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Spillvarme - en kilde til kraftproduksjon

Waste heat – a source for power production

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Facts ROMA and CREATIV projects

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Resource Optimization and recovery in the MAterials industry (182617/140)

- KMB BIA 2007-2013, Total 58,5 MNOK, Energy Rec 18 MNOK
  - **SINTEF** (Materials and Chemistry, Energy Research, ICT)
  - **NTNU** (Materials Science and Engineering, Geology and Mineral processing, Energy and Process Technology, Technical Cybernetics)
  - **Al-consortium** (Hydro Al, Elkem Al, Søral)
  - **FFF** (Elkem, Eramet, Fesil, Finnfjord, Tinfos)
  - **Ti-minerals** (Tinfos TI)
  - **Alstom** (supplier)

CREATIV

Competence project for Reduced Energy use through Advanced Technology InnoVations (195182/S60)

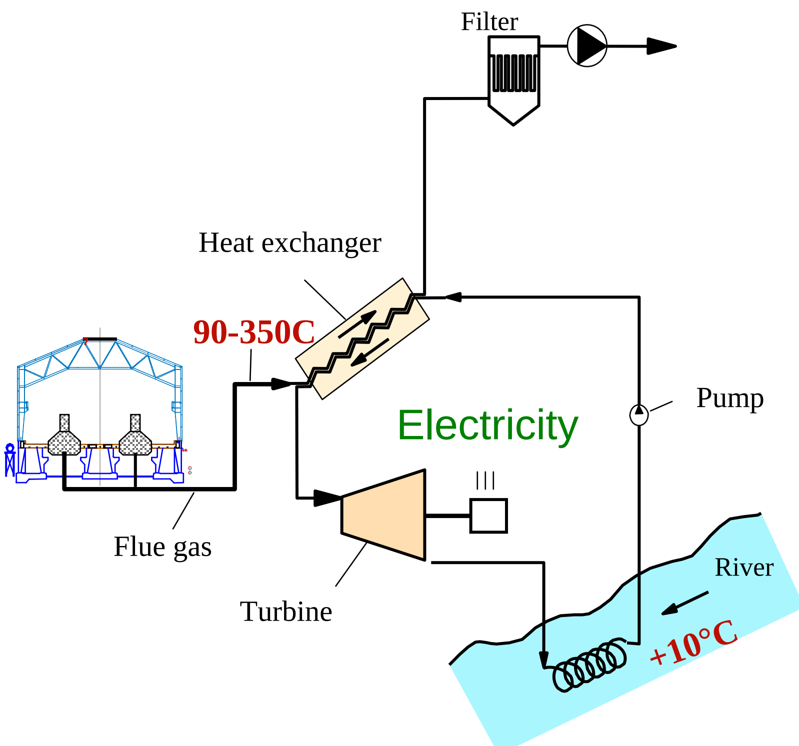
- KMB Renergi 2009-13, Total 53 MNOK, Power prod 10 MNOK
  - **SINTEF** (Energy Research, Materials and Chemistry), **NTNU** (Energy and Process, Samfunnsforskning)**, NGI, IFE, KTH (S), Obrist (AU), Shanghai JTU (China), Doshisha U (JP), TLK (D), TU Braunschweig (D)**
  - **Danfoss, Systemair, Jim Bean Techn, Bitzer**
  - **Rema, Tine, FHL, Norske Skog, Nortura, Hydro Al**

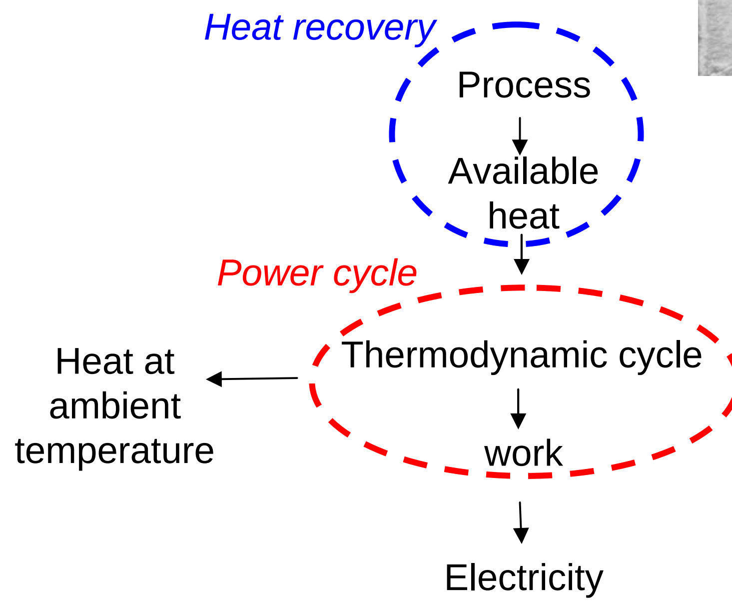
Projects are complimentary and will cooperate to mutual benefit
Hydro Al is major financial contributor to both

