Planning of infrastructure for energy distribution and CO_2-capture

Master thesis NTNU 2006

Ingrid Velken

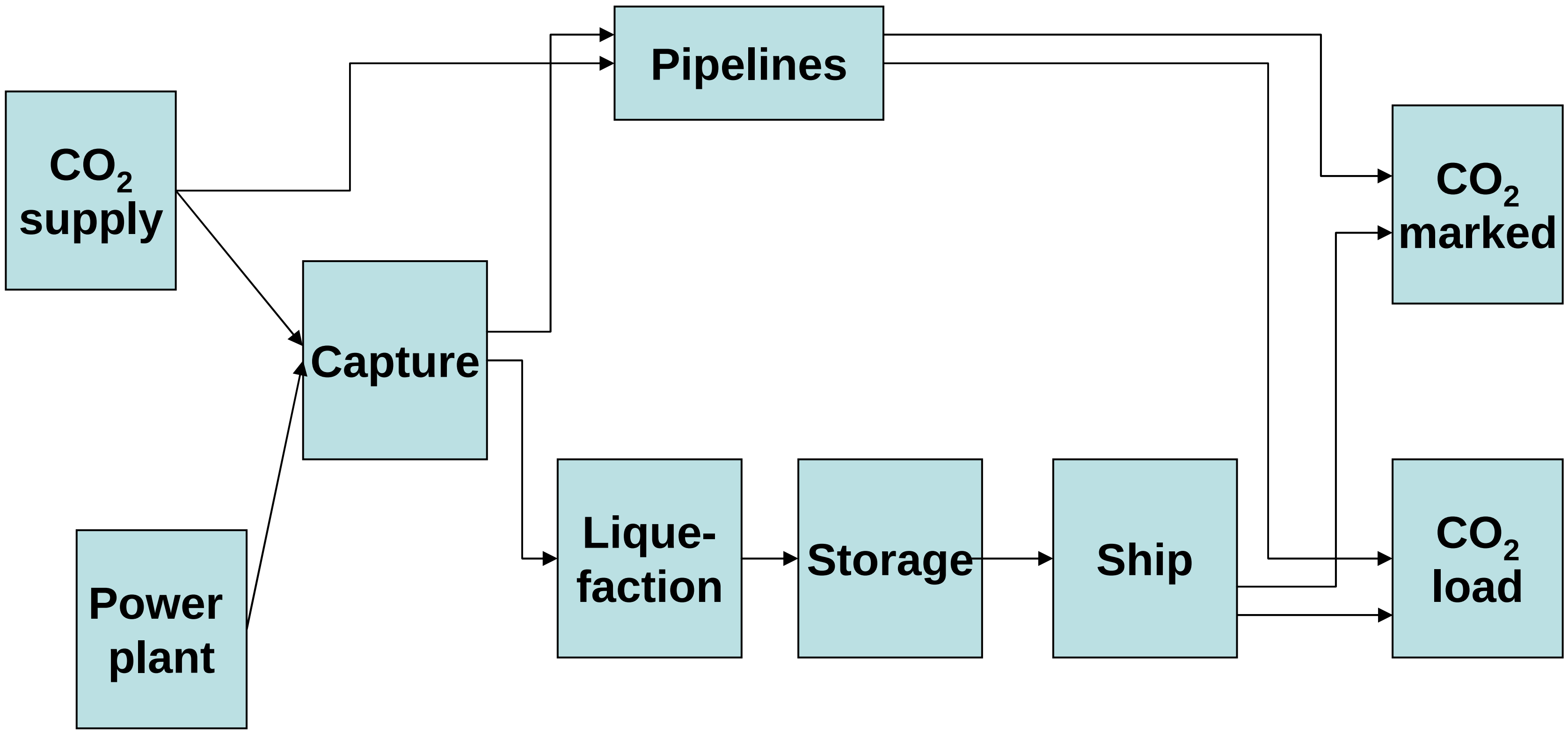
ingridvo@stud.ntnu.no

Planning of infrastructure for energy distribution and CO_2-capture

- Problem:
  - How will profitability of gas pipelines and electricity production be affected if infrastructure for CCS is included in the investment analysis?

