WP5
Biomass and the Energy Transition

Annual Conference, September 10, 2020 | Virtual Conference
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Introduction & Role of EPFL in SCCER BIOSWEET

- Modeling and design of biomass conversion systems and process chains.
- Definition and assessment of scenarios highlighting the role of biomass in the Swiss energy transition.
- New biomass conversion roadmap.
Biomass resources: Available Potential in Switzerland

Input in the scenario modeling comes from WSL in the form of sustainable biomass potentials. Aggregated values were used as a basis:

Wood: $50.2 \text{ PJ} \sim 14 \text{ TWh/y}$

Wet biomass: $46.8 \text{ PJ} \sim 13 \text{ TWh/y}$

and varied while defining the different scenarios.

Cost of resources:
Wood: $30.1 \text{ CHF/MWh} (420 \text{ MCHF/y})$

Wet biomass: $0 \text{ MCHF/GWh}$

Biogenic CO$_2$:
Wood: $5.43 \text{ Mt/y}$

Wet biomass: $4.89 \text{ Mt/y}$

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V. Burg, G. Bowman, M. Erni, R. Lemm, O. Thees, 2018, Analyzing the potential of domestic biomass resources for the energy transition in Switzerland, Biomass and Bioenergy, 111, 60-69.
Biomass Conversion for the Swiss Energy System

**Biomass to fuels (and heat):**
- Anaerobic digestion **Biogas (WP1)**
- Methanation **Biomethane (WP2)**
- Power-to-Gas
- Biomass to hydrogen
- Pyrolysis
- Gasification/HTG **HTG (WP3)**
- Fischer-Tropsch
- Biomass to ethanol **Liquid fuels (WP4)**
- Methanol synthesis

**Heat Production:**
- Combustion **(WP3)**
- CHP
- Fuel Cells **(WP2)**
- Gas engines/CCGT
- CHF **(WP4-WP5)**

**Power Production:**
- CHP **(WP3)**
- Fuel Cells **(WP2)**
- Engines
- BECCS

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Adapted from JA S&M Report “Technology characteristics” (in progress)
Integrating biomass in district systems
Integrated District Energy System (DES)
National potential

Wet bio. use [MWh/yr]
- 0 - 155
- 155 - 175
- 175 - 175
- 175 - 252
- 252 - 2339

Model parameters
# climate z. 7
# buildings 1.75 M
# rep. buildings 210
# districts 46'440
# rep. districts 42

Wet biomass use: 1’200 GWh/yr
Integrating biomass in District Energy System
National potential of integrated district energy systems

**Building stock**
Population: 8.3 Mhab.
Total ERA: 600 Mm²

**Biomass resource**
Primary pot.
- Wet bio.¹: 6.20 kWh/m²

Biomethane pot.
- tot. wet. b.: 7.10 kWh/m²
- tot. wo. b.: 17.5 kWh/m²

SNG pot.
- tot. wet. b.: 44 kWh/m²
- tot. wo. b.: 184 kWh/m²

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<table>
<thead>
<tr>
<th>/ERA m²</th>
<th>2015</th>
<th>Without Biomass</th>
<th>With Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating oil imp. kWh/yr</td>
<td>125.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Natural gas imp. kWh/yr</td>
<td>56.5</td>
<td>10.7</td>
<td>10.9</td>
</tr>
<tr>
<td>Electricity imp. kWh/yr</td>
<td>77.4</td>
<td>36.2</td>
<td>27.0</td>
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<tr>
<td>Wet bio. use kWh/yr</td>
<td>0</td>
<td>0</td>
<td>6.2</td>
</tr>
<tr>
<td>Invest. building CHF/yr</td>
<td>6.8</td>
<td>31.4</td>
<td>31.4</td>
</tr>
<tr>
<td>Invest. district CHF/yr</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
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<tr>
<td>Total expenses CHF/yr</td>
<td>40.4</td>
<td>39.7</td>
<td>43.2</td>
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<tr>
<td>CO2 emissions kgCO2-eq./yr</td>
<td>61.0</td>
<td>7.4</td>
<td>6.2</td>
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<tr>
<td>CO2 sequestrated kgCO2-eq./yr</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
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</table>

¹Primary potential from 1) sewage sludge, 2) green waste from landscape and households & 3) organic fraction of households garbage
Combined Heat and Fuel from woody energy biomass

Intensified processes for simultaneous production of fuels and heat

35% - 50% (using heat integration) of total process heat demand (20 PJ = 5.55 TWh) can be satisfied via proposed CHF plant using sustainable wood in Switzerland.

