Load Change and Power Storage Requirements for Renewable Energies

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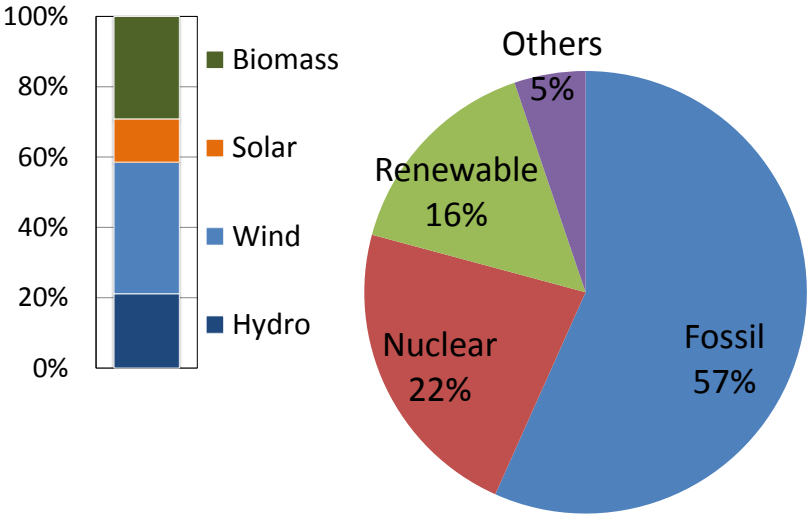
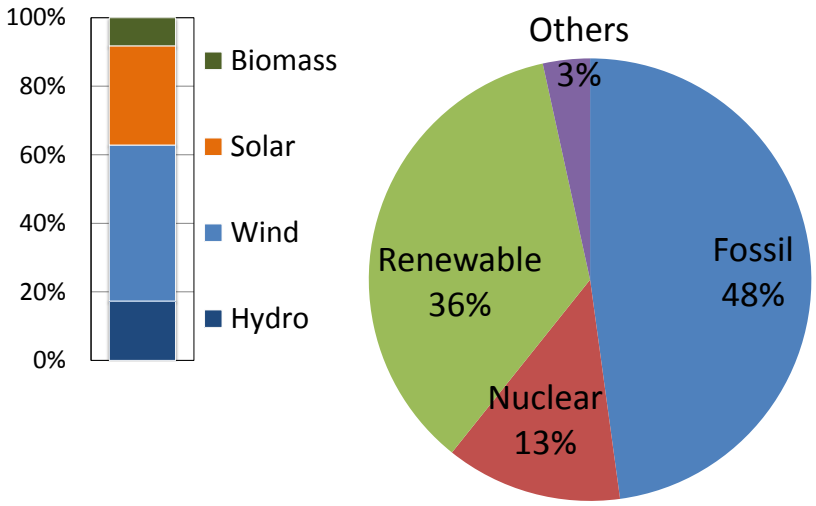
Where do we get our power from?

