Swiss Federal Laboratories for Materials Testing and Research - Empa

EMPA
Materials Science & Technology

36th Discussion Forum
LCA of Future Biofuels

LCA of the Production of Synthetic Natural Gas from Wood and Considerations to the Optimal Plant Scale

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Empa Akademie, November 17th 2008

Technology and Society Laboratory, Überlandstr. 129, CH-8600 Dübendorf, www.empa.ch/tsl

Outline

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- Introduction
- Production of Synthetic Natural Gas (SNG)
- LCA Energy-Hub Baden
- Considerations to the Optimal Plant Scale
- Conclusions

Introduction: energetic uses of wood

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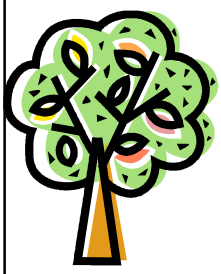
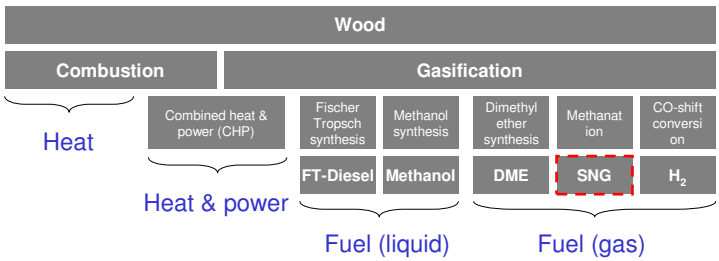
Wood as a renewable energy source…





Current use, CH	90%	5-10%	<1%
Efficiencies	60-95%	45-90%	~ 60-80% (SNG)
Exergy	< 25%	30-50%	~ 60-75% (SNG)

Advantages and disadvantages of Synthetic Natural Gas (SNG)

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Advantages

- Flexibility, SNG allows for a wide range of uses
  - Transport
  - Heating
  - Cooking
  - Use in the chemical industry
- Storage

Disadvantages

- Higher production costs than combined heat and power (CHP) and no guaranteed feed-in tariffs
- Direct combustion might be more efficient – but keep exergy concept in mind!

SNG technology development

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Early wood gasification

Wood gasification from 1920's on…

Wood driven automobile 1940s

Coal gasification USA, 2 GW

Development of the SNG technology

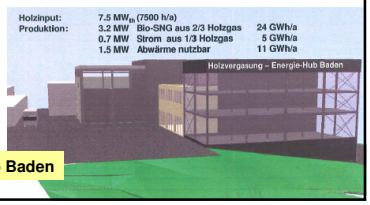
- 1960's / 70's: coal to methane
- 2000: wood to methane, (PSI)
- 2004: Güssing, pilot, 10 kW (PSI)
- 2008: Güssing, industrial pilot, 1 MW (PSI)

Güssing CHP, 8 MW

Güssing SNG pilot, 10 kW

Future projects

- Baden, 7.5 MW
- Eclépens, 20 MW
- Sweden, 140 MW



Energy Hub Baden

How is wood converted into Synthetic Natural Gas (SNG)?