Outline

- Rankine Cycle (RC) concept
- Quality of energy
- Potential heat sources
- Power processes
- CO_2 as working fluid
- Cost analysis
- Experimental development
- Conclusions

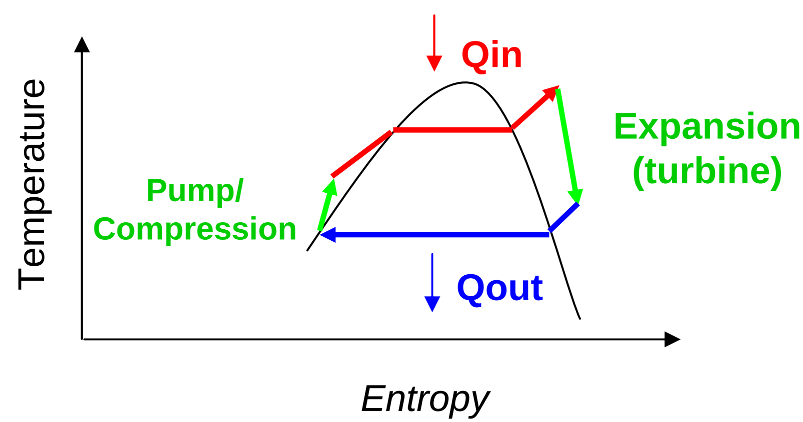
Rankine Cycle (RC) principle





$$\varepsilon_{th} = \frac{W_{turbine} - W_{pump}}{Q_{evaporator}}$$

$$W_{net} = \varepsilon_{th} \dot{m}_{source} c_p \Delta T$$



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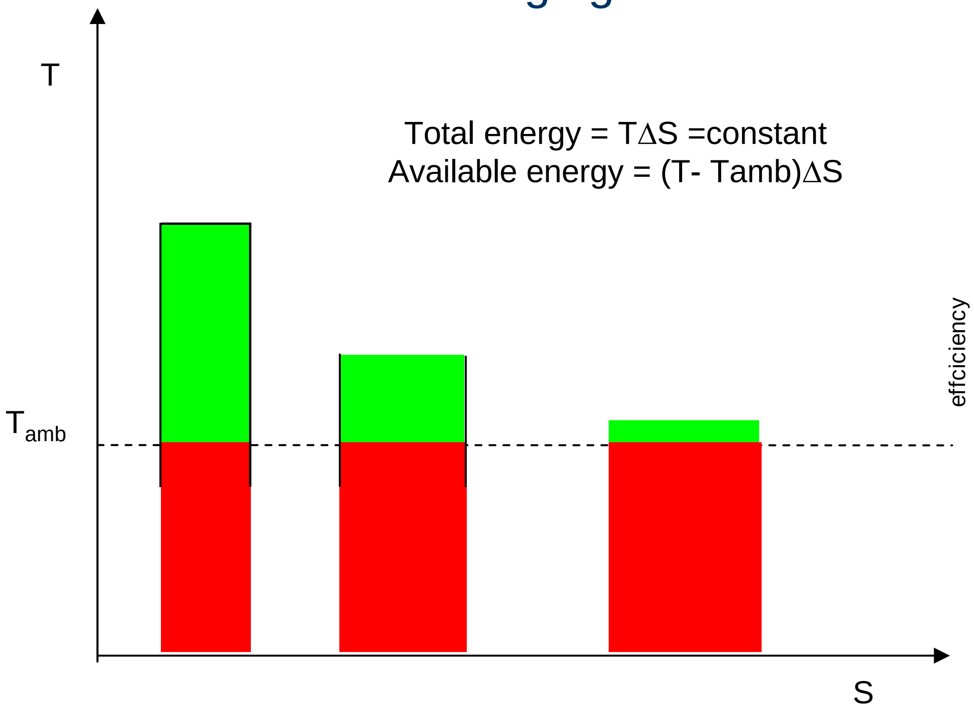
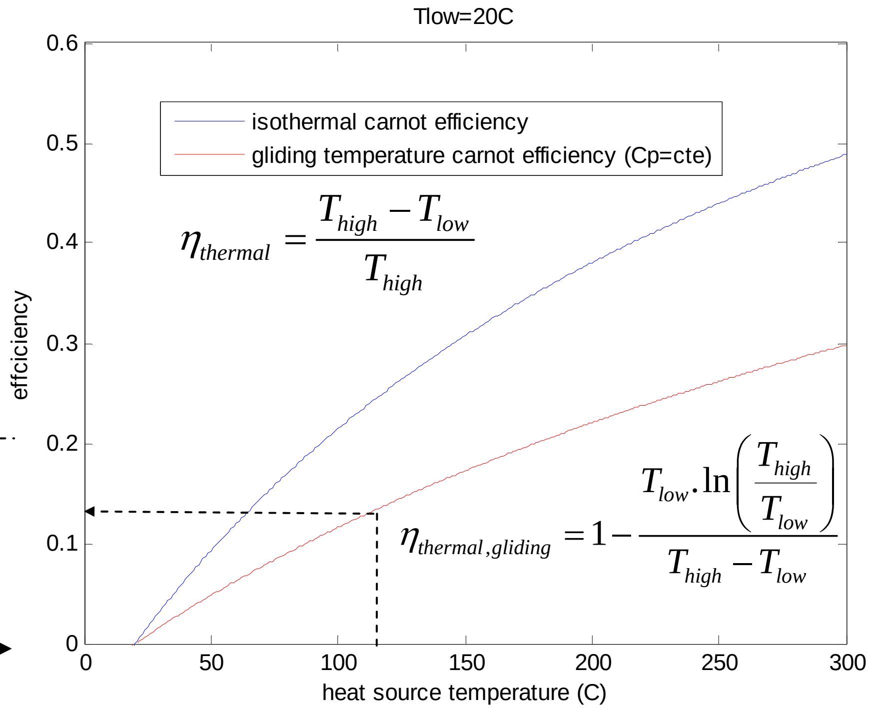
Quality of energy