Power Generation	In 2010
Renewables	98 TWh
Wind	37 TWh

Power Generation in 2010: 625 TWh



Capacity installed in 2010: 153 GW



Capacity	in 2010
Renewables	60 GW
Wind	27 GW

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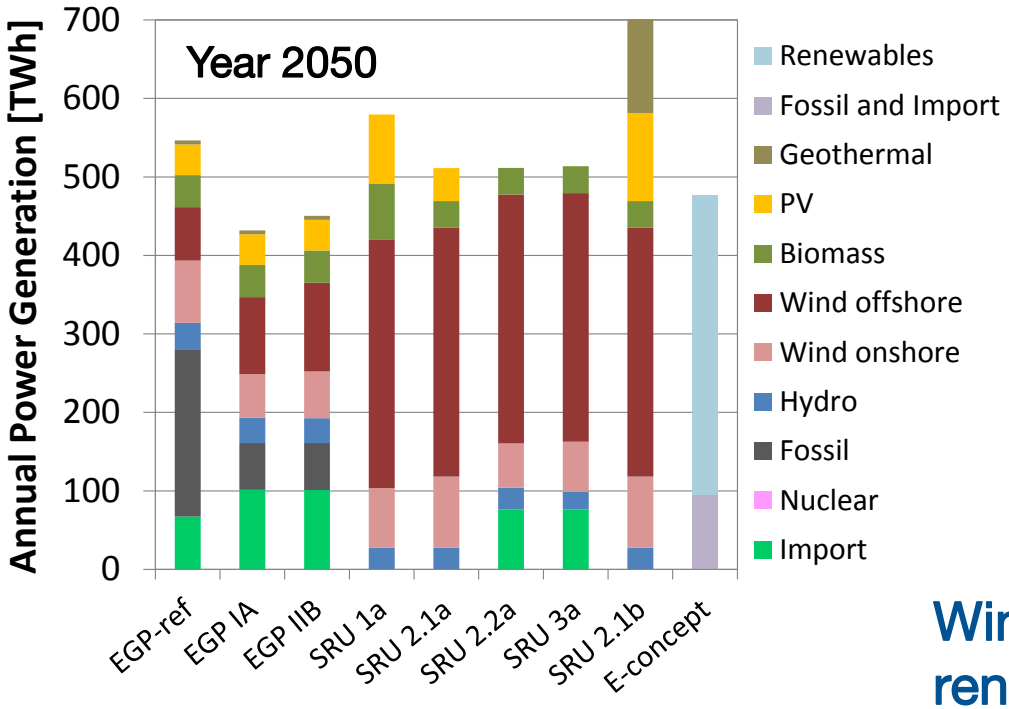
Where are we going?

- Shut down of nuclear power plants
- Reduction of CO_2 emissions

Capacity	in 2010	in 2050*
Renewables	60 GW	~170 GW
Wind	27 GW	50-110 GW

*average and ranges for different scenarios



Wind is and will be the most important renewable energy source !

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Outline

- Analysis of wind data in Germany
- Load change requirements to balance fluctuations
- Energy storage requirements to balance fluctuations
- Technical options for power storage
- Future power plant concepts

