPEX

Parameter		
Increase in provisions	48.0	*[M EUR p.a.]*
Material and third party costs	2,000.0	*[M EUR p.a.]*
thereof electric power	1,000.0	*[M EUR p.a.]*
thereof oil	0.0	*[M EUR p.a.]*
Personnel costs	100.0	*[M EUR p.a.]*
Other operating expenses	500.0	*[M EUR p.a.]*
Other operating		*[M EUR p.a.]*
Start up costs	1,000.0	*[M EUR p.a.]*
Maintenance	2.0	*[M EUR p.a.]*
Total OPEX	**4,650.0**	*[M EUR p.a.]*

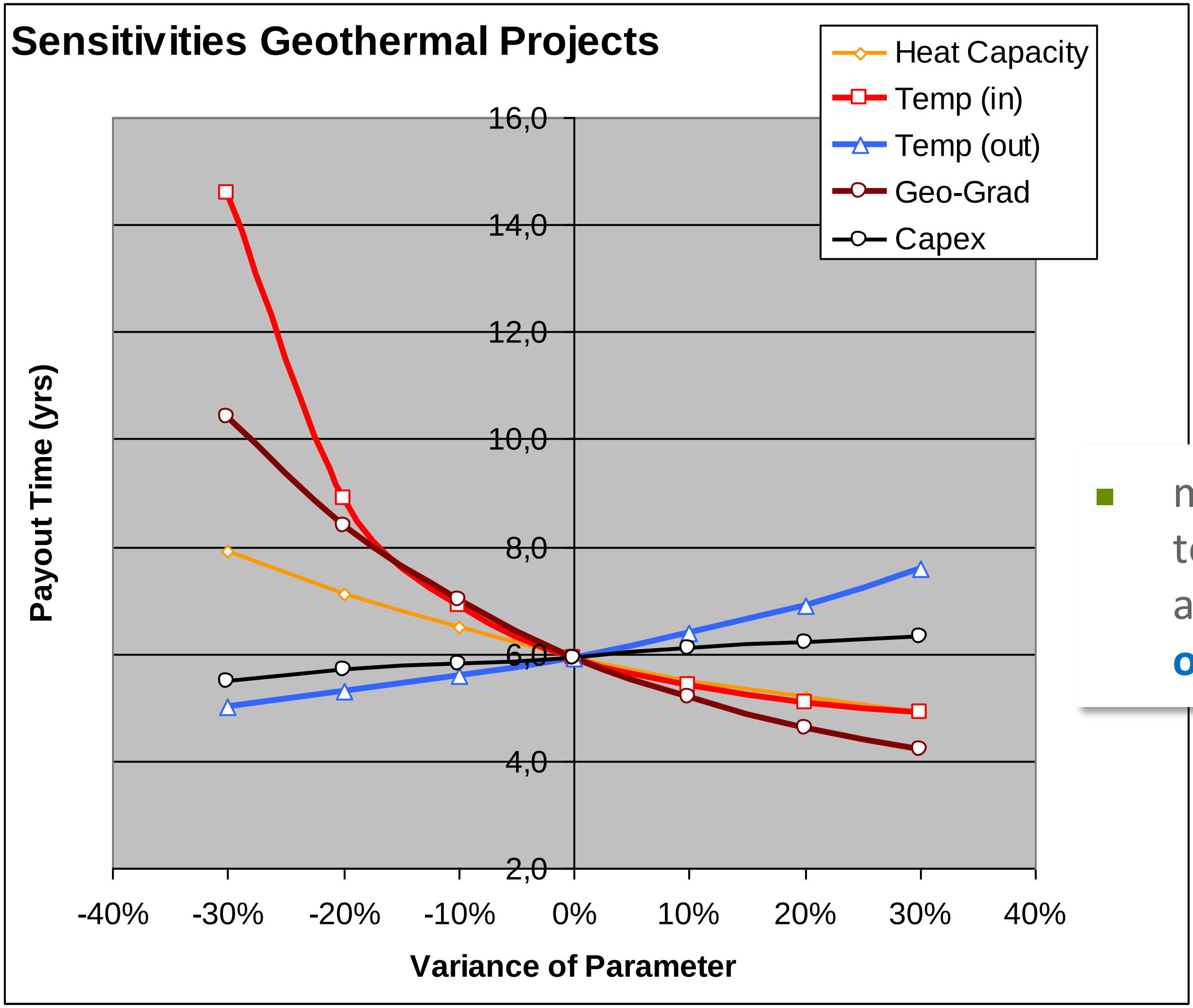
Geothermal Project Economics – Results

Results	BT	AT	
Internal rate of return (ROR)	20.4%	17.2%	*[%]*
Net present value (NPV)	52.1	39.3	*[MM EUR]*
Pay back period	6.6	7.8	*[years]*



- Detailed Economics include inflation, depreciation, before (BT) and after tax (AT) results
- Example shows very satisfactory economics → **but don't forget assumptions made**!

Geothermal Project Economics - Sensitivities



- most sensitive parameter: temperature difference across process (**inlet** vs **outlet** temperatures)

What is Geothermal Energy up against?

- Globally, **coal will remain dominant** on short term
- **Gas will eventually replace oil** – but ‘Peak Oil’ is a myth
- Despite Fukushima, **nuclear returns** (selective amnesia!)
- **“CCC” - Carbon Credit recovering** (a good chance to clean air)
- **Renewables will grow** – some places faster than others
- **Energy efficiency** is on the rise (car mileage, heating)
- Regionally, differences depend on geographic location, infrastructure, distance to resource → **no uniform picture!**

Geothermal in the Future Energy Mix - Summary

- Geothermal Energy has large potential to increase efficiency by technological advancements → **technological developments can (and will) improve situation**
- Low Enthalpy geothermal energy needs cascading heat recovery to be economic → **pure electricity generation (without direct heat use) will likely result in marginal economics**
- Electricity generation requires favorable investment environments → **supportive FIT schemes are growing globally**
- Projects must become and remain financeable → **clear and de-mystified definition of reserves and resources**
- Comparison to nuclear power generation needs transparency and fairness → **full cycle economics for nuclear fuels to include spent fuel storage and plant dismantling costs**
- Rise and maintain reputation of Geothermal Energy → **no corner cutting and 'cheap solutions'**

Geothermal in the Future Energy Mix - Summary

- Rise and maintain reputation of Geothermal Energy → **no corner cutting and 'cheap solutions'**

Thank You