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Toward Green and Blue Ammonia

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CASALE SA

- CASALE SA is an engineering/technology company founded in 1921 to sell ammonia plants, its headquarter is in Switzerland
- It has his own design for ammonia plants and for the main equipment like reactors and critical heat exchangers, and more recently a synthesis catalyst, together with Clariant
- The CASALE synthesis technology is applied in more then 200 plants worldwide

Market Changes

- Ammonia market will be subject to important changes in the next decade, two contrasting forces will appear:
  - The introduction of fertilization by atmospheric nitrogen fixing bacteria, replacing synthetic ammonia
  - The utilization of ammonia as fuel and energy vector, increasing ammonia demand

Market Changes

The utilization of ammonia as fuel and energy vector

- This development will likely involve an increase in demand larger then the decrease due to fertilizer replacement from microbes
- It is therefore likely that the net demand for ammonia will rise, although for different applications

Two examples

- it is expected that Japan will start importing carbon free ammonia as fuel for power generation to replace 20% of the coal from 2030
- The possible use of ammonia as fuel for ships may add up to 450 MT/y if it is to replace completely fossil fuels

Main Obstacles

- To satisfy the new needs Blue and Green ammonia production methods will be needed, but they have to overcome obstacles:
  - Green ammonia:
    - Lack of proper definition of what is green and of corresponding certification
    - Lack of a specific market
    - Electrolizers technology development, it is still the main capex component
    - Renewable power availability and cost. It's availability at low cost is key to have a competitive production
      - Needs lots of renewable power, present ammonia production alone would need 70% of the global renewable power production non Hydro

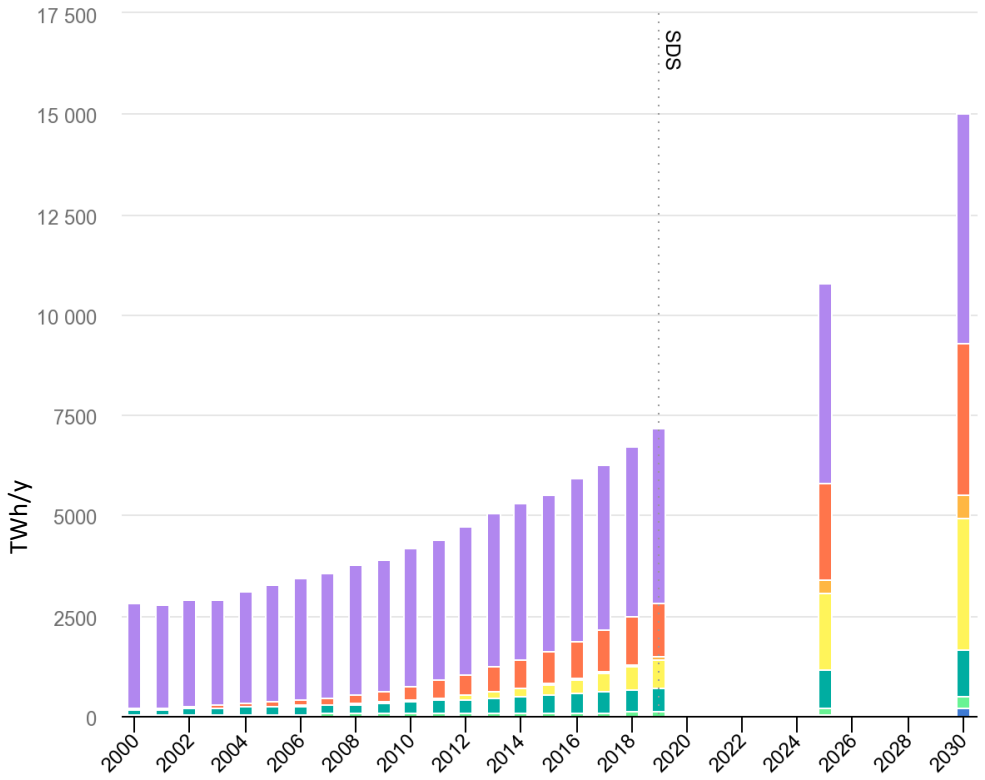
Main Obstacles

Green ammonia:

- Present renewable power production, non Hydro[1] (2019) 2'806 TWh/y
- Present NH3 production worldwide 190 MMt/y
- Corresponding power consumption (10 MWh/t) 1'900 TWh/y