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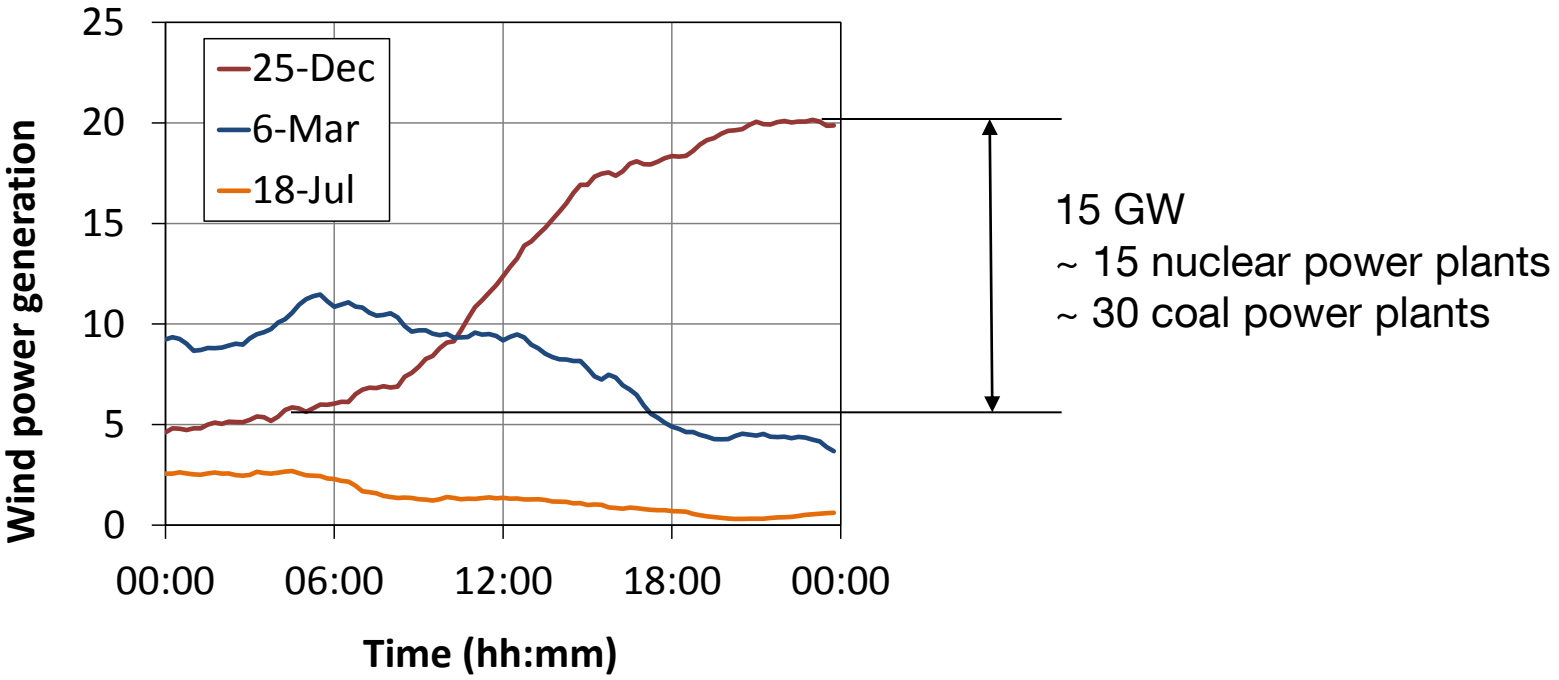
Analysis of Wind Power in Germany I

- 15 min data for Germany Nov 09 – Aug 10