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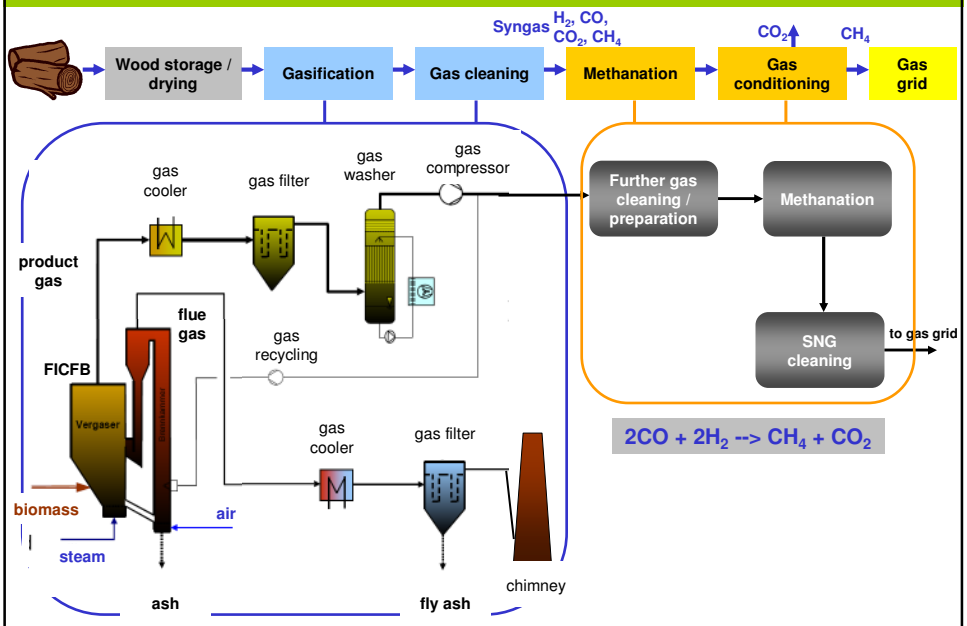
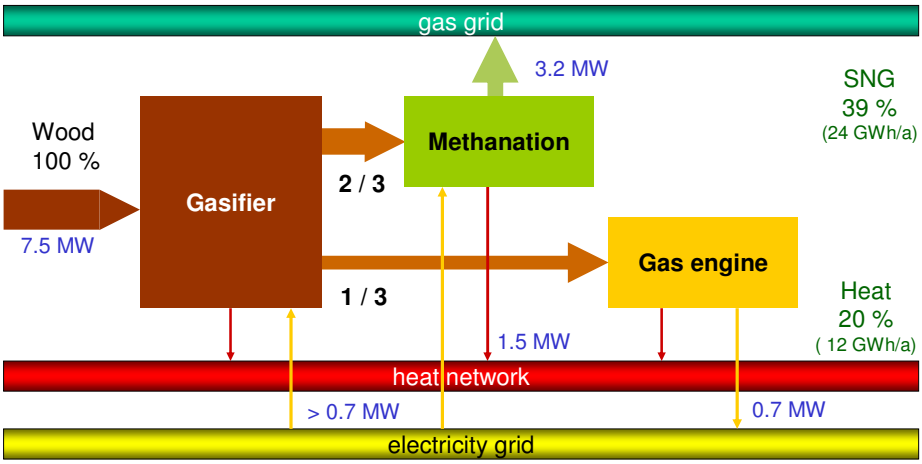


$2CO + 2H_2 \rightarrow CH_4 + CO_2$

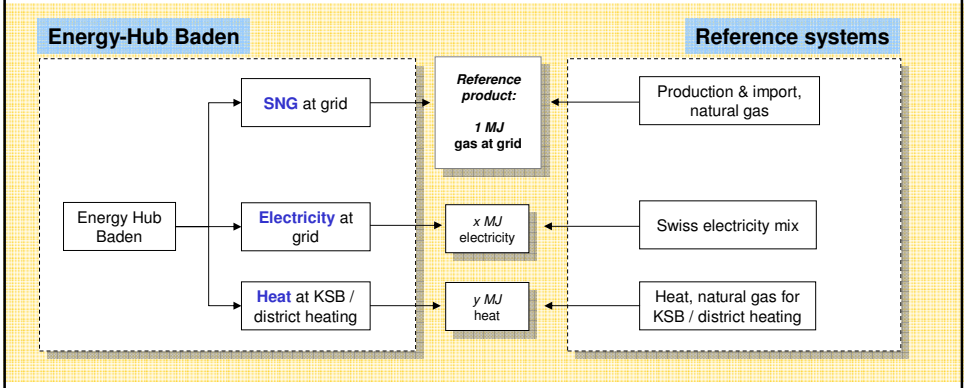
Energy Hub Baden – polygeneration of SNG, heat and electricity



Overall energy efficiency: 59 %

Life cycle analysis

Is SNG from the Energy-Hub in Baden better from an environmental perspective than imported natural gas?



