CCS at small scale WtE plant, experiences from pilot at Thisted Varmeforsyning, Denmark.

- Ultra short presentation of SEG A/S
- Thisted Varmeforsyning, Technology and Numbers
- First steps with CCS pilot plant in 2021
- Roadmap and Feasibility studies from 2022-2023
- Challenges within each roadmap and how they are being adressed
- Current status & projections

Ultra Short Presentation of SEG A/S

SEG has +25 years experience within:

- Flue gas condensation and –treatment plants
- Geothermal installations
- Large absorptions heatpumps, chillers, scrubbers etc.
- Thermodynamics, Chemistry, Mechanics and Electrical Engineering
- Turn-key and stand-alone
- E.g. +40 MW absorption heat pump installation at Amager Ressource Center for flue gas condensation

Morten Pipper
Administrerende direktør
T: +45 26 81 93 81
E: morten.pipper@segenergy.dk

Henning Sloth
Direktør og kemiingeniør
T: +45 24 23 67 88
E: henning.sloth@segenergy.dk

Per Bakke
Projektleder og maskinmester
T: +45 25 77 24 23
E: per.bakke@segenergy.dk

Thomas Kristensen
Manager, Design & Concepts
T: +45 60 16 44 30
E: thomas.kristensen@segenergy.dk

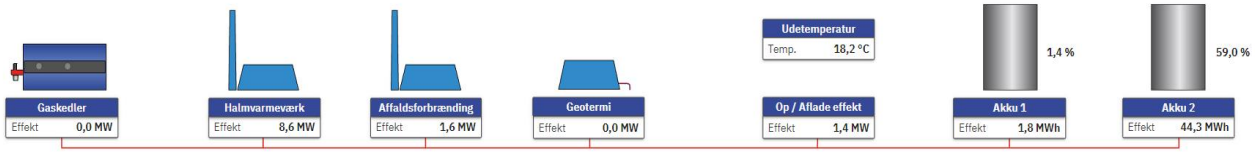
Thisted Varmeforsyning, Technology and Numbers

Waste Incinerator:
- 18 MW fired
- 3.5 MW electrical power [3.0 sold]

Geothermal installation
- 7MW
- Flow 220 m3/h @ 42°C
- Well depth 1200 m

Straw Burner
- 12 MW
- Hot Water @ 160°C
- Driving energy for
- AHP's for FGC and Geothermal