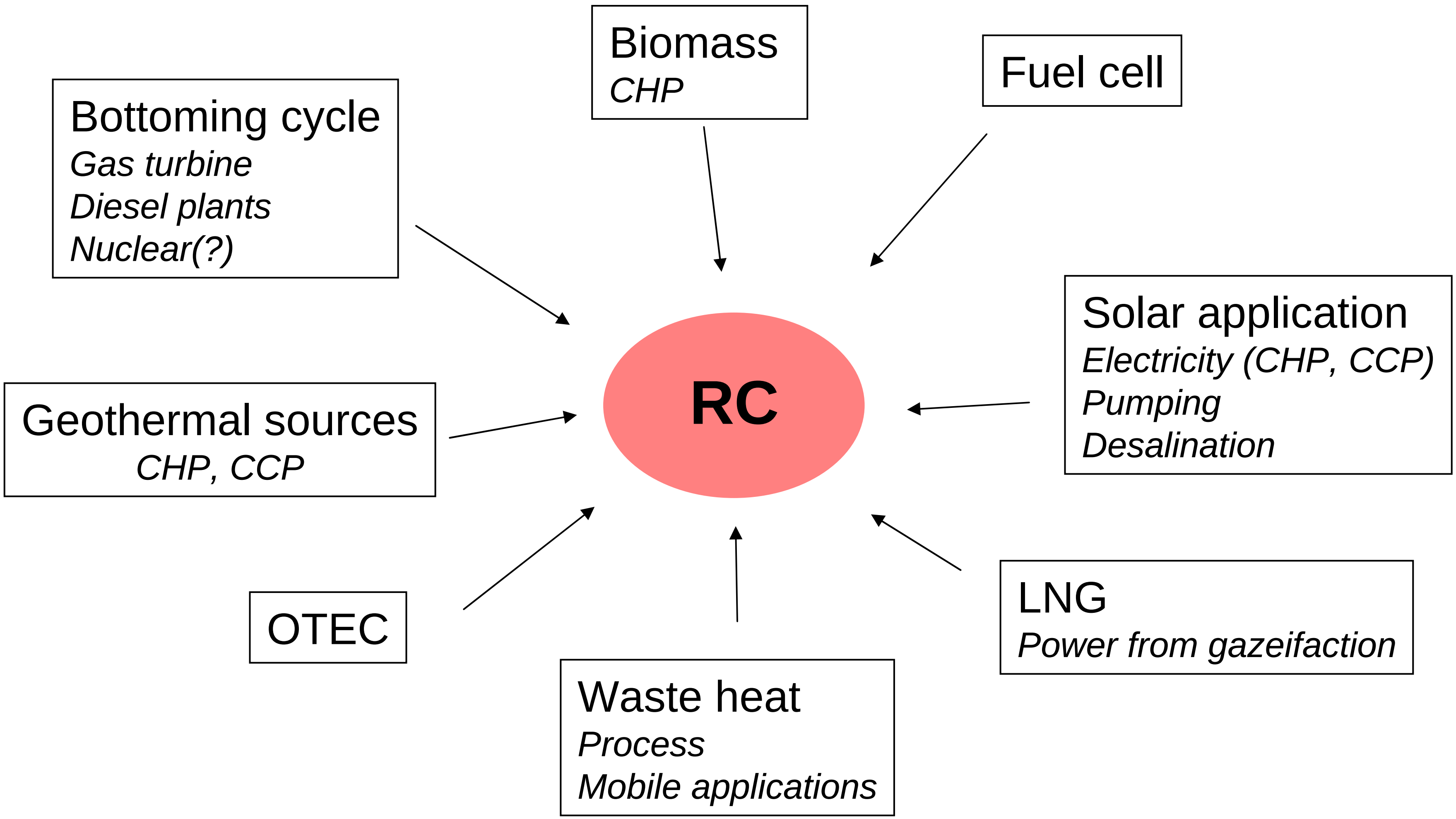
- Energy available for work production decreases with source temperature
- Energy recovery from low grade source is a challenging

