Solid Fuel Gasification: an Old Technology with Modern Challenges

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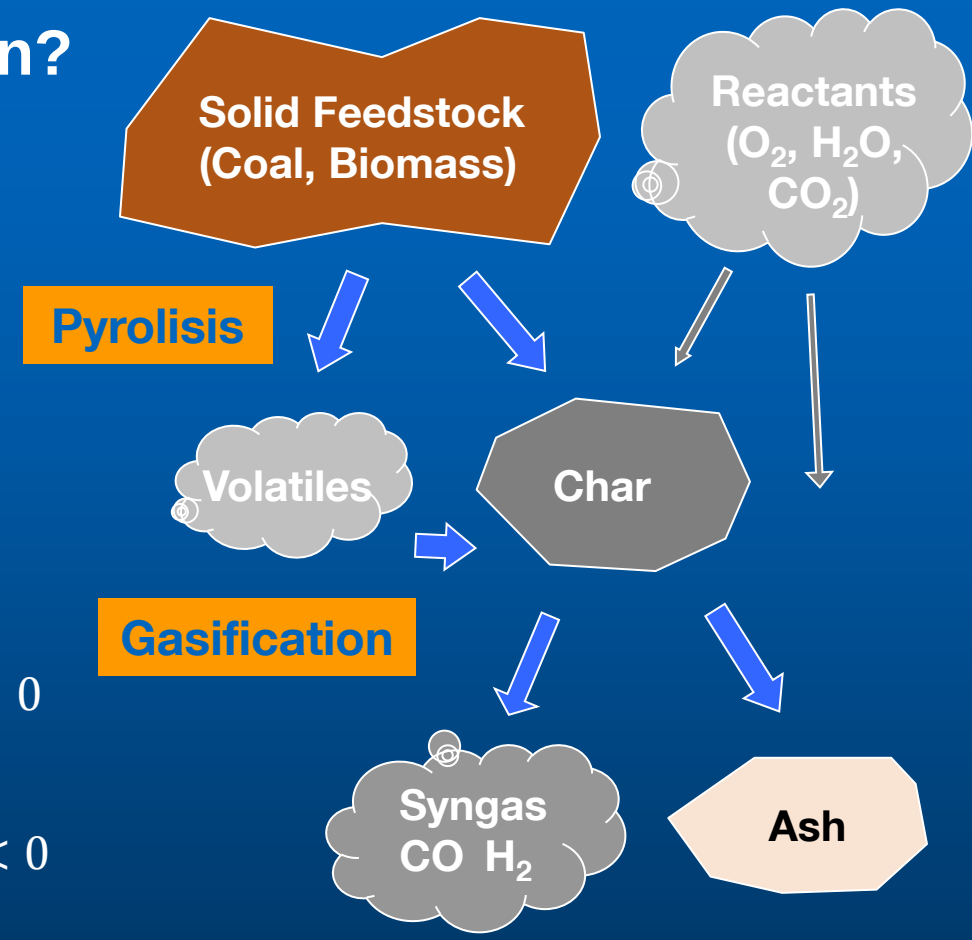
Outline

- What is solid fuel gasification?
- Gasification through History
- Which are the Challenges?
- Which role will this technology play in the future?
- Activities at the chair of energy systems

What is solid fuel gasification?

- It is a chemical process which converts a solid feedstock in an energetic gas stream (or Syngas) mainly composed by Hydrogen and Carbon Monoxide.



- Boudouard :

$$C_{(s)} + CO_{2\,(g)} \leftrightarrow 2CO_{(g)} \qquad \Delta H^0 < 0$$

- Water gas reaction :

$$C_{(s)} + H_2O_{(g)} \leftrightarrow H_{2\,(g)} + CO_{(g)} \qquad \Delta H^0 < 0$$

- CO shift reaction :

- $$CO_{(g)} + H_2O_{(g)} \leftrightarrow H_{2\,(g)} + CO_{2\,(g)} \quad \Delta H^0 < 0$$

High temperature process!!