LCI data from ecoinvent database version 2.01

Ecological Scarcity

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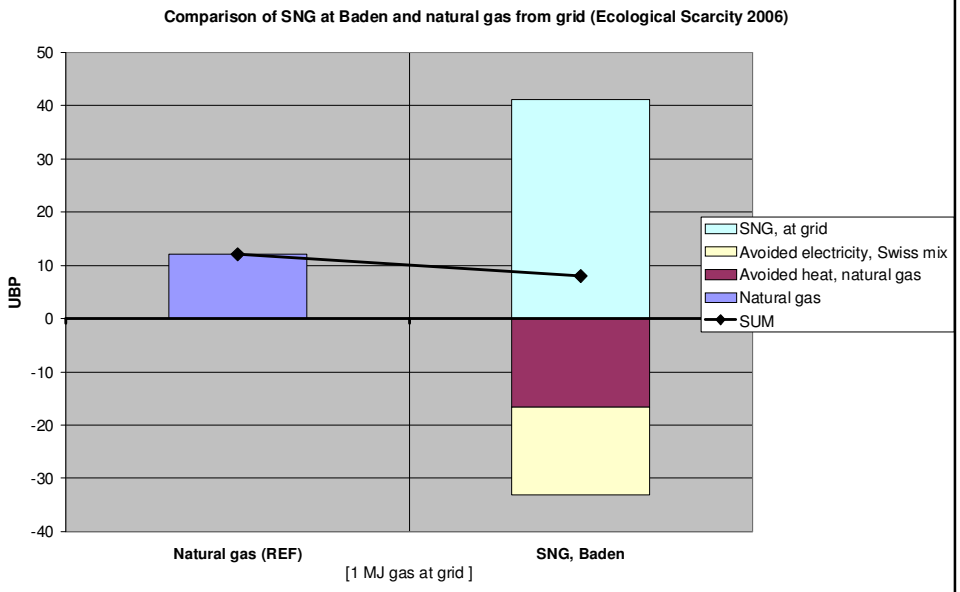