Gas Burners for back-up and peaks



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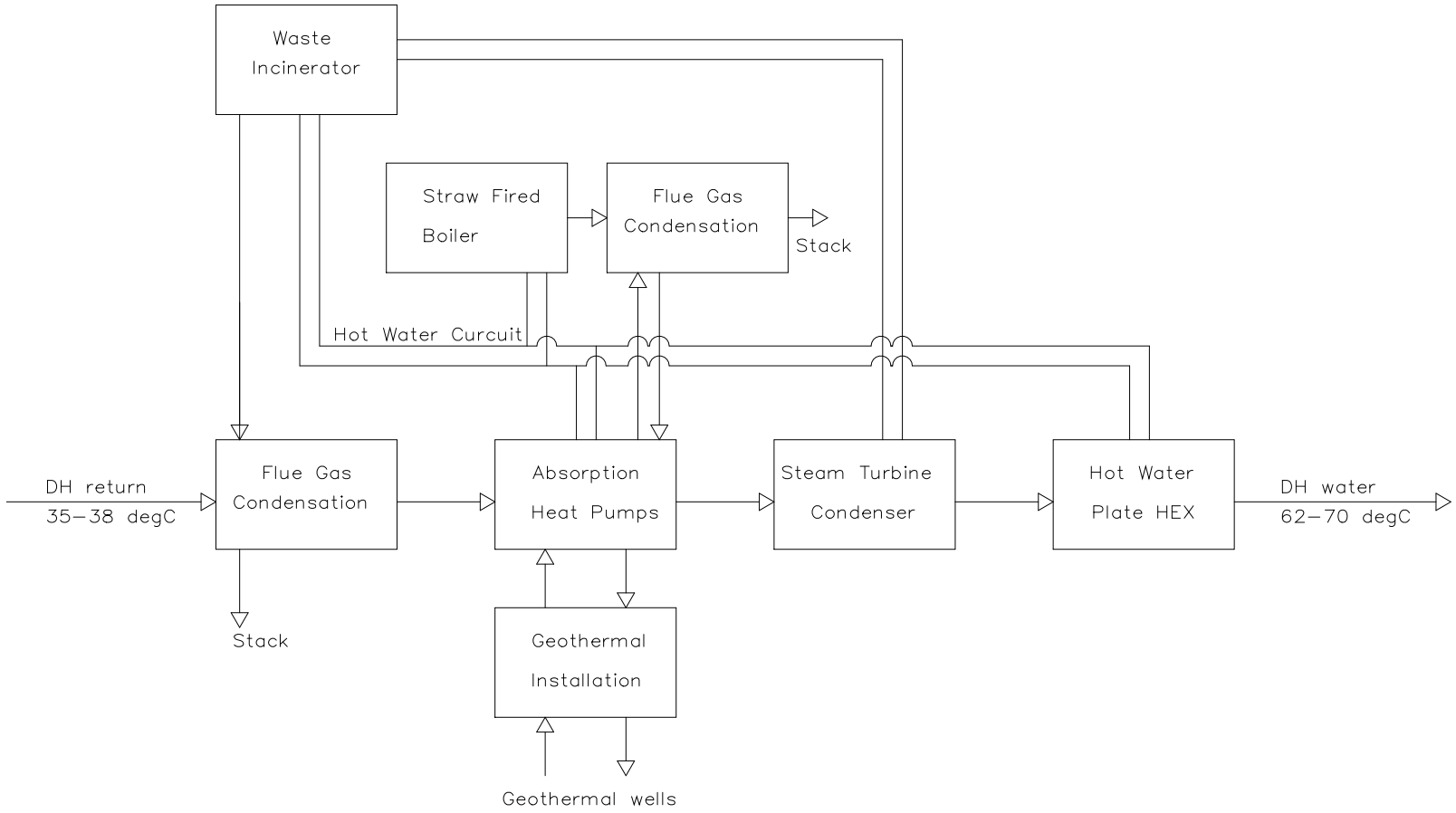

First Steps with CCS in 2021

- December 2018 - Initial Contact between SEG / Ammongas
- January 2021 - 2nd contact and project initiation
- March 2021 - Collabortion agreement between KVVT, TVF, Ammongas and SEG
- May-June 2021 - Test Plant erected May-June 2021
- July – Nov 2021 - Test Plant Operation Test Plant
- December 2021 - Test Plant Dismantled

Major Findings:

- Standard Biogas Upgrade capture system worked
- Economical capture rate 97.5%
- Flue Gas from Incinerator was ”well suited” for standard amine plant
- Energy integration with DH system appeared to be realistic
- Environmental issues are manageable
- A lot of figures to feed into FULL SCALE FEASIBILITY STUDY and CCS ROADMAP

Roadmap and feasibility studies from 2022-2023

- Steering Committee established to drive the process
- Grant for Full Scale Feasibility Analysis Study from ”CO2 Vision - Fyrtårns projekt”
- Road Map defined and tasks started

- Track 1 – CC Technology
- Track 2 – Transport and Storage/Utilization
- Track 3 – Energy Integration
- Track 4 – OPEX / CAPEX Business Model
- Track 5 – Regulation/Taxes

- Track 6 – Scenarios – Dynamic Full Scale Scenario Model

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Paradigms:

- Energy Cost Neutrality
- Mature technologies / TRL
- Agile Strategy Process
- Collaboration and Sharing

Challenges within Track 1: CC Technology

Amin Technology → full scale design options explored with potential suppliers

- Requires 140℃ driving energy for the reboiler -> Challenges electrical output.