Gasification through History

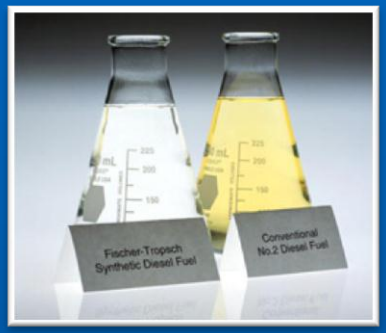
Charcoal Production is known since centuries: Pyrolysis of biomass (wood) to obtain a carbon rich fuel

First and second Industrial revolution in the 19th century: town gas was produced from coal to supply fuel for street lights, domestic heating and cooking

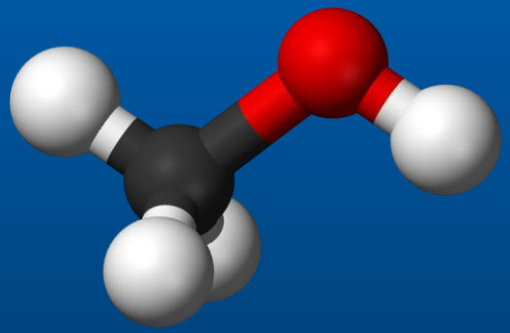
During the World War 2, shortage of oil (especially in Germany) drove the development of integrated gasification systems on Vehicles (charcoal or coal).

Gasification through History

The Fischer-Tropsch process to produce hydrocarbons (Diesel, Lubricants etc.) from syngas sped up the industrialization on a large scale of this technology