Ecoindicator '99

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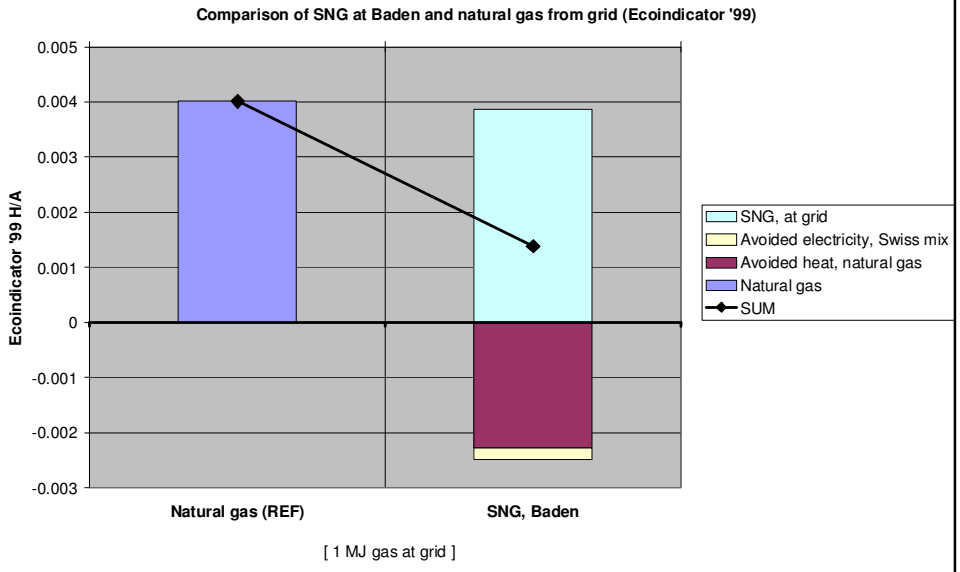
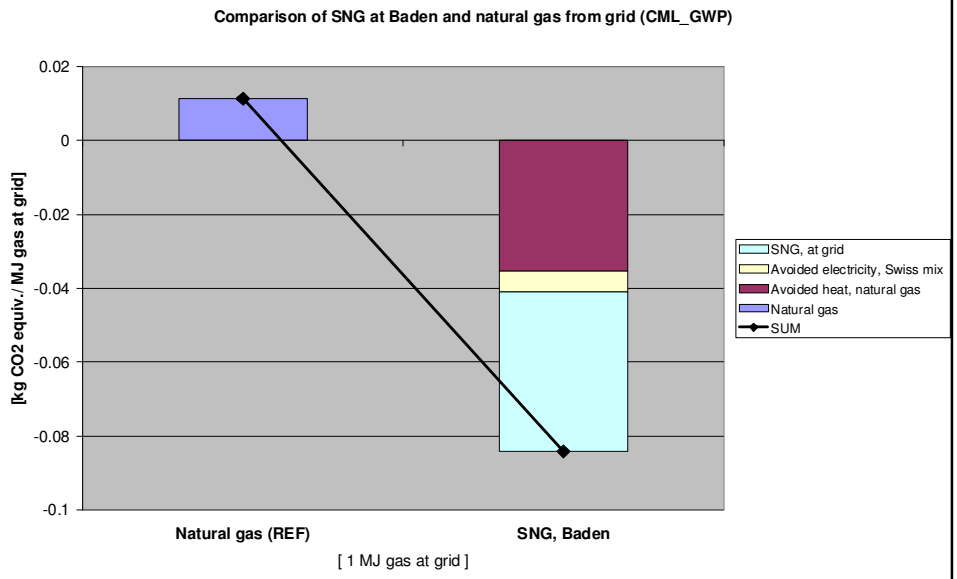


CML, GHG

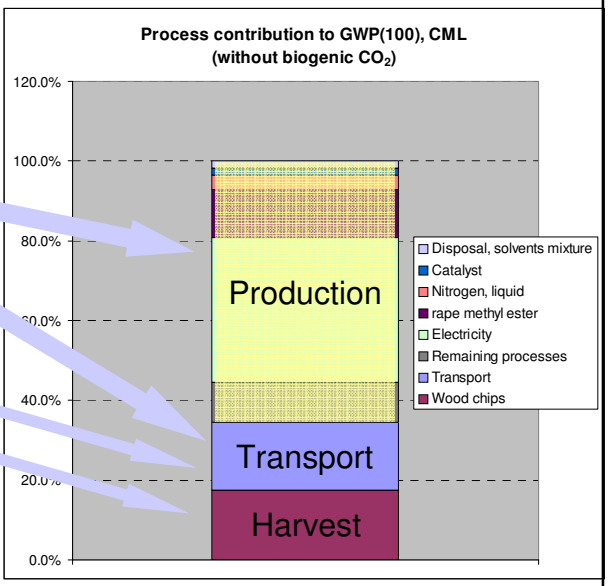


Process contribution to GWP (100)