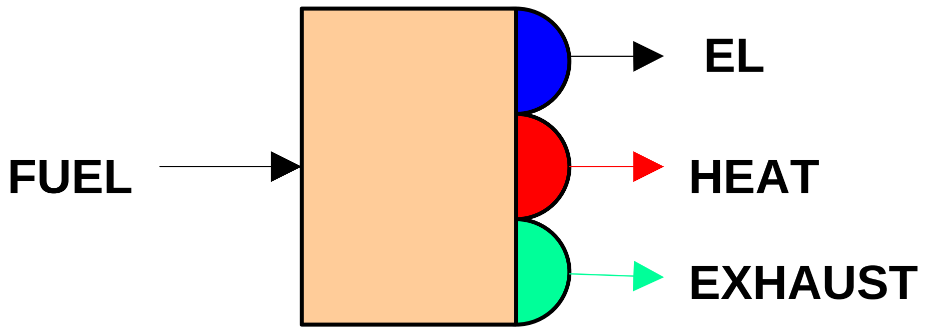
- Main challenge:
  - Integrate LP-models for CCS components with models for electricity and gas, i.e. include mass transfer in the energy system

Value chain



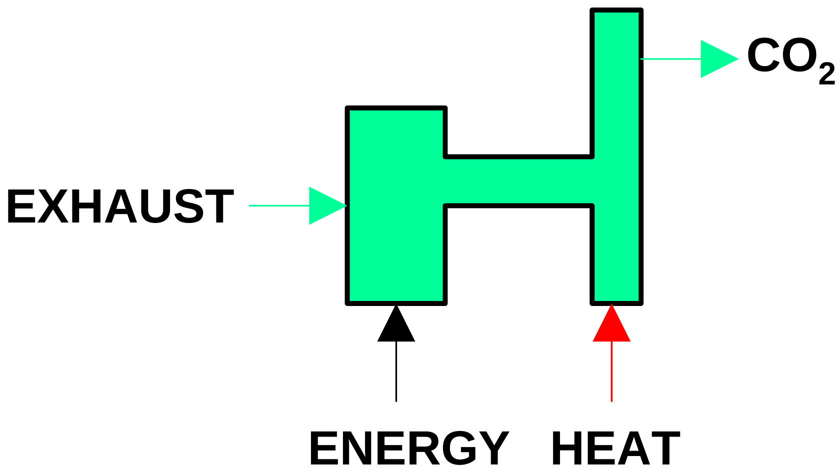
Pipelines
CO_2 supply
Capture
CO_2 marked
Power plant
Lique-faction
Storage
Ship
CO_2 load

Power plant



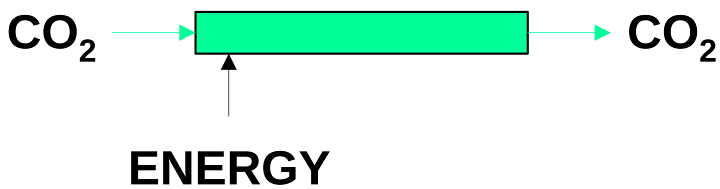
- Combustion of natural gas
- The fuel is converted to electricity and heat
- Exhaust gas with a certain CO_2-concentration is produced
- The optimal amount of EL and heat is produced according to demand and market price
- LHV = EL + α HEAT