- Often possible to extract heat at higher temperatures
- However, significant amounts of heat available at 60-150’C





Applications of RC



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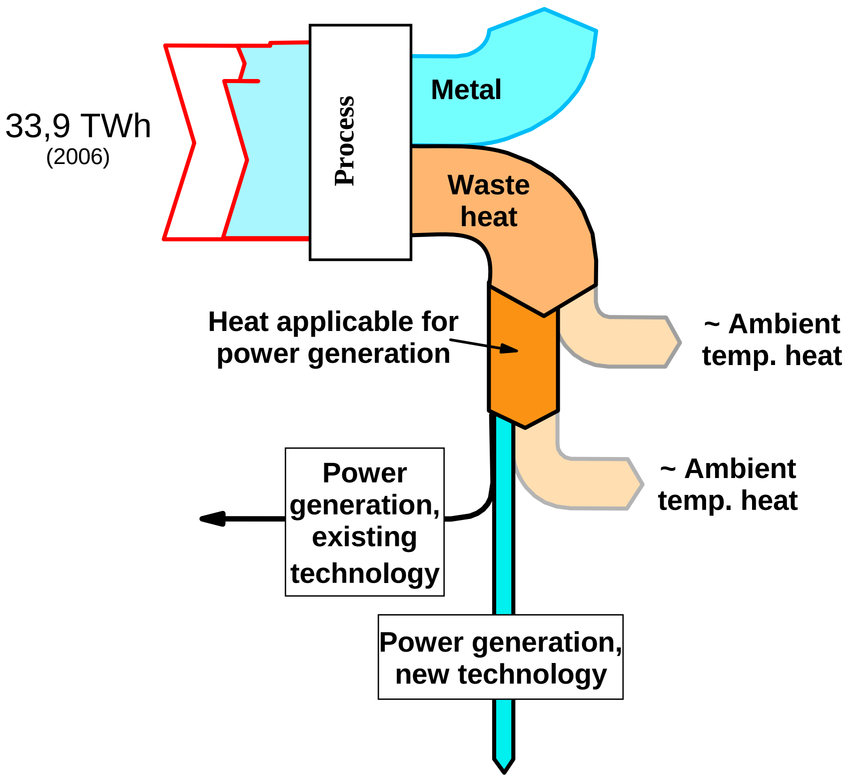
Potential in metallurgical industry

Aluminium:

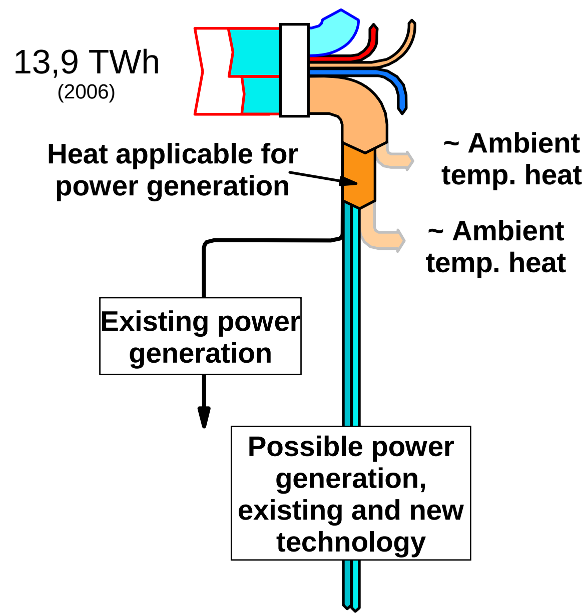
Low waste heat temperatures – moderate el-power yield



1 TWh El-power ?

Ferro alloys:

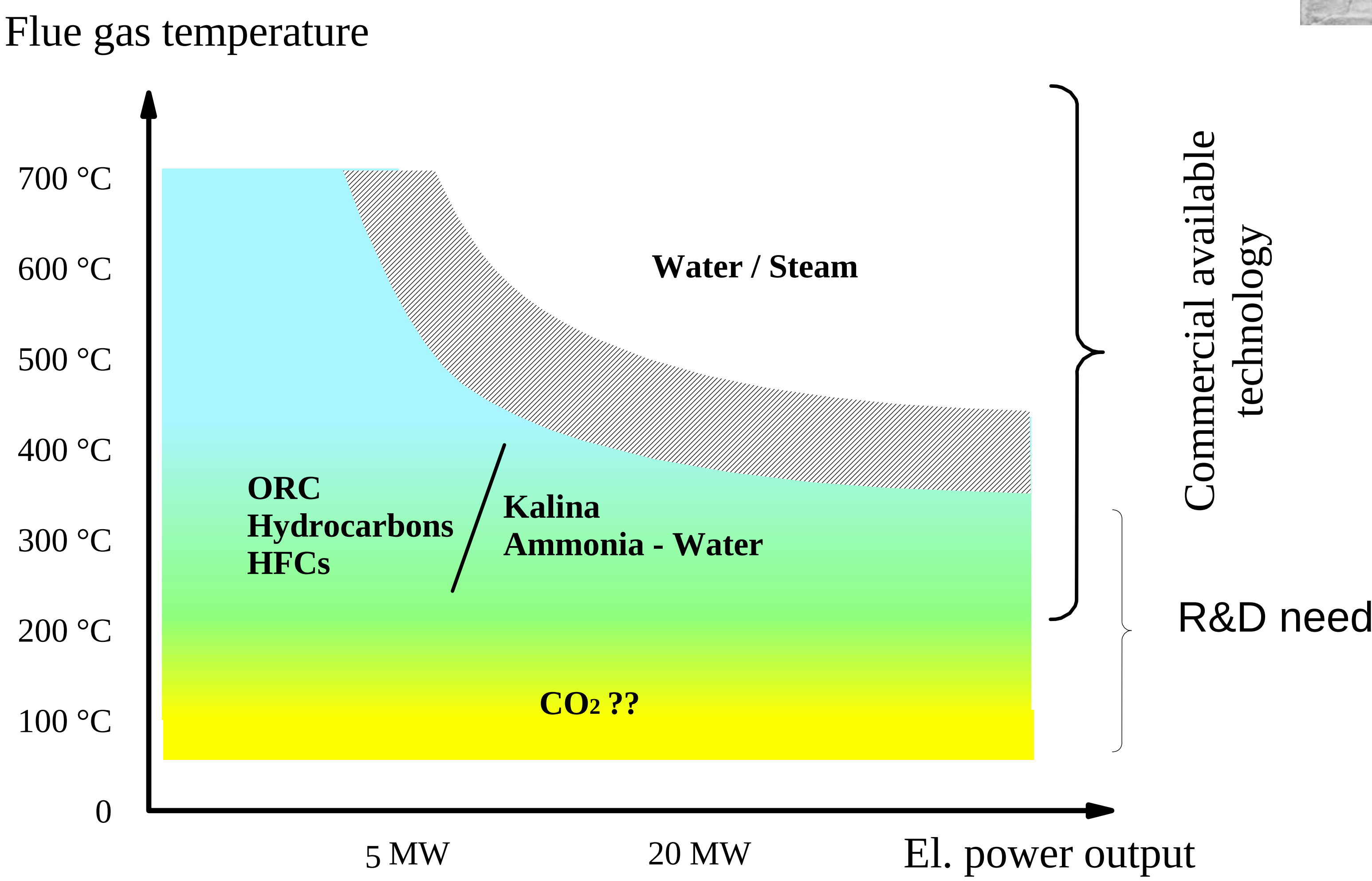
High waste heat temperatures – better el-power yield



2 TWh El-power ?

Ref.: Håkon Skistad

Power processes and working fluids



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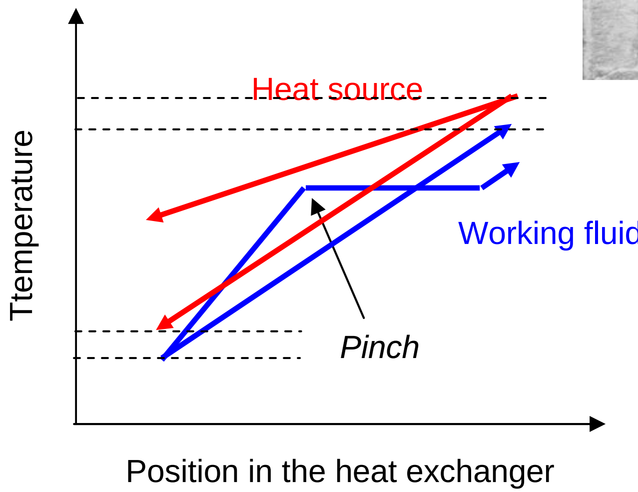
Motivation for R&D on CO_2 process

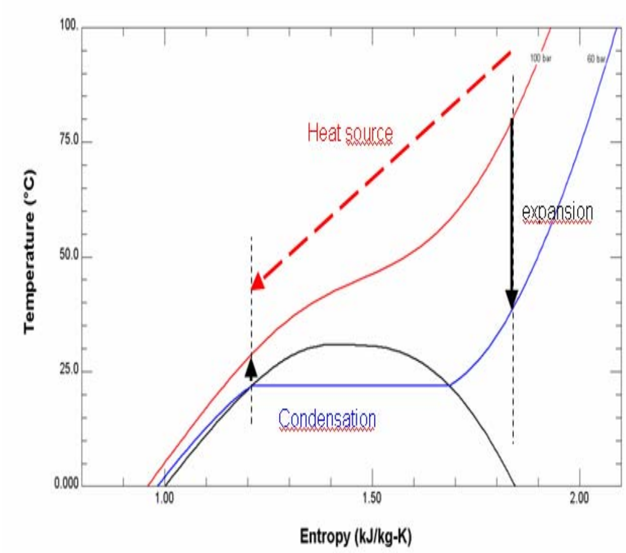
- Low grade energy source:
  - Theoritical (Carnot) efficiency is limited
  - Net work is proportional to the source temperature drop

$$W_{net} = \varepsilon_{th} \dot{m}_{source} c_p \Delta T$$

=> T_{out} of working fluid should be high
=> T_{out} source should be low

- The pinch problem :
  - Limits temperature for heat absorption
  - Limits the temperature drop of the source





