

Long-Term Power Generation Visions in the Context of Economical and Political Realities

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Content

1. Global Context	Page 3
2. State-of-the-Art Technology and its Potential	Page 7
3. Analysis and Conclusions	Page 22

Vision for the Future



Everyone in the world can get access to energy and electricity according to his needs.

Basic right would increase worldwide installed power generation capacities to 25'000 GW (basis electricity consumption on North American level)

- ▶ What capacity is needed and possible considering all technical and political options

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Energy – the Foundation of Every Economy

Electricity generation represents **> 1/3 of worldwide** demand for primary energy

Global installed capacity for power generation: **4'550 GW (2008)**

1/3 of installed capacity **older than 30 years**

China: installed base at the end of 2008 was about **800 GW**

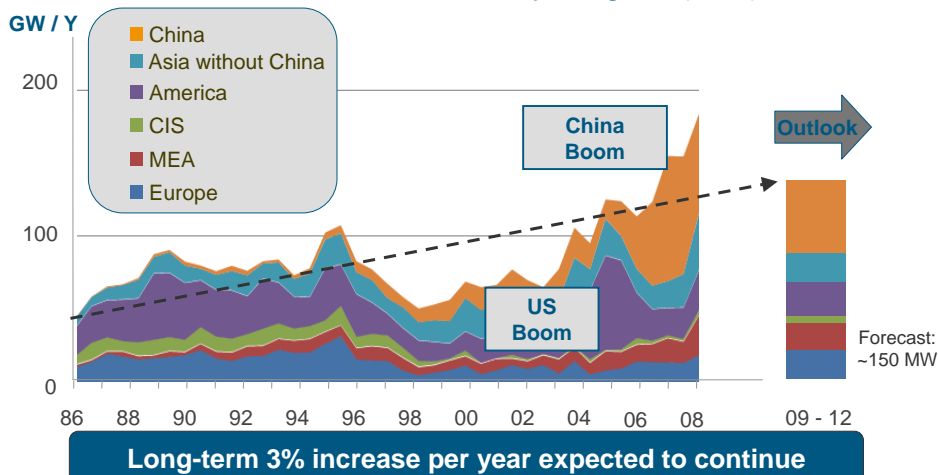
- ▶ Large installed base with high involved capital



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Economic Regions as Drivers: Peaks in Growing Markets

Power Plant Additions by Region (GW)



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Notes: Large GTs, Large Conv STs, ST CC, Nuclear, Hydro >50MW
Source UDI2008, CN official installed base, PS BD, MACA 2007

Power Generation – Drivers

Worldwide rise in **living standards**

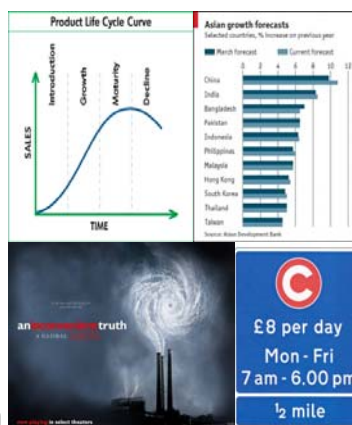
Increasing infrastructure needs in fast growing **emerging markets**

Stricter environmental regulation

Life-cycle extension of existing assets

Strong push towards **'clean'** technologies

Complex alignment of all economical, technical and political drivers



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Content

1. Global Context

Page 3

2. State-of-the-Art Technology and its Potential

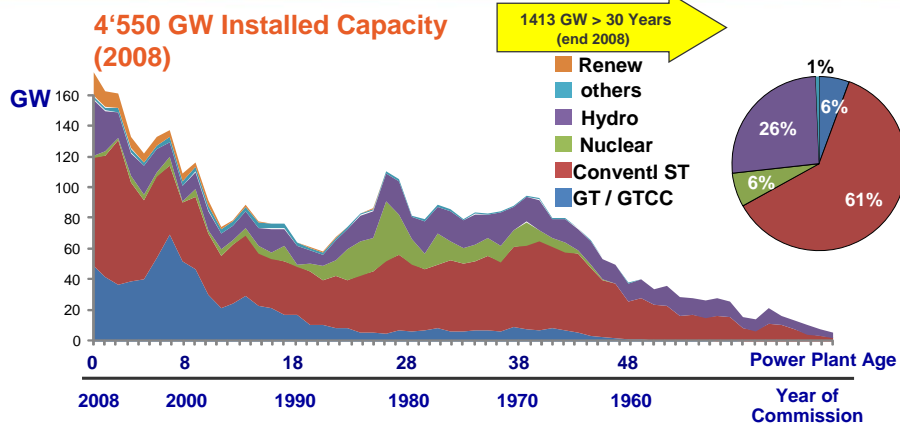
Page 7

3. Analysis and Conclusions

Page 22

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World Installed Power Generation Capacity By Age and Technology



▶ A growing fleet, old fleet dominated by coal-fired plants

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What Factors Influence the Future Energy-Mix?