1)Renewable power production incl. Hydro 7'139 TWh/y

Source IEA



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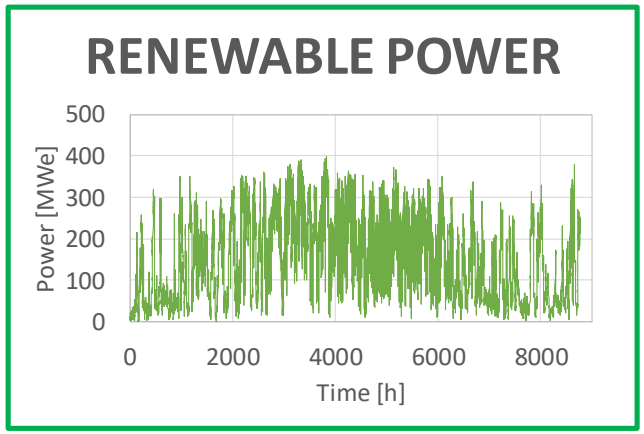
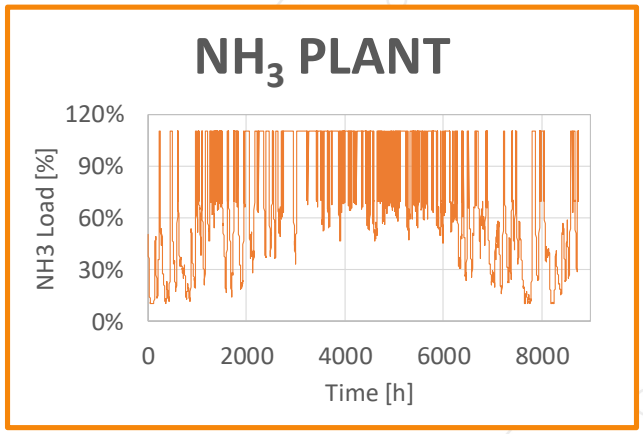
Main Obstacles

Green ammonia:

- Renewable power load variability, it is a problem for the synthesys loop, and the bigger the plat the more important the problem
  - It requires:
    - Energy and/or H2 storage solutions, their cost is high at present
    - New synloop control system strategies to reduce the impact on the operation
    - New design for the main equipment and catalyst, to cope with the fluctuations in temperature and pressure





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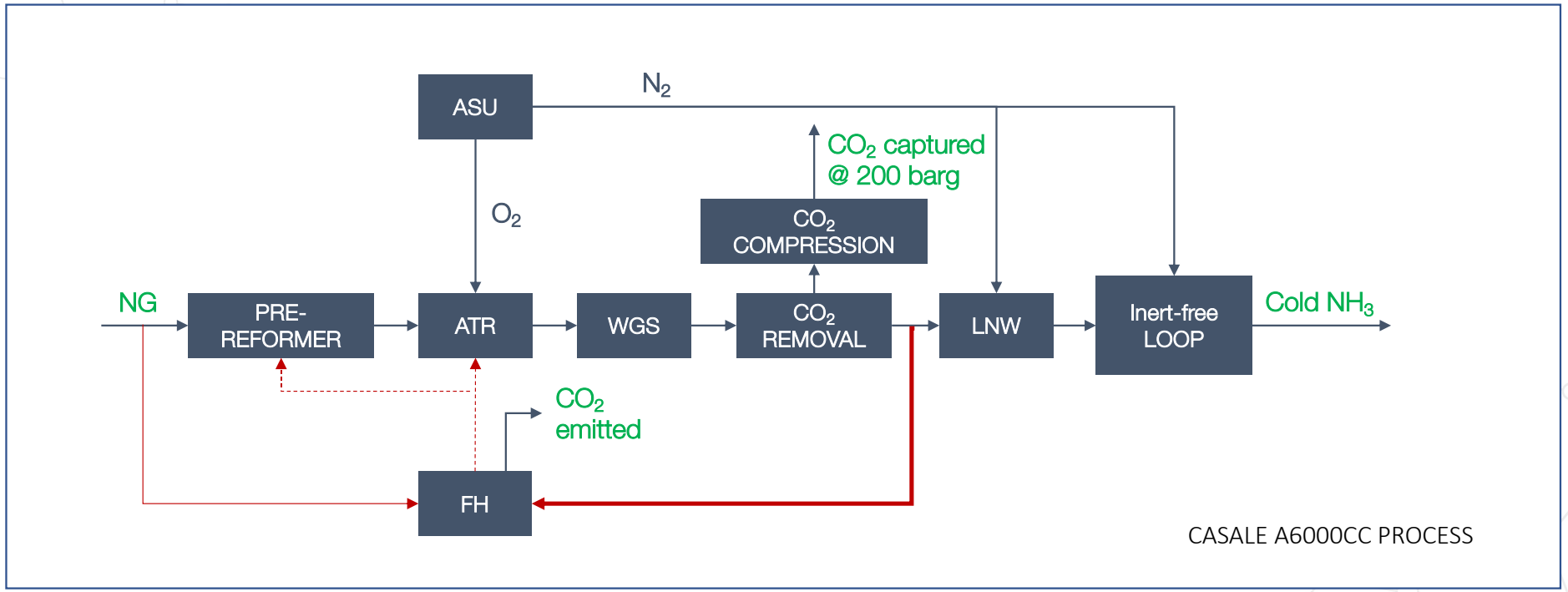
Main Obstacles

