Biomass CHP, Heat Networks, and Negative Emissions Modelling Multiple Products for Affordable Decarbonization





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Energy system and carbon optimization modelling excluding:

Biomass combined heat and power
Heat networks
Negative emissions

will generate erroneous or unrealistic results.

Models must be able to integrate three products from a single site.



Biomass CHP

CRCHLIGHT Energy Demand in New Brunswick, 2021



- Thermal energy (red shades) is almost 2/3 of New Brunswick's energy demand
- Electricity is only required for 13% and is 22% of current energy consumption





Energy Consumption in Sweden



58% renewable energy \bullet

FÓRCHLIGHT BIORESOURCES

>80% of biomass is forest-based



Bioenergy Demand in Sweden





Stockholm KVV8 CHP Plant

• 410 MW_{th}

- Heats 190,000 homes via DE
- 100% wood chips (3,500 t/day)
- Commissioned in 2016
- CapEx: C\$750 M
- 1,700 GWh heat (>2x Enwave)
- 750 GWh electricity
- 60% marine/40% rail
- Reduce: 650,000 t CO₂e/yr
- Footprint: 6,000 m²
- PM emissions < natural gas



















Current Industrial Bioheat Consumers

DIAGEO DANONE ABInBev BRIDGESTORE









Heat Networks



District Heating





Heat Network









Heat Network









Population Served by Heat Networks





Energy Consumption in Denmark, 2021



Biomass has a 96% share of Denmark's renewable district heating market (2/3 overall)

Co-generation electricity = 56% of wind generation



Bioenergy Demand in Denmark





Copenhagen Bio4 Biomass CHP Plant

- 550 MW_{th}
- 25% of heat for Copenhagen
- System peaks at ~4,000 MW_{th}
- 100% wood chips (4,700 t/day)
- Commissioned in 2019
- CapEx: C\$1 B
- 2,700 GWh heat
- 1,200 GWh electricity
- 100% marine chip delivery
- Reduce: 1.0 Mt CO₂e/yr
- PM emissions < natural gas













Biomass CHP for Economic Growth





Negative Emissions via BECCS

Bioenergy with Carbon Capture & Storage



Bioenergy Carbon Capture & Storage

- Lowest cost approach for permanent carbon dioxide removals – CDRs (negative emissions)
- Four decabonizations at once: electricity, heat, hard-to-abate, forests
- Three sources of revenue



CRCHLIGHT BECCS is Required to Meet Climate Goals

IPCC Mitigation Pathways Compatible with 1.5 C





GHG Cost Abatement Curve



Multiple Products = Economic Viability



Combined Cycle w CCS

ORCHLIGHT

Gas Co-Gen w CCS

BECCS



Canada Energy Regulator

- No Net Zero Grid or energy system without BECCS
- In 2050 Global Net Zero, CER modelled biopower as #1 electricity supply in SK and #2 in AB
- Modelled limit is biomass supply, not cost
- Negative cost electricity





"As the carbon price increases, biomass CCS units become a negative cost generation option, where its average cost of production in 2050 is -\$85/MWh. Therefore, biomass CCS partially displaces all other generation technologies in Alberta and Saskatchewan."



NORTHERN LIGHTS SCOPE









New Brunswick GHG Emissions, 2021







Net Zero NB with Six Projects

NB 2021 GHG Emissions = $11.9 \text{ Mt CO}_2 \text{ e}$

Emitter	Volume	
Irving Oil CCS	-2.7	BECCS @ Belledune reduces NB GHG emissions by 50%
Belledune Fuel Switch	-1.5 to -2.2	
Belledune BECCS	-4.3	
Irving P&P BECCS	-1.8	
AV Nackawic BECCS	-0.9	
AV Atholville BECCS	-0.6	
Twin Rivers BECCS	-0.8	
Total	-12.6 to -13.3	

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BECCS in Other Countries

Klemetsrud WtE Plant, Norway

- Part of Longship/Northern Lights
- Capture being added to waste-toenergy plant heating Oslo
- Shell Cansolv
- Under construction
- 400 kt CO₂/yr, North Sea storage
- Pilot plant and FEED showed technical viability

PT Tanjungenim Lestari Pulp & Paper, ID Pertamina and Marubeni (TELPP owner) partnering to develop BECCS plant at Kraft pulp mill in Indonesia (Sumatra)

- Mikawa Biomass Power, Japan
- 50 MW_e BECCS demonstration plant owned by Toshiba
- Operational

KVV8 Biomass CHP, Stockholm

- Wood chip-fuelled plant heating Stockholm via district energy system owned by Stockholm Exergi
- Plan to add capture (hot potassium capture by Capsol); pilot plant operated for multiple years
- >\$250 M in EU grant funding
- 800 kt CO₂/yr, North Sea storage via Northern Lights
- FEED study complete, 2026 commissioning planned

Avedøre Biomass Plant, Denmark

- Plant owned by Ørsted fueled by straw heats Greater Copenhagen
- Combined 430,000 t CO₂/yr to be captured from plant and Kalundborg CHP
- Microsoft purchasing 250,000 t CDR/yr for 11 years
- CO₂ to be stored by Northern Lights

Drax Power Plant, UK

- 4,000 MW pulverized coal power plant fuel switched to wood pellets (8-9 Mt/yr)
- Formerly largest GHG emitter in Europe
- Plan to initially add capture (MHI) to 2 of 6 units
- 8 Mt CO₂/yr (2 units), North Sea storage
- >\$20 M FEED underway (Worley, MHI)
- MHI operated pilot plant at site to test flue gas

Mönsterås Pulp and Paper, Sweden

- Njord Carbon partnership on BECCS between Equinor, Södra (major forest products company), and Verdane (Nordic private equity firm)
- Södra owns three pulp mills, with Mönsterås the largest (~2 Mt CO₂/yr)
- CO₂ shipping via Northern Lights