Availability of resources (fuel)

Global and local **political interventions (Kyoto, etc)**

Technical **developments**

Regional factors (political and economic)

Desire for a **mix** of energy sources to ensure security of supply

▶ Objective is a **sustainable** electricity supply to support the development of all global economies in a balanced way

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Thermal Power Plants (Coal and Gas)

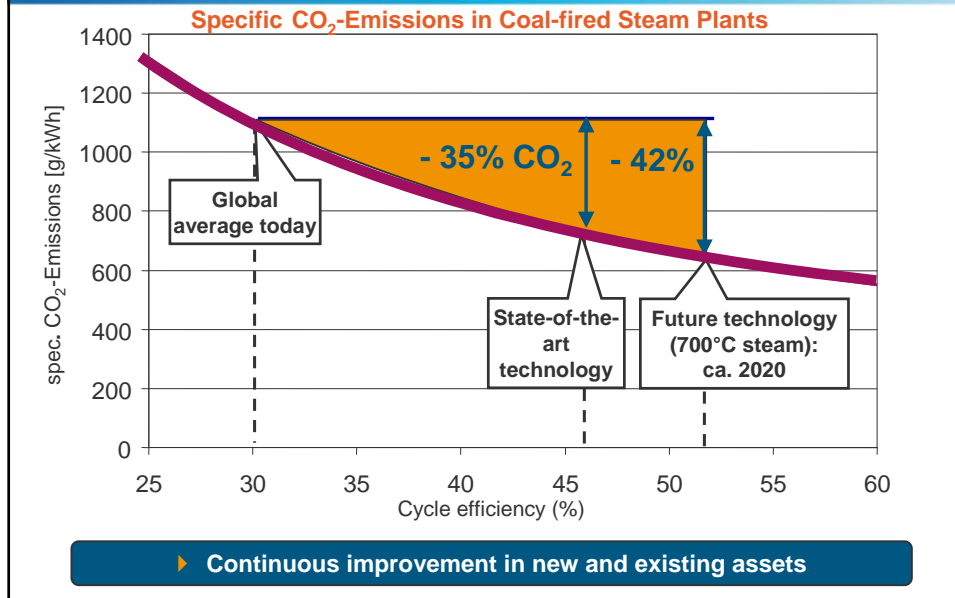
Backbone of today's electricity production worldwide

- Mature technologies with ongoing potential for continuous improvements
- Largest installed capacities today with a huge invested capital
- Availability of fuel in many areas in the world

▶ All identified improvement potentials need to be pushed to reduce the specific CO₂-emissions

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CO₂-Emissions – ex. Steam Power Plant



3 Basic Principles for CO₂-Separation

Before combustion

- Gasification
- H₂-combustion

As part of the combustion

- Combustion in pure Oxygen
- CO₂/H₂O-mix

After combustion

- Absorption process

- Technologies in development process (not yet industrially mature)
- Additional energy consumption in the range of 25-35%
- Cost estimate for the CO₂-capture process: 40-60 €/t CO₂

► Mid-term large potential but with material cost (as of ca. 2015 industrially available)

Pros and Cons for Conventional Power Plants (Coal and Gas fired)

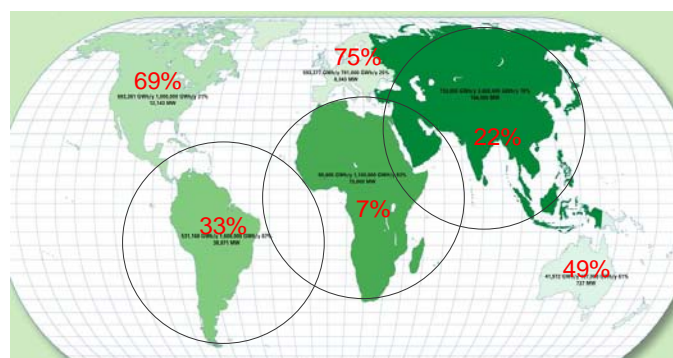
- + Well established and proven technologies
- + Fuel resources in many areas of the world available