Enzym absorbent technology explored with potential suppliers

- Requires 85 ℃ driving energy for the reboiler -> Good for turbine condensate and energy integration
- Favorable for HSE (no hazardous materials or emissions)

Liquefaction:

- Requirements (purity) for CO2 for transport/storage/utilisation have emerged during the last 18 months.

Amine or Enzymatic processess are relatively simple and manageable to implement.

We can achieve energy-cost neutrality. Meaning driving energy is ”borrowed” from DH production at a higher temperature and ”sold” as district heat at lower temperature.

Challenges within Track 2 – Transport and storage/utilization

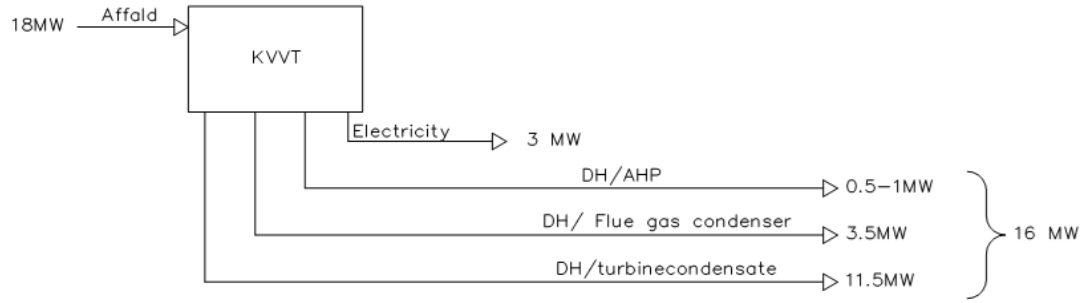
- Pipeline solutions to Hanstholm or Aalborg
- Storage facility for vessel transport out of Hanstholm (20ish km from Thisted)
- PtX option in Hanstholm
- Truck filling station + truck transport from Thisted for onshore storage

- Trucking on shore is viable though counterintuitive
- Off-shore storage out of Hanstholm could be viable on a long term basis
- Off-shore storage with ship out of other ports may/should become viable but not currently in the cards

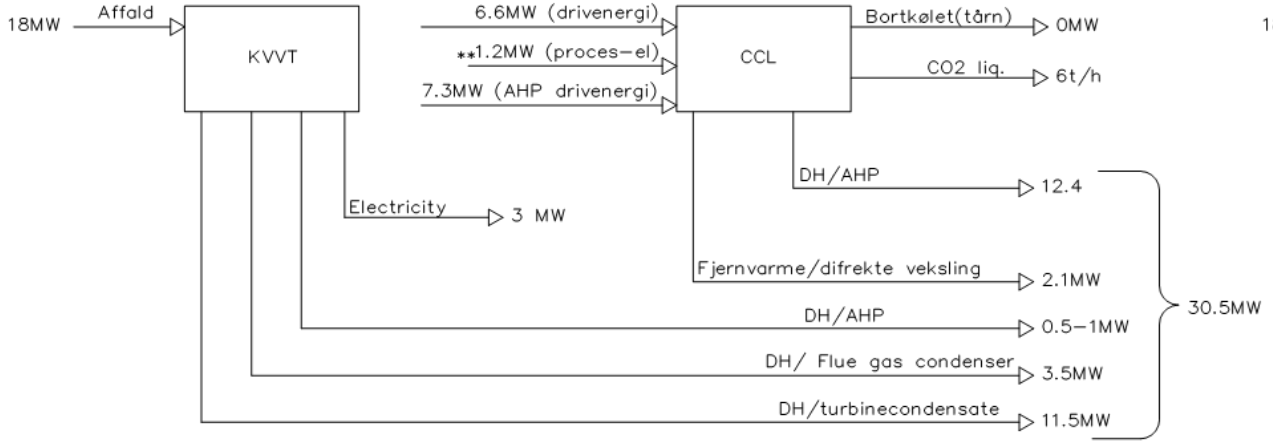
- In the short/medium term CCS will be the viable option
- In the medium/long term CO2 will become a commodity for CCU
- Onshore storage at Stenlille is currently the most viable solution for the short term