CO_2-capture

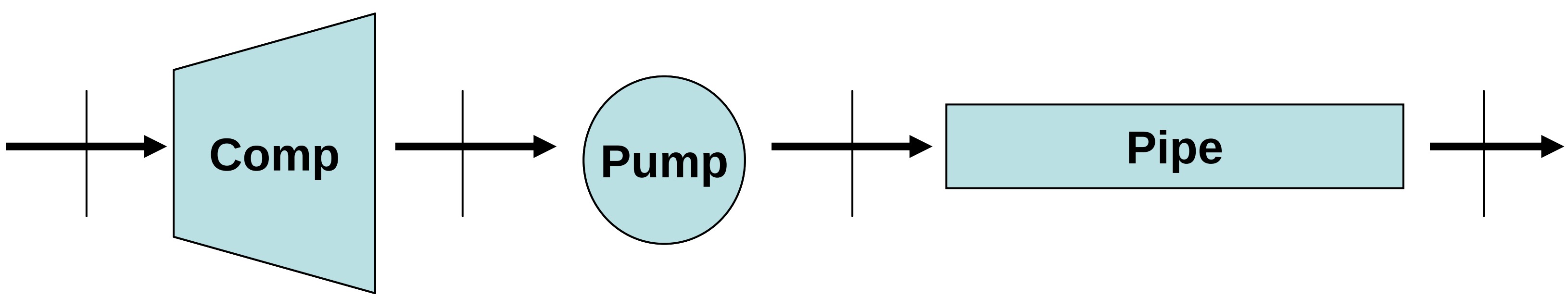


- Post combustion
- Absorption with MEA
- **Absorber:** requires mechanical energy (EL/gas). Size and cost depend on the total amount flue gas / the CO_2-concentration
- **Stripper**: Regeneration of MEA by increasing the temperature. Low quality heat can be used; steam 130ºC
- Chemicals are required to reduce water, SOx, NOx and other pollutants than might disturb the capture process
- Producing a highly concentrated CO_2-stream (>99%)

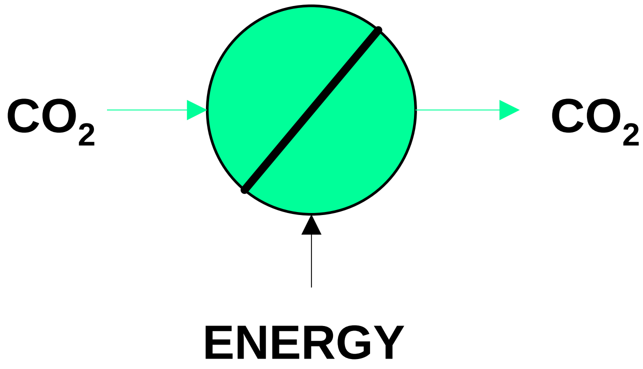
Pipelines



- Module includes both compressors, pumps and pipeline
- The user specifies required inlet pressure, outlet pressure, diameter and length
- Increasing the pressure to ~80bar (liquid CO_2) using compressors
- Further compression is done by pumps
- Energy supplied can be electricity or gas, the efficiency is adjusted according to the energy carrier
- Can not be used as intermediate storage

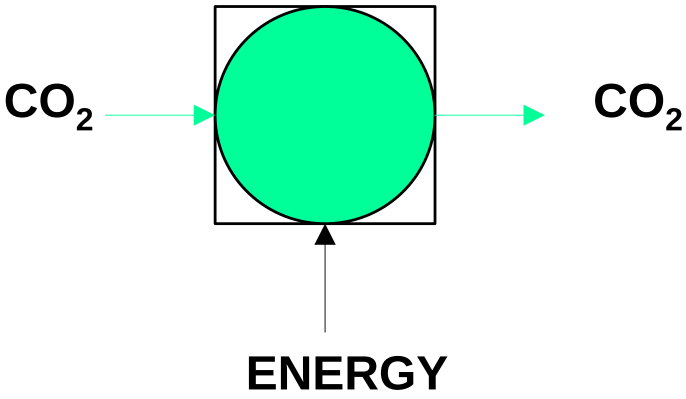


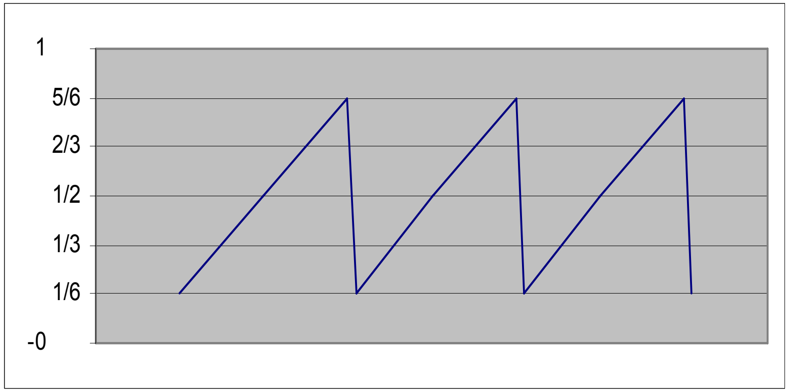
Liquefaction



- Large scale transport of CO_2 by ships favours operating conditions close to CO_2s triple point where the density is fairly high
- The liquefaction is done by compression in several steps followed by expansion and cooling
- The energy consumption is approximately 40% higher than normal compression to 70 bar
- Energy supplied can be electricity or gas, the efficiency is adjusted according to the energy carrier