- High CO₂-release (gas 2.5 x less than coal)
- Dependence of fuel-availability (i.e. gas)

- ▶ **New CO₂-concepts for sustainable long-term use**
- ▶ **Continuous improvements in efficiency are a must (for new but also for existing plants)**

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Hydro Power Plants



Globally only 33% of the potential is realized

No CO₂- issue but large and long-term investments

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Pros and Cons for Hydro Plants

- + No CO₂-emissions
 - + Well proven reliable technology (limited further development potential)
 - North America und Europe only with limited additional potential for new built
 - Strong political and ecological resistance against large new plants
- ▶ **Additional potentials** specifically in Asia and Africa
 - ▶ **Trend in Europe to extend current mid-sized plants towards pump storage plants**

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Solar Thermal Power Plants – the 3 Major Concepts



- ▶ **No industrial maturity yet and relative high cost**
- ▶ **Large potential mid-/long-term in combination with other new developments (Energy/Hydrogen storage)**

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Pros and Cons Solar Thermal Power Plants

- + No CO₂-emissions
- + High political acceptance

- Highly dependent on daytime and geographical region
- Today very high production cost (special funding required)

- ▶ Today technologies not yet economically and industrially mature
- ▶ Mid-term break through with solution for transport/storage of electricity with an auxiliary medium

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Wind Energy – Renewable Energy with Largest Growth Today

Expectation for 2020 globally: 1000 – 2000(?) GW installed



- About 20 GW new capacity yearly
- 25% growth per annum
- Today >100 GW installed capacity

- ▶ Technology comes to industrial maturity
- ▶ In specific regions large potential to be realized

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Pros and Cons for Wind Energy

- + No CO₂-emissions
- + Regions with material potentials

- Relative low availability < 2'500 h/year
- High production cost and visible impact on landscape

- ▶ Due to **low availability** high electricity cost
- ▶ Only **feasible linked with other electricity production** (pump storage or gas combined cycle)

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Nuclear Power Plants

In Europe 1750 MW reactors are under construction



- >500 units globally in operation
- Advanced security systems
- Generally mature technology, but design update with new engineers is the challenge
- Cost management for new plants critical success factor (economy of scale)

Installed fleet solid contributor to electricity base load, high utilization of assets

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Pros and Cons for Nuclear Power Plants

- + No CO₂-emissions
- + Well proven technology with upgrade potential (high unit power >1'000 MW and cost efficient in running plants)

- Different political approach per country
- Missing political will to resolve long-term storage of nuclear waste

- ▶ **Security and waste issues** are primarily political matters
- ▶ **Large differences** in the approach of the various countries

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Content

1. Global Context	Page 3
2. State-of-the-Art Technology and its Potential	Page 7
3. Analysis and Conclusions	Page 22

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Vision for the Future - What is Realistic?



Practical limitations
in technology and economy!

R&D be organized to achieve
fastest good results?

Players in this fields:
Industry, Universities and
Research Centers

Funding of long-term projects
as well as qualified human resources
are key success factors

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Technology Development on the Time Scale

From Visions to Realities is the Challenge

**Short-term projects
(5 to 8 years):**

Improved state-of-the-art technology
Experiences and limited risk

**Mid-term projects
(8 to 15 years):**

Clear step up in technical parameters
New materials and processes
Advanced new manufacturing procedures
Good view on potential business plan
but material risk for failure

**Long-term projects
(15 to 50 years):**

Think "out of the box"
Develop visions towards reality
No business vision yet
and success uncertain

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Players to accept their Roles

<p>Industry</p>	<p>Typically 2-5% of sales invested in R&D Continuous improvements, limited step changes Limited risk taking (protect shareholders' value)</p>
<p>Universities / R&D Center</p>	<p>Longer term view and development of basics Cooperation with industry for further advanced projects</p>
<p>States / Governments</p>	<p>Investments for long-term projects with high uncertainties Funding limited and subject to a political distribution process Re-allocation of tax money according to short-term priorities</p>

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Power Generation – Drivers and Conclusion

Worldwide rise in **living standards**
 Increasing infrastructure needs in fast
 growing **emerging markets**
Stricter environmental regulation
Life-cycle extension of existing assets
 Strong push towards '**clean**' technologies



Complex and long-term issue
 Close link between available
 technologies and the political
 realities
 Major impact on the sustainability
 of our world (climate change)

► **Resolutions of all the issues require time and capital, but can only be done with a well global coordinated approach**

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