- Installed Capacity: ~ 26 GW



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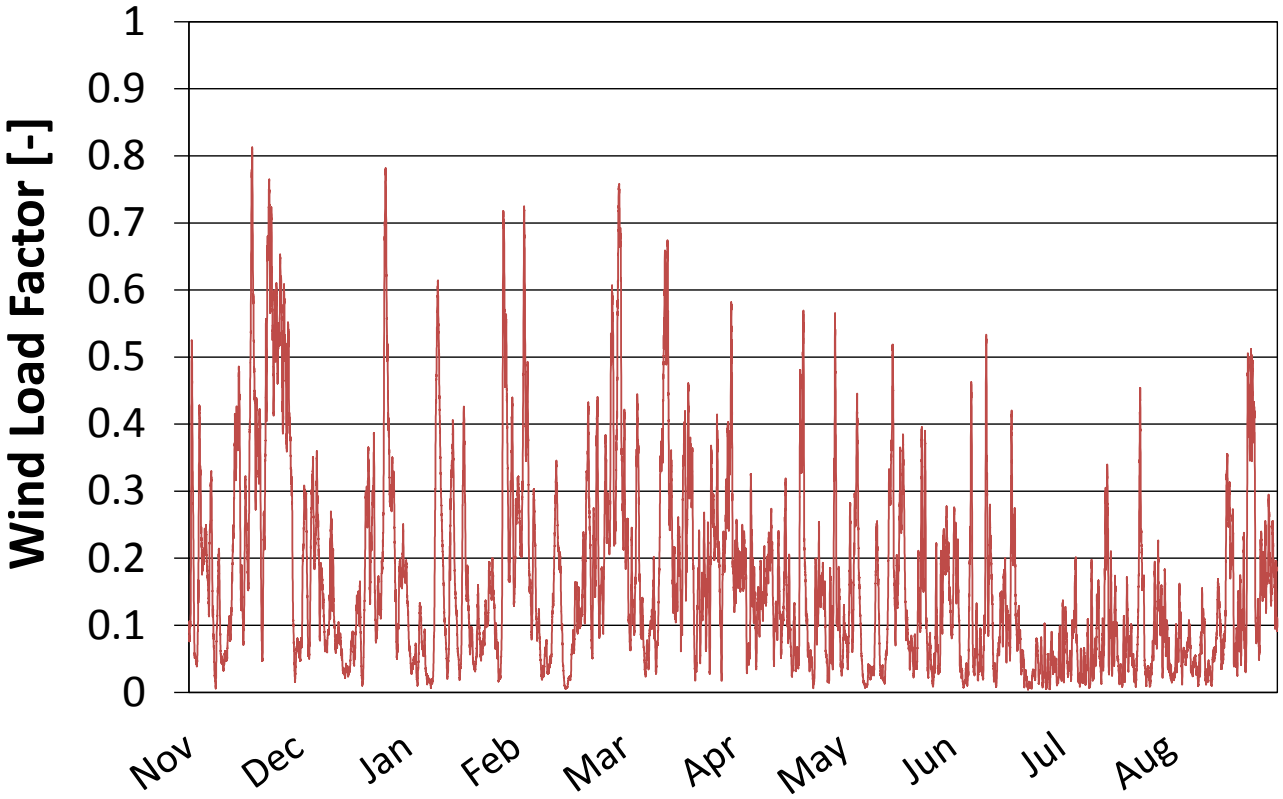
Analysis of Wind Power in Germany II