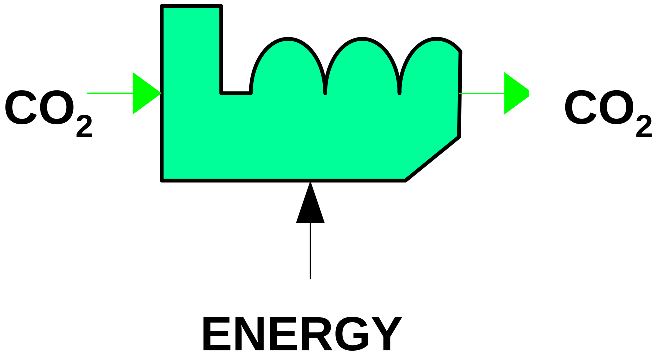
Intermediate storage





- Ship transportation is a discrete process, thus a storage for CO_2 is necessary
- 1,5 *capacity of ship
- Energy requirement is assumed to be small
- Large area is needed;
  A storage of 30 000m^3 : 10 * 3000m^3 requires about 80m * 200m
- Energy supplied can be electricity or gas, the efficiency is adjusted according to the energy carrier

Ship

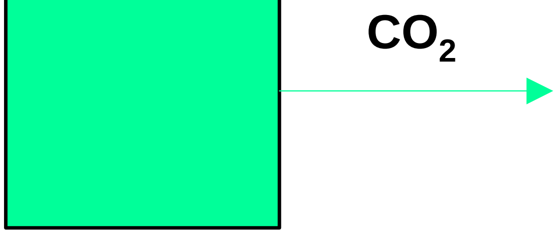


- Similar to LPG transport
- Liquid CO_2

  P = 5,2 bar

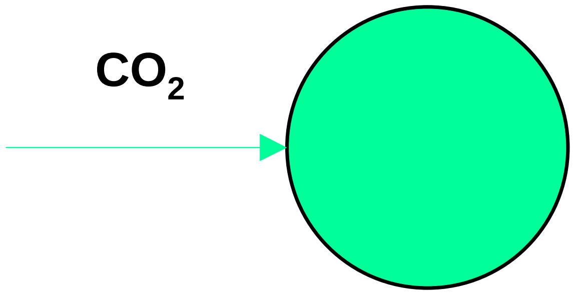
  T = – 50 ºC
- Currently, continuous transport module with mean values of CO_2 and energy flows is used as a simplified approach
- Energy required is calculated using the transportation length, speed and the hours needed for loading etc
- Energy supplied can be oil, gas or electricity
- If investment costs are very uncertain, the user can decide to lease the ship paying an hourly amount

CO_2-supply



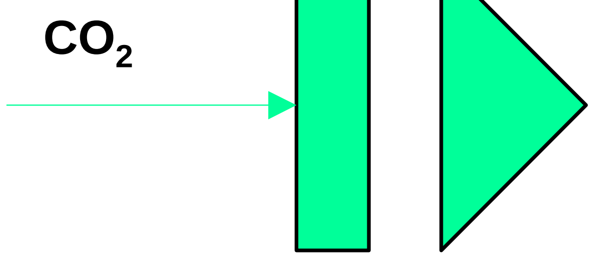
- CO_2 can be supplied from somewhere outside the system boundary at a given price
  - The price can even be negative if someone is willing to pay for disposing CO_2
- A CO_2 supply can also represent an exhaust gas from industry or utilities with a certain concentration of CO_2. In that case, the supply can be connected to a CO_2-capture where the CO_2 is separated from the flue gases