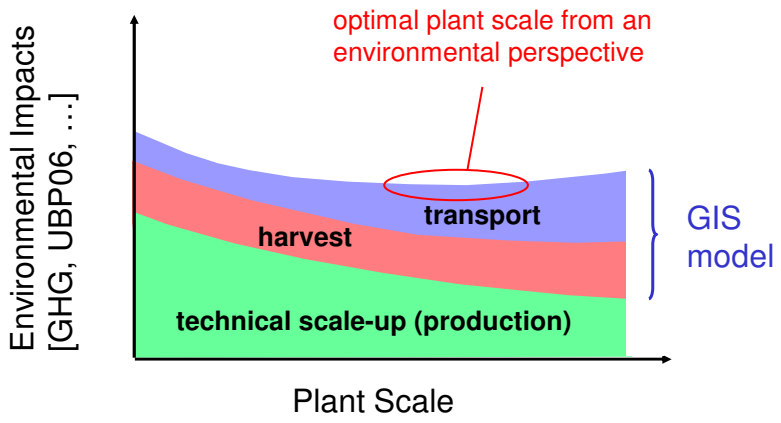
Driving factors:

plant size

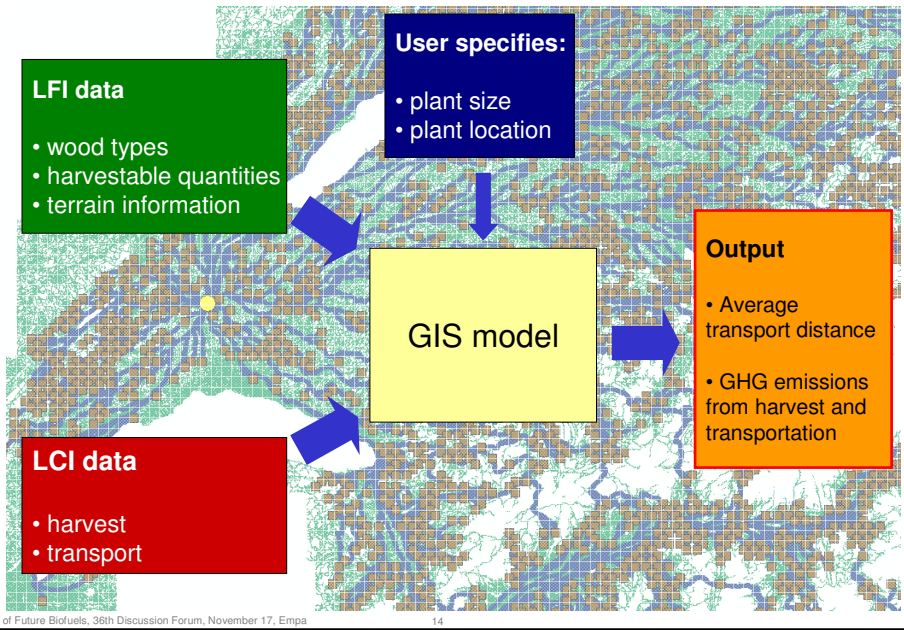
plant location



Is there an optimal plant scale (from an environmental perspective)?



The dynamic GIS model



Approaches used to calculate the impact of harvest, transport and production

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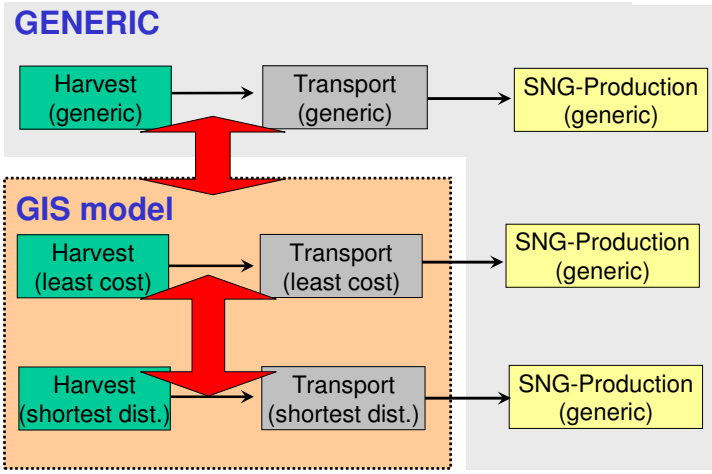
Generic approch (average LCI data)