Results

- High fluctuation
- Average load: 16.3% (4.2 GW)

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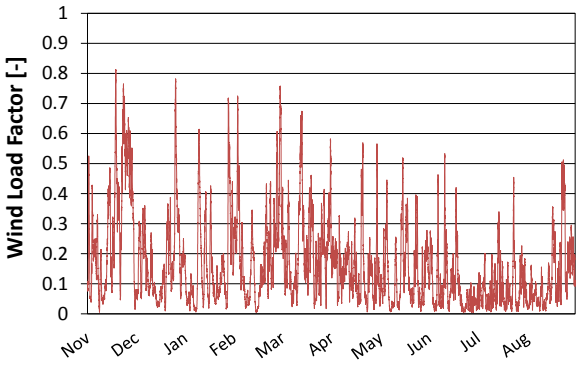
Load Change Requirements



- Numerical differentiation for 15 min intervals

$$\text{gradient}\left[\frac{\text{GW}}{\text{h}}\right] = \frac{P_2 - P_1}{t_2 - t_1}$$

- Wind gradient = Gradient to be balanced by conventional/new systems

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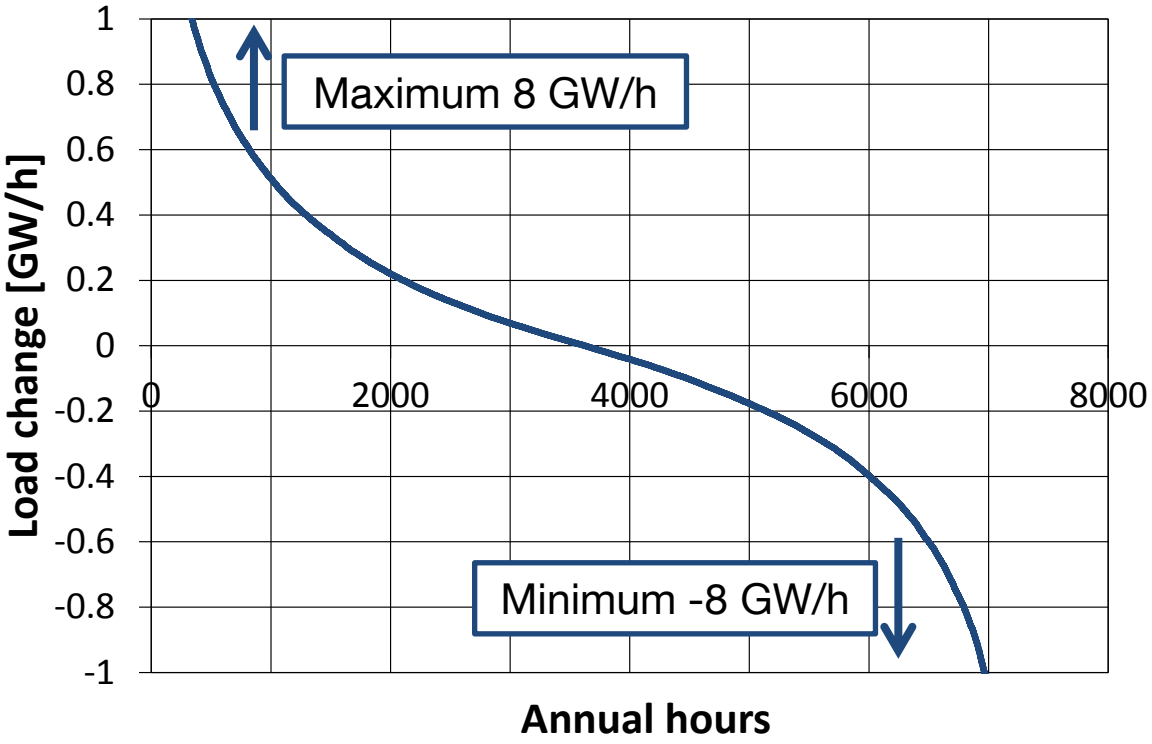
Load Change Requirements



Installed Capacity	
2010	27 GW
2050	50-110* GW

Load change flexibility of existing power plants

- State of the art power plants (hydro, coal, gas)
- Combined cycle flexibility: 4-8 %/min (≈ 1.2-2.4 GW/h per power plant)

* 53.4 GW (EGP-Reference), 60.9 GW (EGP-IIB), 106.3 GW (SRU-1.a), 112.7 GW (SRU-2.a)

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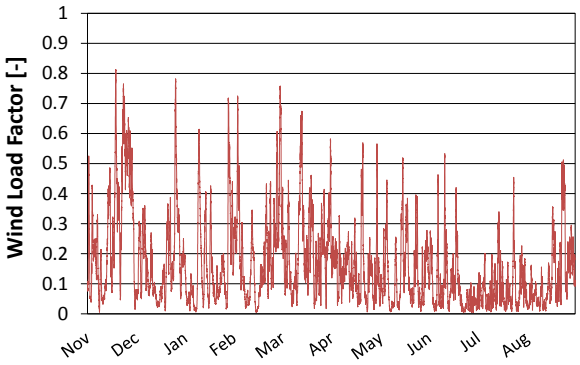
Power Storage Requirements



- **Assumption:** Wind is in base load (4.2 GW)
- Current overproduction is stored
- Underproduction is balanced by storage
- Numerical integration for 15 min intervals

$$\text{storage level [GWh]} = S_{n-1} + \left(P_n - P_{average}\right) \cdot \left(t_n - t_{n-1}\right)$$