CO_2-load



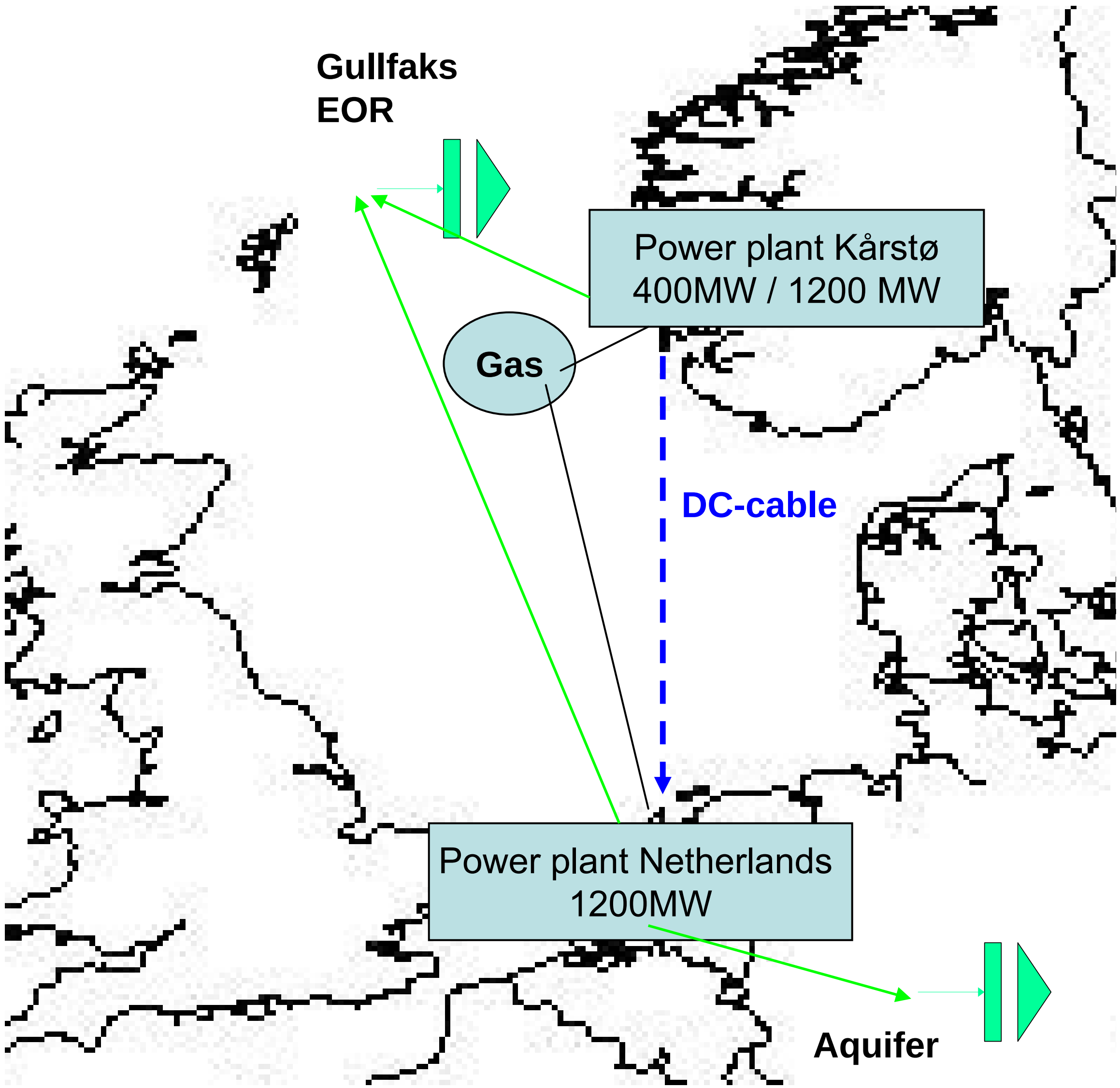
- If there are a given demand of CO_2 this is represented by a CO_2 load.
- The load require a certain amount of $CO_{2,}$ for instance it can be an oil field that needs CO2 for EOR
- The CO_2 is delivered at a user defined price. This price might be negative.