Source: http://www.nrel.gov

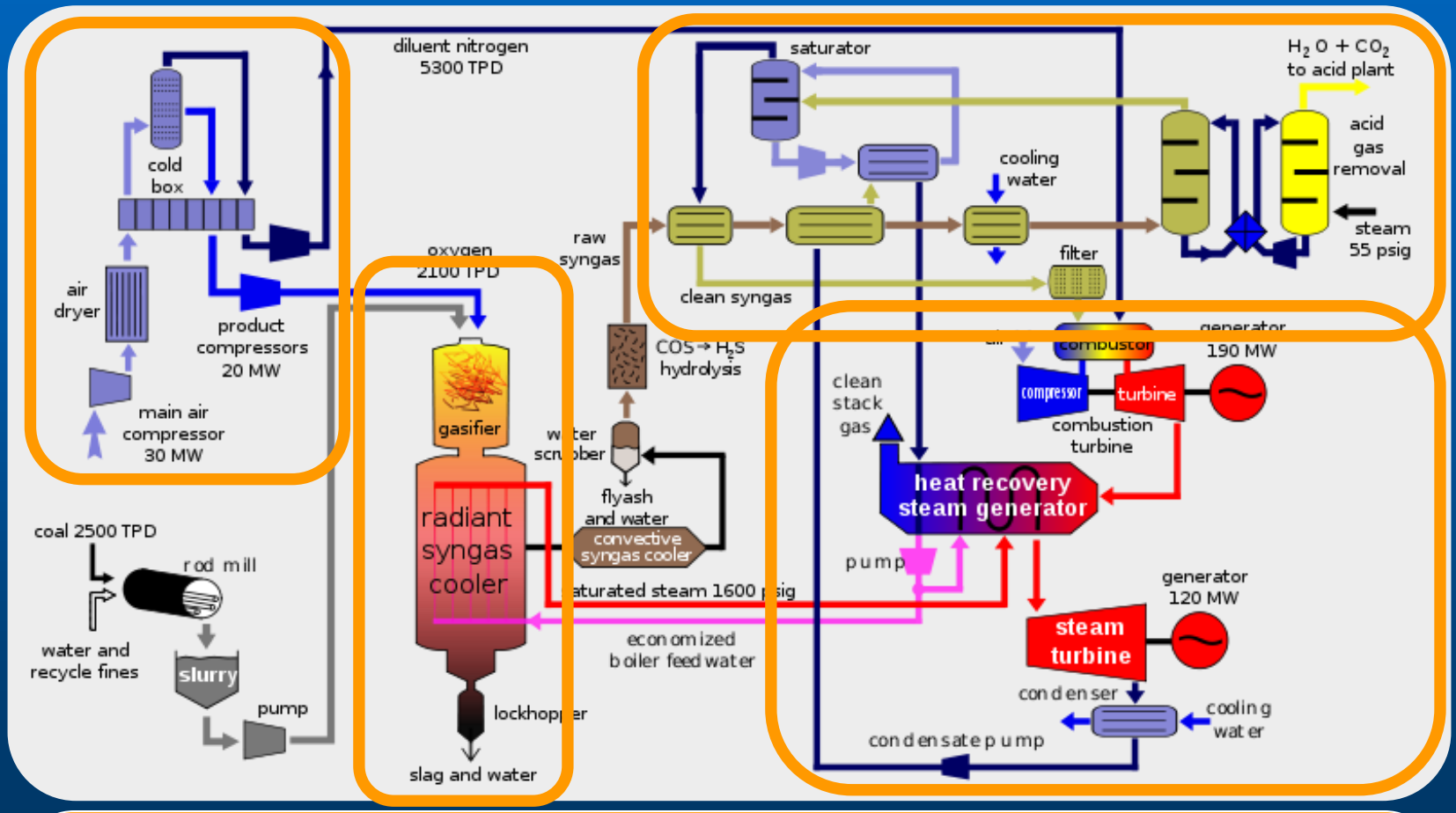


During the second half of the 20th, solid fuel gasification has been mostly used for the chemical industry: ammonia, methanol and SNG (substitute natural gas) syntheses.

Only during the last 30 years, the interest arose to apply this technology for power production:

Integrated Gasification Combined Cycle (IGCC)

Modern Challenges: IGCC Power Plant



Source: netl.doe.gov

GAS TURBINE COMBINED CYCLE

- Produce electric power combining gas and steam turbines

Modern Challenges: IGCC Power Plant

Advantages:

- High efficiency ε ≤ 45% (NG Combined Cycle ε ≤ 58%)
- Effective pollutants removal in the gas stream
- CO_2 capture

Disadvantages:

- High investment costs (25% more respect to conventional systems)
- High level of integration leads to:
  - the need for an accurate control system
  - low flexibility (base load)

Modern Challenges: IGCC Power Plant

Increase the efficiency:

- Hot gas cleaning system (1200˚ C instead of 300-400˚ C)
- Increase integration

CO_2 separation and storage (CCS)

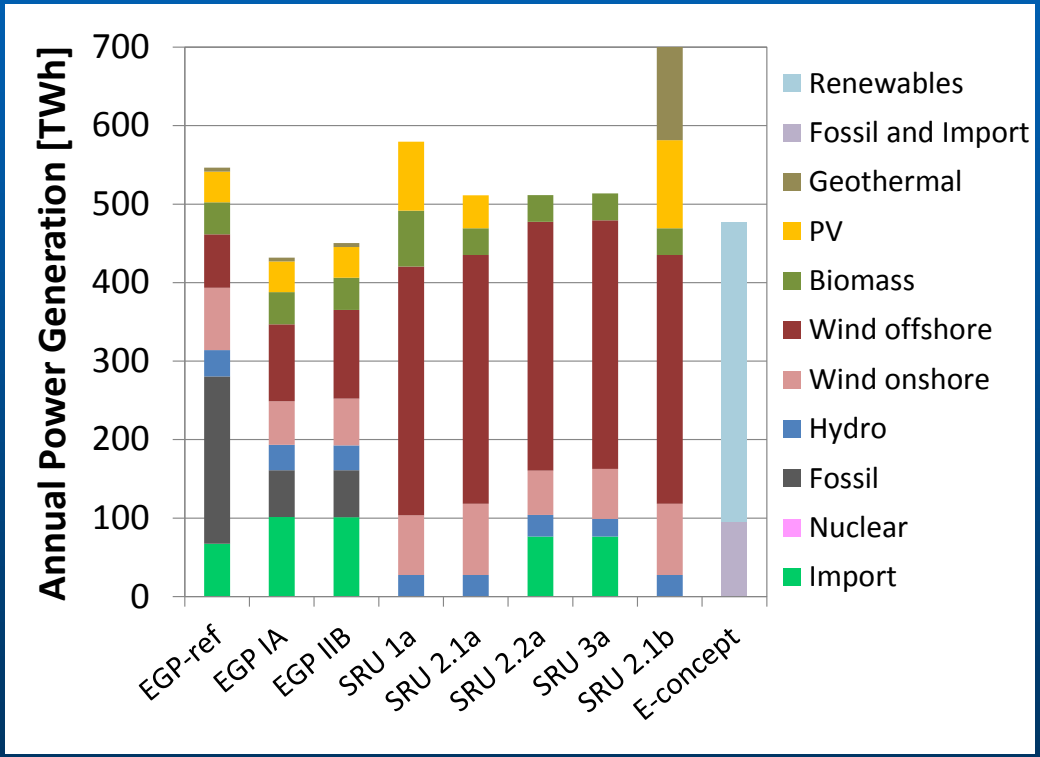
- Design of membrane shift reactor in which Hydrogen and Carbon Dioxide are produced and simultaneously separated
- Integrated CCS affects greatly the overall efficiency

Versatility of the feedstock

- Every Feedstock has different gasification behavior
- Optimization of the gasification chemistry

Which role will this technology play in the future?