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Working fluid: a strategic choice

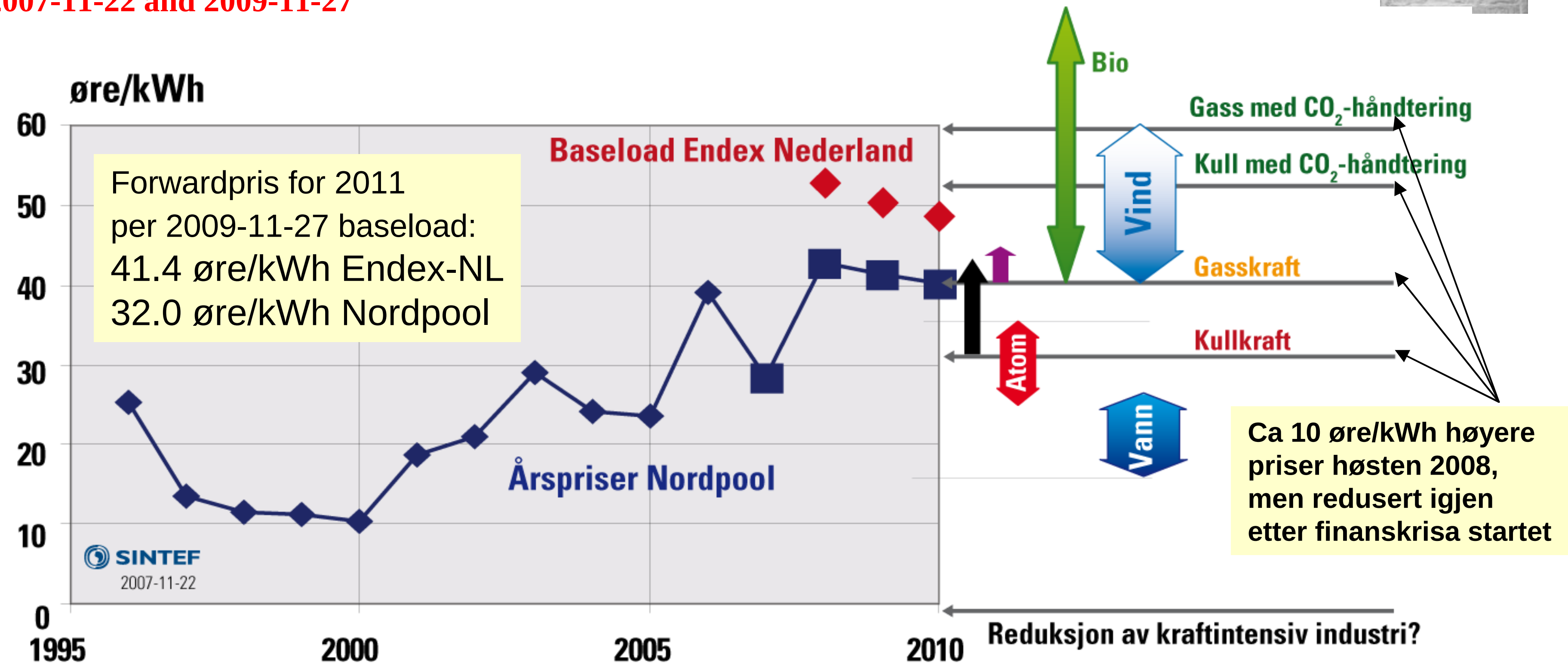
- Established technology
  - High GWP (HFC)
  - Toxic (NH3, toluene)
  - Flammable (hydrocarbons)
  - Components and systems available

- New technology *trans-critical CO_2*
  - GWP=1
  - Non toxic
  - Non flammable
  - Components and systems to be developed
    - Potential for size reduction

Extensive expertise at NTNU/SINTEF

Cost new power – baseload

Sammenstilling med spotpriser og forwardpriser på Nordpool Nordic og Endex
2007-11-22 and 2009-11-27



Gasspris 5.8 €/GJ eller 20.9 €/MWh; Kullpris 2.3 €/GJ eller 8.3 €/MWh, 1€ = 800 øre