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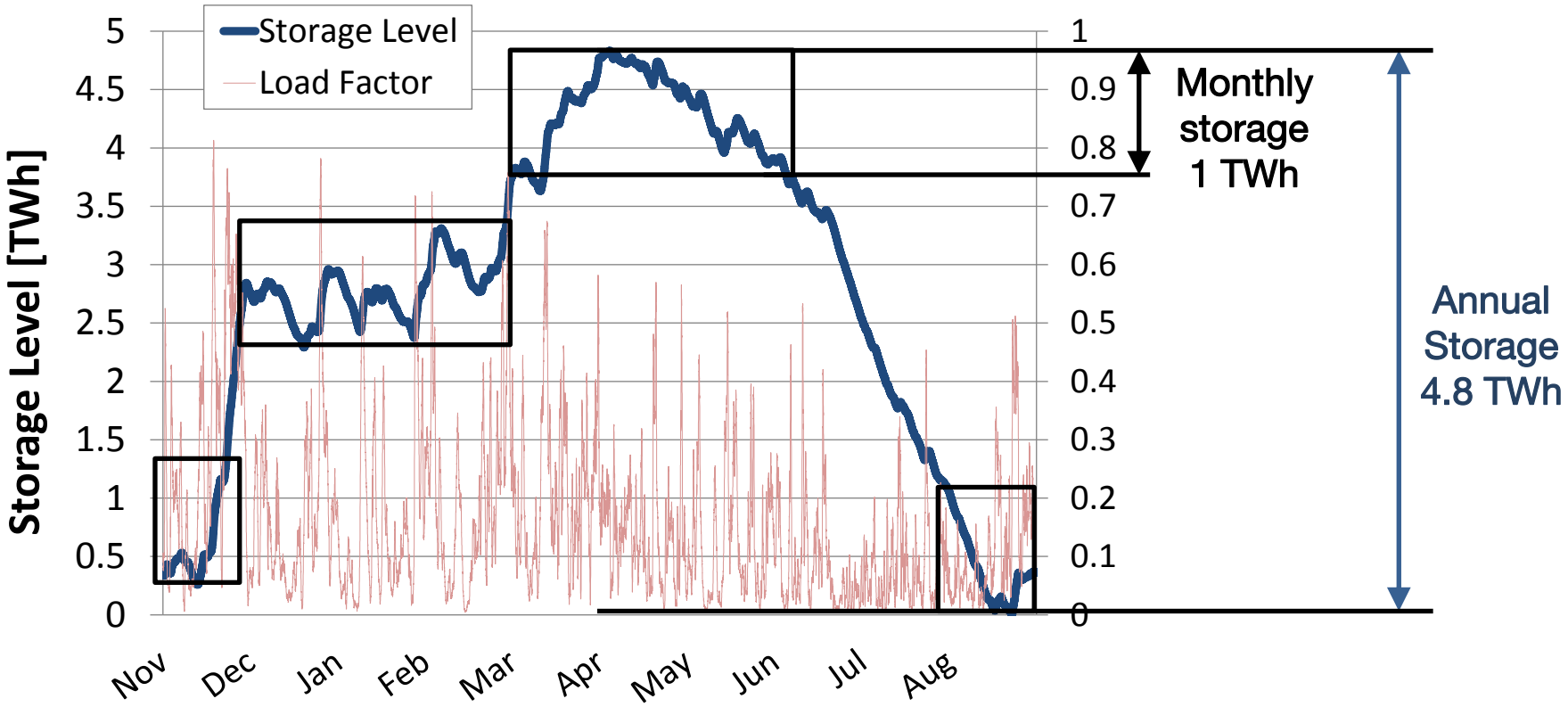
Power Storage Requirements



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Storage Requirements and Capacity

Storage Requirements for Wind Power

- Annual Storage 2009/2010: 4.8 TWh
- Monthly Storage: ~ 1 TWh

Power Generation	in 2010	in 2050*
Renewables	98 TWh	~430 TWh
Wind	37 TWh	150-400 TWh

* 53.4 GW (EGP-Reference), 60.9 GW (EGP-IIB), 106.3 GW (SRU-1.a), 112.7 GW (SRU-2.a)

Huge gap between current technology and future requirements !

Currently Discussed Storage Options and Capacities

- Hydro pumped storage ▶ Goldisthal 8.5 GWh
- Compressed air storage ▶ Huntdorf 0.58 GWh
- Electromobility ▶ 1 million cars (Tesla Roadster): ~50 GWh

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Chemical Storage Potentials

Storage Requirements for Wind Power

- Annual Storage 2009/2010: 4.8 TWh
- Monthly Storage: ~ 1 TWh

- Huntdorf 0.58 GWh

Huntdorf filled with H_2: 0.04 TWh

Huntdorf filled with CH_4: 0.32 TWh

1 TWh Fischer Tropsch Fuel = 100,000 m³ = 1/3 oil tanker

What can be the technology ?