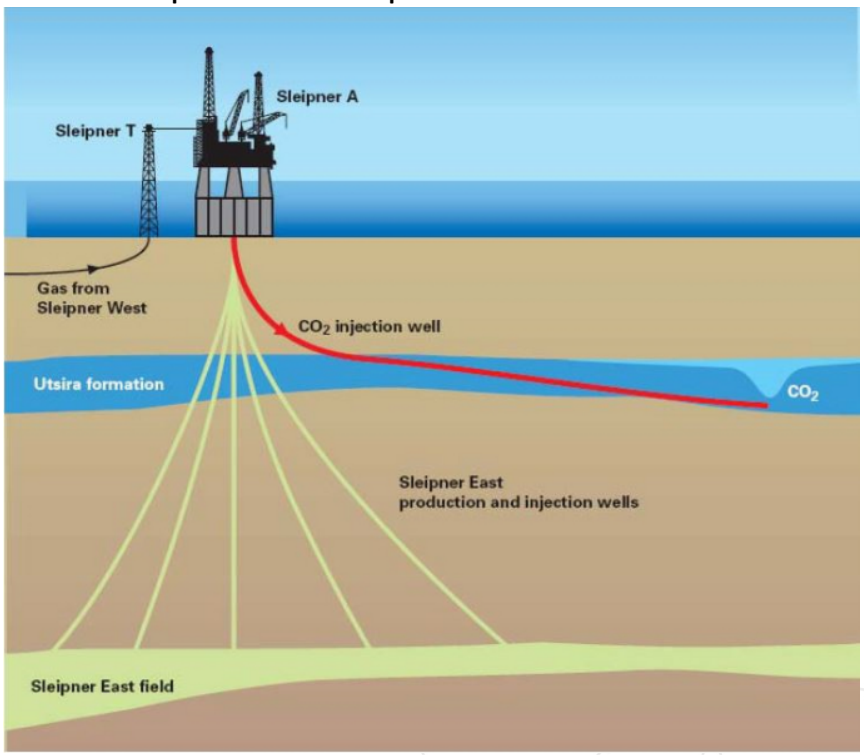
- Blue ammonia:
  - Technology is available to build new blue ammonia plants, as efficient and with same capex as grey ones, or to revamp existing grey units to blue.



Main Obstacles

- Blue ammonia:
  - Lack of a proper definition of what is Blue and of corresponding certification
  - Lack of a specific market
  - Lack of CCS infrastructures.
    - The real obstacle is the transportation and sequestration of CO2. At present there are no pipelines to collect CO2 and little geological sink for CO2, except for EOR.

Sleipner CO2 Sequestration Site



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Improvements

- Blue ammonia:
  - Reductions in energy consumption and Capex are key, main points are:
    - CDR,
    - ASU,
    - Process CO2 removal,
    - Rotating machinery,
    - NH3 synthesis catalysts and converter,
    - NH3 separation

CONCLUSIONS

- The next decade will be crucial for the production of Ammonia
- It is likely that the market for ammonia will grow more then in the past
- The production methods though will have to change, low/zero emissions will be key
- This involves very important changes, technical, commercial and in the infrastructure
- The solutions to the problems to be faced is not always available, and an important technical development activity has to take place.

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THANK YOU