Mulig CO_2-kostnad for gasskraft , CO_2 pris = 20 €/tonn

Mulig CO_2-kostnad for kullkraft, CO_2 pris = 20 €/tonn

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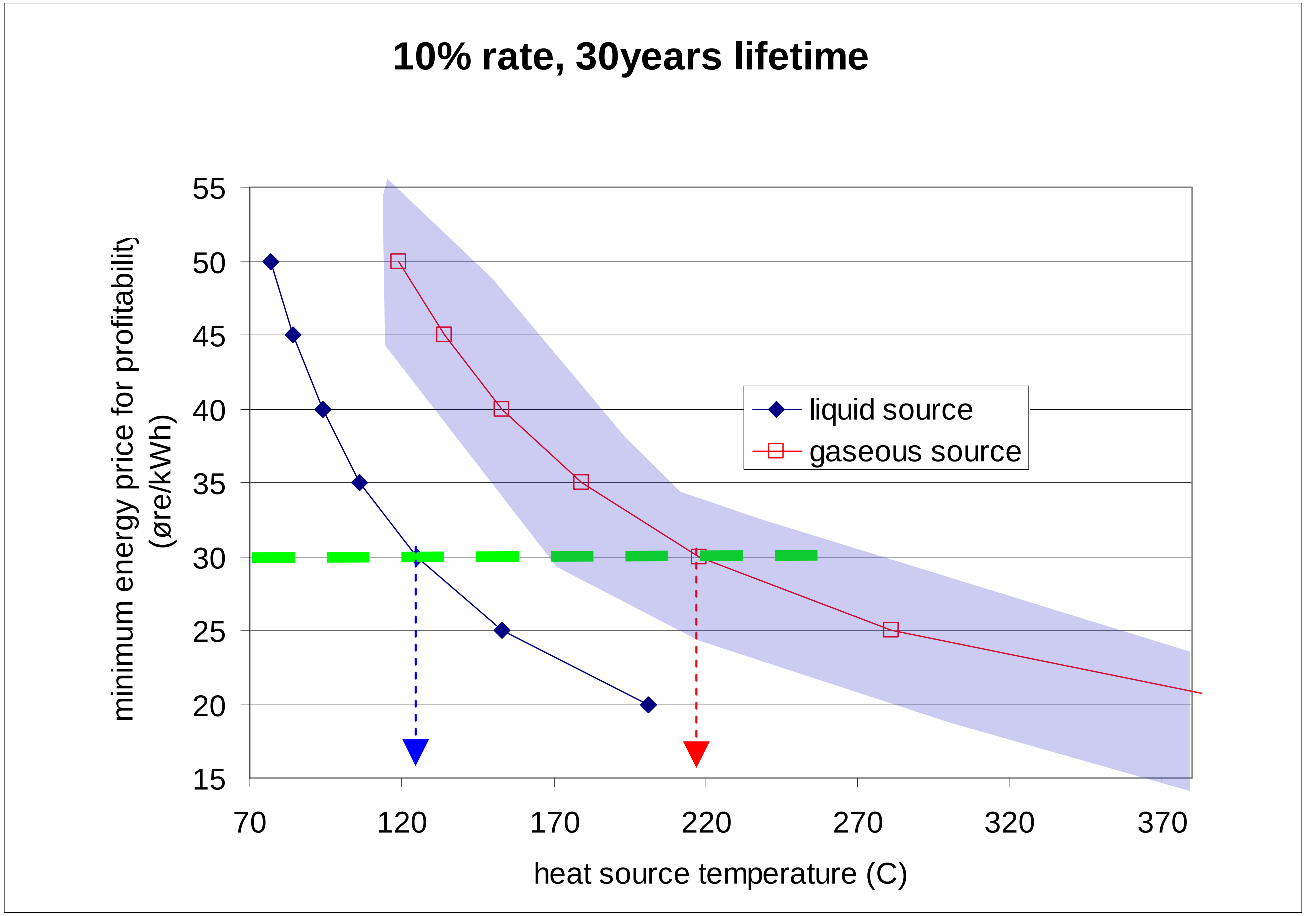
Profitability existing technology