Different Scenarios in Germany for the year 2050



Source: DLR, BMU, BMWi

- Massive presence of Renewables in all the scenarios
- Shut down of nuclear power plants in 2020
- 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

Which role will this technology play in the future?

Need for the future to follow the demand and to cope with the variability of the renewable sources!

Increase storage capacity!

- CAES Compressed air in geological cavities
- Pumped-storage Hydroelectricity (PSH)
- Battery Clusters
- Thermal Energy Storage
- **Chemical synthesis**

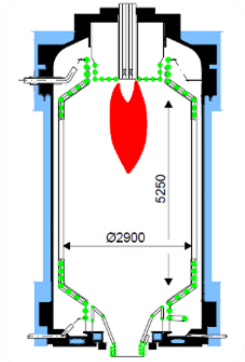
Which role will this technology play in the future?

Solid Feedstock

Renewable Power

Electrolysis

H_2



Gasifier

CO, H_2

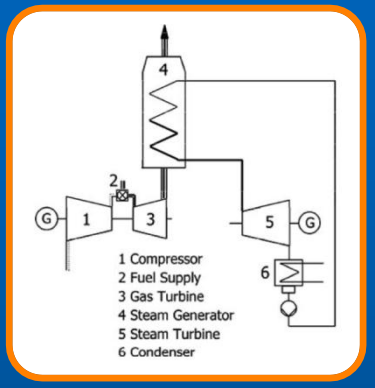
Syngas

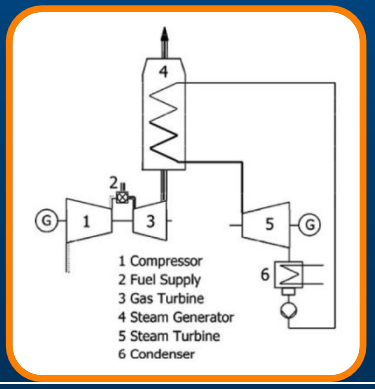
Chemical Synthesis

- Methanol
- SNG
- FT liquids

Storage

for SNG and FT fuels infrastructures are already present



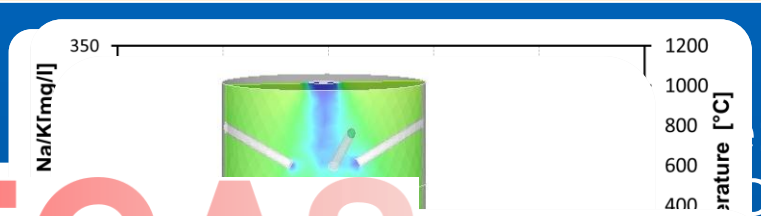


Flexible power production with combined cycles

Activity at the Chair

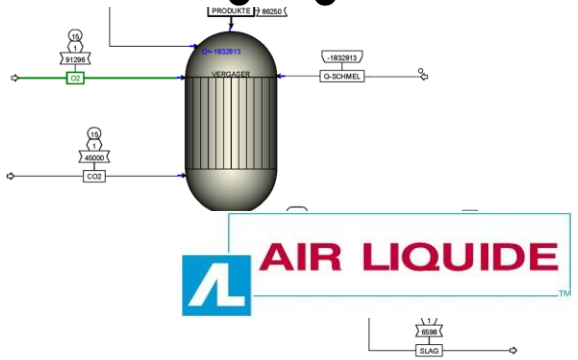
- Investigation of gasification kinetics
- Study on th
  trace eleme
- CFD simulations for IGCC power
- d fuel

Gasifier flowsheet



HOTVEGAS

Hochtemperaturvergasung und Gasreinigung



VORWEG GEHEN

Bundesministerium für Wirtschaft und Technologie

AIR LIQUIDE

VATTENFALL

SIEMENS

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Conclusion

- Alternative Technology to use solid/fossil fuels for power production
- The technology can meet low emission standards
- Concrete possibility to capture and store CO_2
- With increasing share of renewable energy, the design offers high flexibility through the integration of electrolysis and chemical synthesis
- No commercial power plants in operation until now
- Economically not competitive until the price of energy rises and CO_2 trade emission market grows

Thank you for your attention!