Substituted fossil carbon per unit of biogenic carbon in wood

For wood boiler (WB) 0.3 kg of fossil carbon are substituted per kg of biogenic carbon
How much fossil carbon can be substituted per unit of biogenic carbon
Carbon Flows in the Energy System

CO$_2$ from processing biogenic and non-biogenic resources captured and used for fuel and bio-product synthesis.

Biogenic CO$_2$: Wood: 5.43 Mt/y Wet biomass: 4.89 Mt/y
The EnergyScope Model

• Target year: 2050: population: 10Mcap
• Energy system optimization
  \[ \min C_{\text{tot}} = \min \left( \sum_{j \in \mathcal{E}} C_{\text{inv}}(j) + \sum_{j \in \mathcal{E}} C_{\text{maint}}(j) + \sum_{r \in \mathcal{R}} \sum_{t \in \mathcal{T}} C_{\text{op}}(r,t)_{\text{top}}(t) \right) \]
• Time resolution: monthly/hourly (typical days)
• Space resolution: national/cantonal

Carbon Flow Modeling

No CO2 accumulation in Atmosphere (constraint)
Biomass Technologies in the Swiss Energy System

Solutions generation

Energy flows in TWh, storage volumes in Mm$^3$, total cost in CHF/MWh/capita.

Connection with BIOSWEET WPs

- WP1: Biomass to Biogas
- WP2: Biomass and Wood Gas to Biomethane
- WP3: Biomass to Advanced Heat and Power
- WP4: Biomass to Liquid Fuels
- WP5: Biomass and the Energy Transition
Decarbonization of the Swiss Energy System

Total system cost: 16.10 bCHF/y 1.610 kCHF/y/cap

CO₂ sequestrated: 11.3 Mt/y 1.1 ton/y/cap

Energy flows (TWh/y)

<table>
<thead>
<tr>
<th>Other Renewables</th>
<th>70.7</th>
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</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>37</td>
</tr>
<tr>
<td>Wind</td>
<td>4.3</td>
</tr>
<tr>
<td>PV</td>
<td>25</td>
</tr>
<tr>
<td>Geothermal</td>
<td>4.4</td>
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<tr>
<td>Electricity</td>
<td>74.8</td>
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</tbody>
</table>

Biomass / waste: 47.5

Biofuels: 15.9

Bio-SNG: 14.5
Bio-ethylene: 0.2
Bio-diesel: 1.2

Fuel storage (*10³ m³): bio-SNG: 6053
H₂: 2711
bio-gasoline: 0.8
bio-diesel: 5.3

Biomass conversion: 1.3 (12%)
Decarbonization of the Swiss Energy System

Total system cost:  $3.13 \text{ bCHF/y}$  
$\text{CO}_2$ sequestrated:  $0.9 \text{ Mt/y}$

Energy flows (TWh/y)

- **Other Renewables:** +40
- **Hydro:** +0
- **Wind:** +0
- **PV:** +40
- **Geothermal:** +0
- **Electricity:** +29.7

- **Biomass / waste:** +0
  - Wood: +0
  - Wet biomass: +0
  - Waste: +0
  - HT Heat: +4.2
  - biomass conversion: +0.5 (+3.2%)

- **Biofuels:** +0.4
  - bio-SNG: -8.5
  - bio-$H_2$: +3.7
  - bio-gasoline: +0.2
  - bio-diesel: -0.2
  - bio-jet fuels: +21.1

- **Fuel storage ($*10^3 \text{ m}^3$):**
  - bio-SNG: -5047
  - $H_2$: +37600
  - bio-gasoline: -0.8
  - bio-diesel: +4.6

- **Electrolysis:**
  - $H_2$: +17.6
Biomass Technologies Utilization
Biomass Technologies Investment Costs

Biomass technology cost [CHF/y/capita]

1. Hydrothermal gasification
2. Aerobic digestion
3. Bio oils from Fischer-Tropsch
4. Wood gasification H2
5. Wood gasification SNG
6. Wood CHP

Total system costs

1570 - 2250 CHF/y/capita

Total Biomass Conversion costs

48 - 90 CHF/y/capita

i = 2.25%, lifetime 20-25 years
Conclusions

- Cascaded use of biomass in products before entering in energy
- Waste Biomass is a key resource for energy management
- Power to gas competes with
  - hydro power dams
  - CO2 sequestration
  - hydrogen (seasonal storage)
- The efficient use of easy to store and distribute energy is a key
- Reuse waste heat whenever possible
- When carbon based fuel is used, CO2 should be captured
Acknowledgement

Supported by:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

Innosuisse – Swiss Innovation Agency