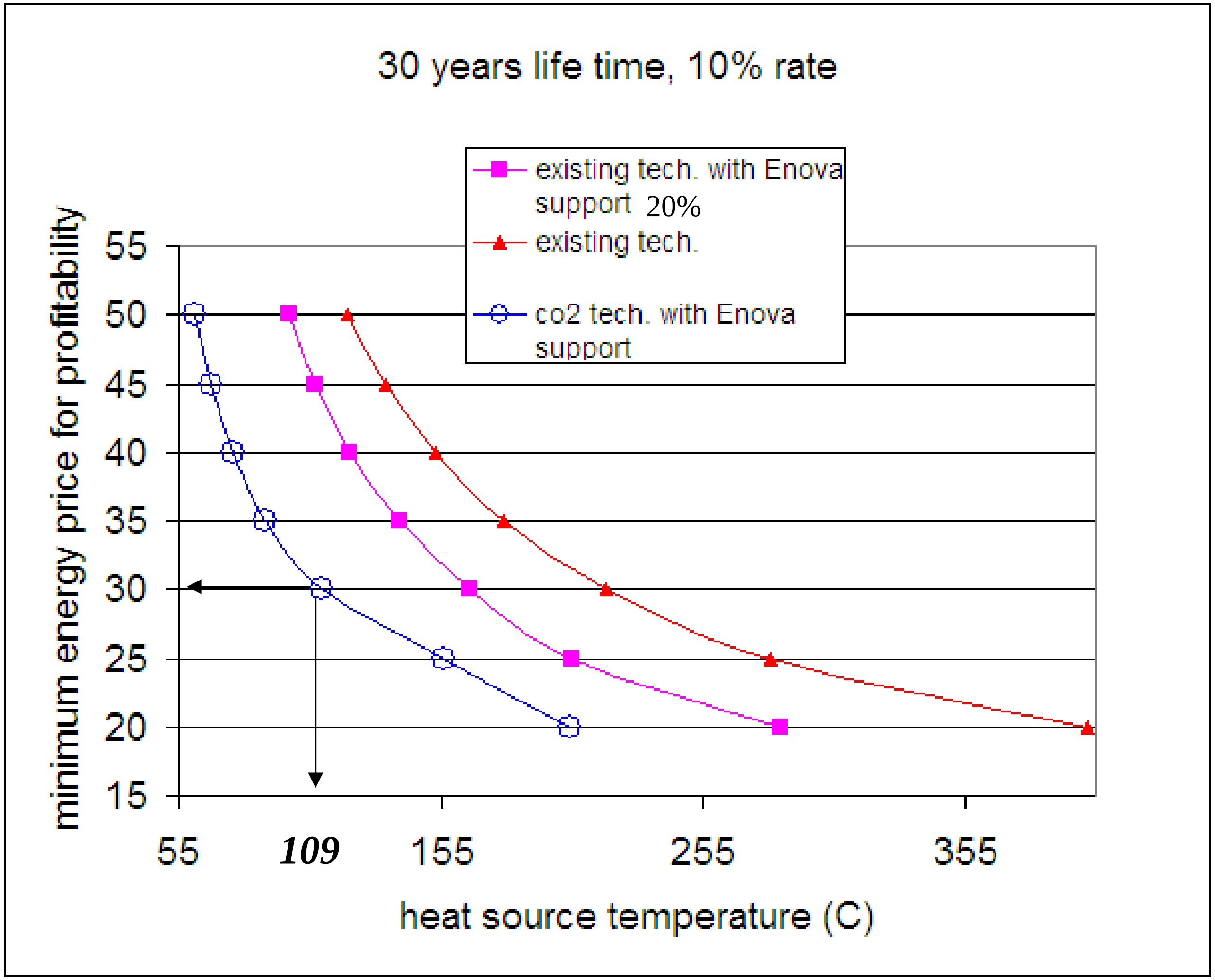
Profitability (NPV=0) limit of existing technology (sparse reference material)



- 10% interest rate
- 30 years lifetime
- 0.002USD operation cost
- 95% operation

Large uncertainty *(operational cost for the heat recovery unit etc)*

Profitability limit estimates: benefit of using CO_2 technology



Assumptions CO_2:
Up to 30% more power at 70'C
20% less investment

These are preliminary estimates based on several assumptions

However, it shows that there is a great potential for utilisation of surplus heat

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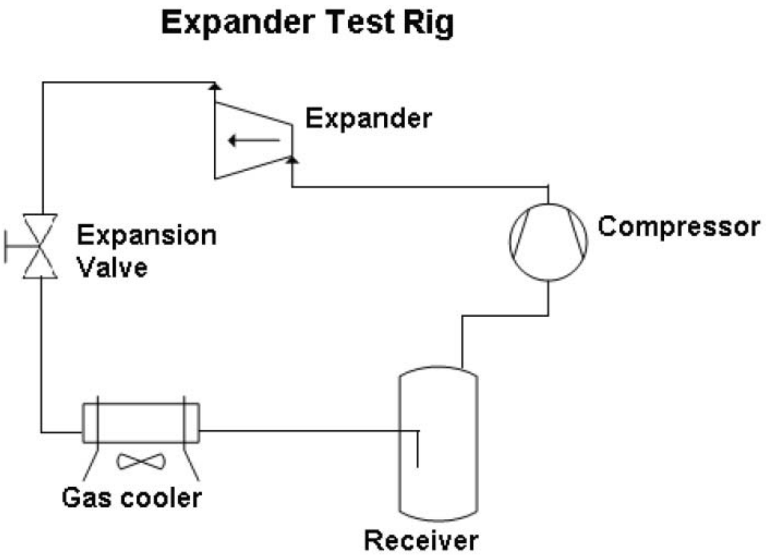
Roma project test rig for CO_2 process

- El. heater
  - 30kW
  - Max Temp. 350’C
  - Current heat source range 50-160’C
- 2 Eco HX
  - pre-heater (heat pump)
  - ”boiler
- Heat sink temperature 20 to -10’C
- Used in development of components, systems and to investigate optimal system operation

CO_2 expander

- Purchased from SINTEF investment funds
- Protoype from Obrist (MAC) (about 500W shaft power)



Conclusions

- **Power production from surplus heat is profitable already today at given conditions**
- **Less costly than many alternatives for new baseload power**
- **Low temperature heat utilisation will require development and incentives**
- **CO_2 as working fluid looks very promising for utilisation of low temperature surplus heat**

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Thank you for your attention