Challenges within Track 3: Energy Integration

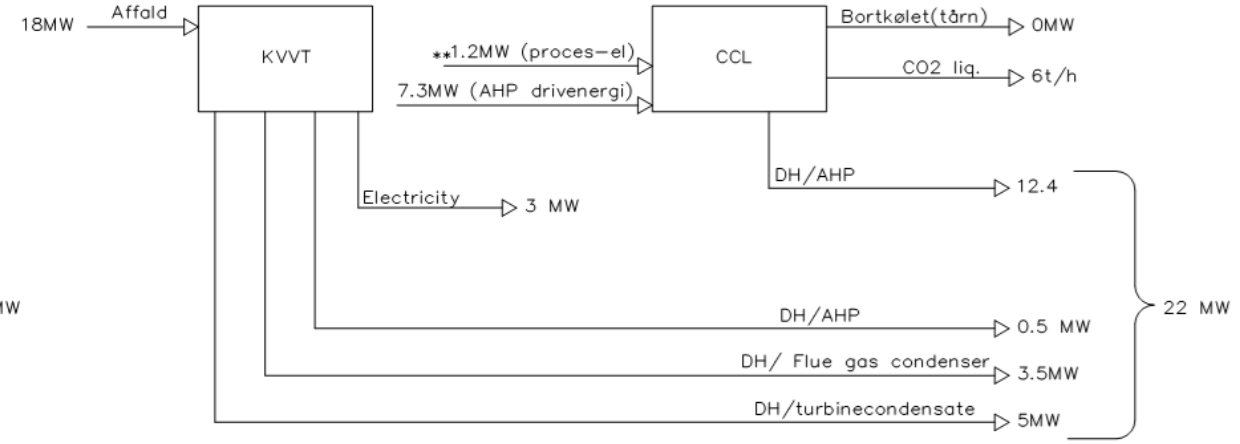
Case 0: Current operation



Case 4: Amine process, ER with AHP and Straw boiler for reboiler



Case 10: Enzymatic process



Challenges within Track 4+5

Track 4 – OPEX / CAPEX Business Model

- Budgettary figures for CAPEX provided through market dialogue with CC plant manufacturers
- OPEX figures for energy, chemistry, manpower, maintenance
- OPEX figures for transport and storage was a major headache in the first models

Track 5 – Regulation/Taxes

- Impact of CO2 taxes, incineration taxes, energy production taxes have been analyzed
- Calculation of timing has proven a challenge and is still an area for analysis.
- We DO have a target date set for when we expect the feasibility for a full scale to cross above zero!

Track 6 – Scenarios – Dynamic Full Scale Scenario Model

The sum of track 4 and 5 is amalgated into a ”one pager” strategy – This model has been updated several times!

Current status & projections

If we had to lock our implementation plan today, Thisted could go for the following scenario:

- Enzyme CC process (some budget validation outstanding ☺)
- Liquefaction to food-grade CO2
- Trucking and on-shore storage at Stenlille
- We aim to be up and running from 2028 – but would like to move faster if possible!

Our plans have changed SIGNIFICANTLY a couple of times in the last two years – and we are still constantly monitoring development in all tracks!

The steering committee for Thisted's CCS project

Thomas Sandal
Director, KVVT
Waste Incineration Plant

Søren Damgaard
Director, TVF
District Heating Plant

Lars Toft Hansen
Chairman of the board
KVVT & TVF

Asger Goth
Consultant
Goth Engineering

Morten Pipper
MD at SEG A/S
+45 26 81 93 81
Morten.pipper@segenergy.dk

Thank you for your attention!