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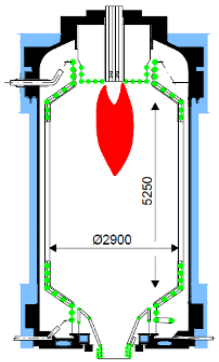
Power Generation based on Gasification

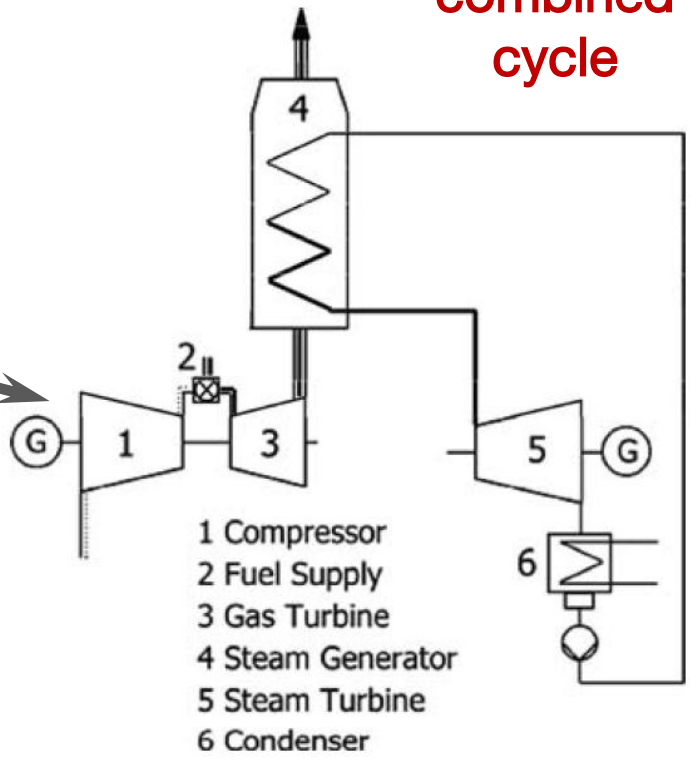
Solid Fuel

Gasifier



CO, H_2

Gas turbine combined cycle



Power

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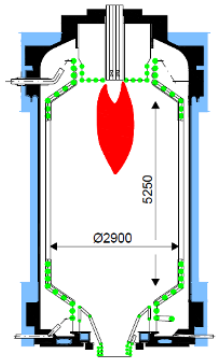
Flexible Power Plant Concept

Solid Fuel

Gasifiers



Renewable Power

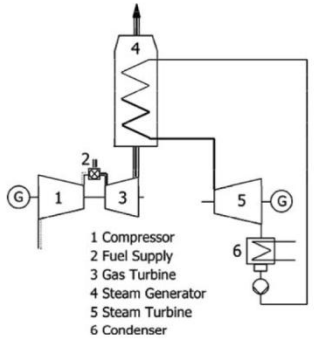
Electrolysis

CO, H_2

Chemical Synthesis

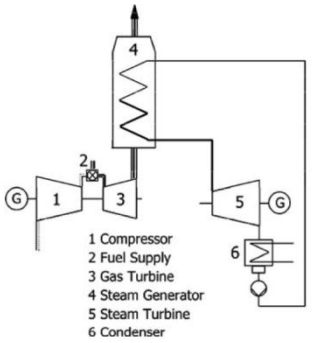
Storage

Methanol
SNG
FT
...



Combined cycles

Flexible power production



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Conclusion

- Wind is a very important renewable energy source
- Wind is fluctuating
- A simple approach for the evaluation of load change and power storage requirements
- Load change -> state of the art technology
- New technologies are required for large scale power storage

Future Work

- Analysis of requirements to balance wind and solar
- Integration of power consumption fluctuations
- Development of future power plant concepts with integrated storage capacity

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Thank you for your attention !

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