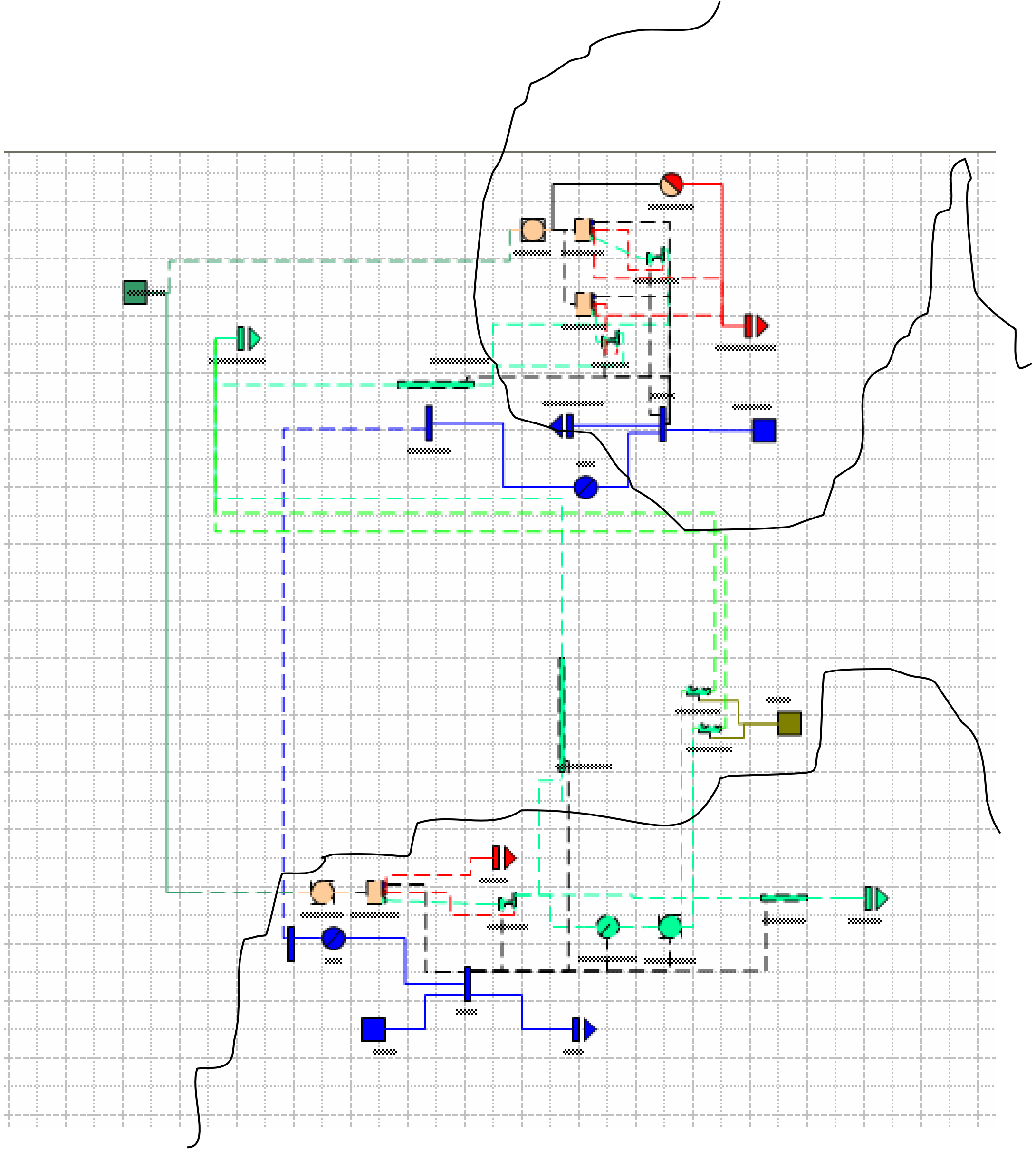
CO_2-market

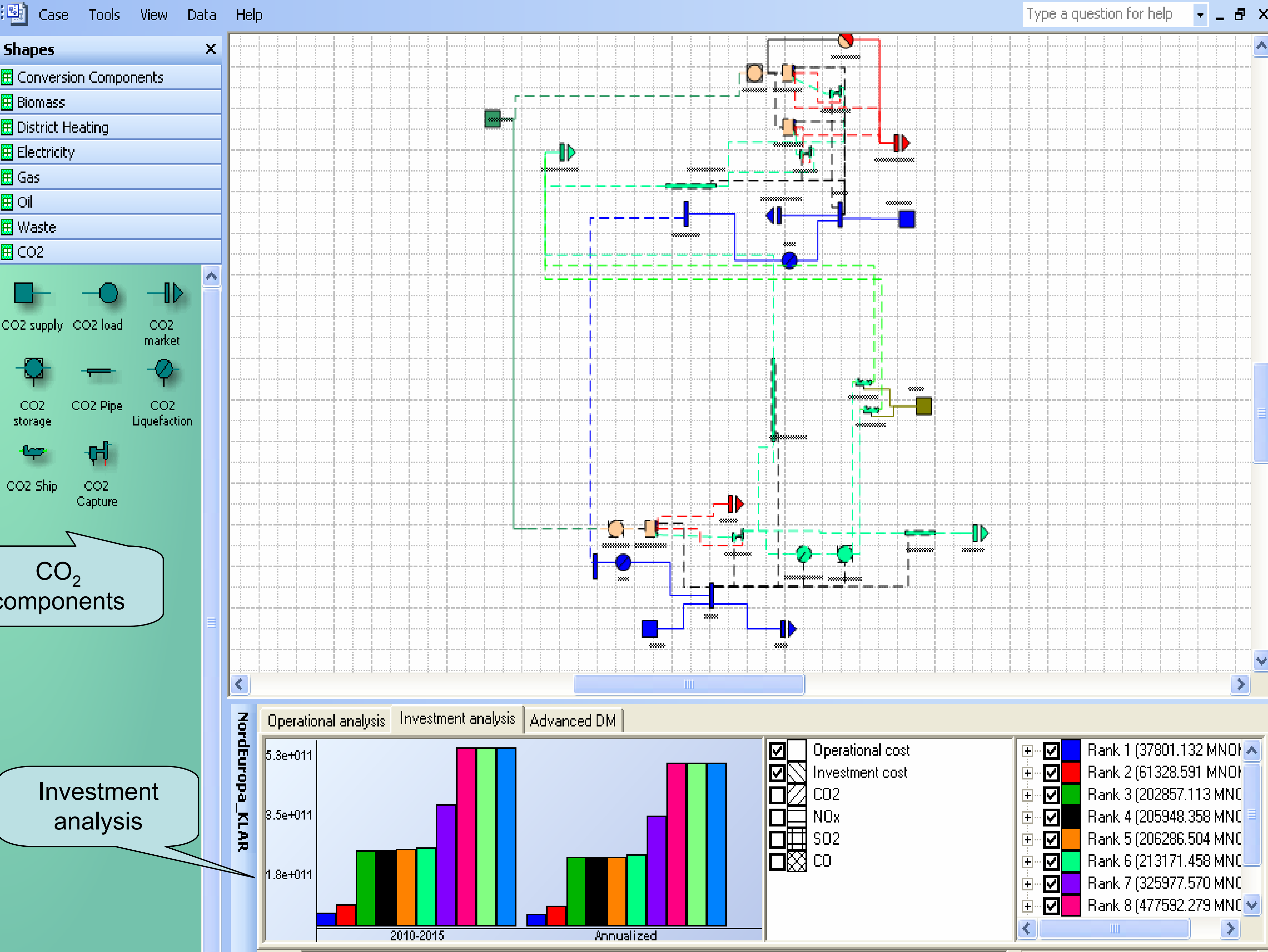


- A market for CO_2 can be an oil field willing to pay for CO_2-delivery
- An aquifer for storage of CO_2 can be modeled as a market without willingness to pay, maybe even with a negative price to cover the injection costs
- A maximum amount can be specified

Simplified case study






Case
Tools
View
Data
Help
Type a question for help
Shapes
Conversion Components
Biomass
District Heating
Electricity
Gas
Oil
Waste
CO2
CO2 supply
CO2 load
CO2 market
CO2 storage
CO2 Pipe
CO2 Liquefaction
CO2 Ship
CO2 Capture
CO_2 components
Investment analysis
NordEuropa_KLAR
Operational analysis
Investment analysis
Advanced DM
5.3e+011
3.5e+011
1.8e+011
2010-2015
Annualized
Operational cost
Investment cost
CO2
NOx
SO2
CO
Rank 1 (37801.132 MNOK
Rank 2 (61328.591 MNOK
Rank 3 (202857.113 MNC
Rank 4 (205948.358 MNC
Rank 5 (206286.504 MNC
Rank 6 (213171.458 MNC
Rank 7 (325977.570 MNC
Rank 8 (477592.279 MNC