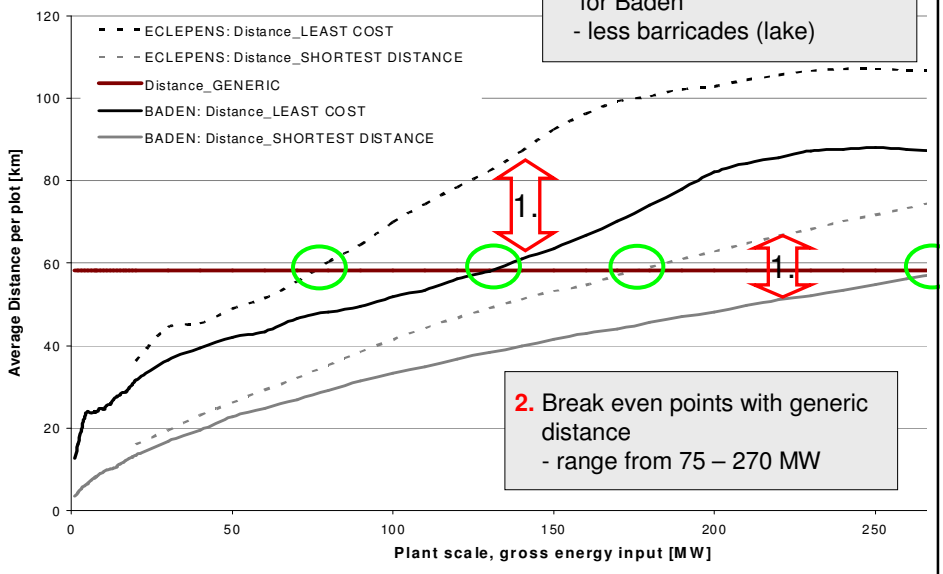
Least cost approach:
- least costly sites first

Shortest distance approach:
- nearest sites first



Transport distance: Eclépens vs. Baden

1. Smaller transport distances for Baden
- less barricades (lake)



2. Break even points with generic distance
- range from 75 – 270 MW

GIS view of the LFI data points in the region of Eclépens

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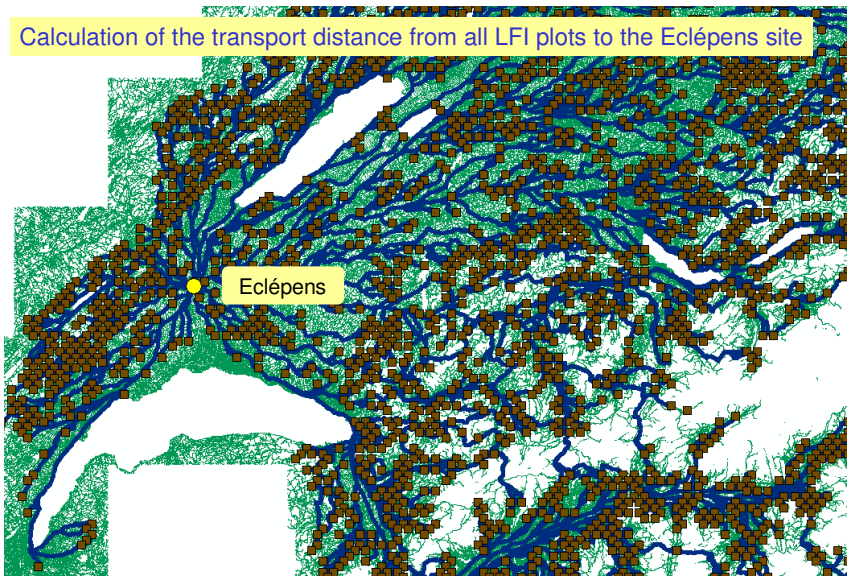
Calculation of the transport distance from all LFI plots to the Eclépens site



Note the influence of the lakes on the transport distance!

Transport: GHG-emissions Baden (GIS) vs. generic

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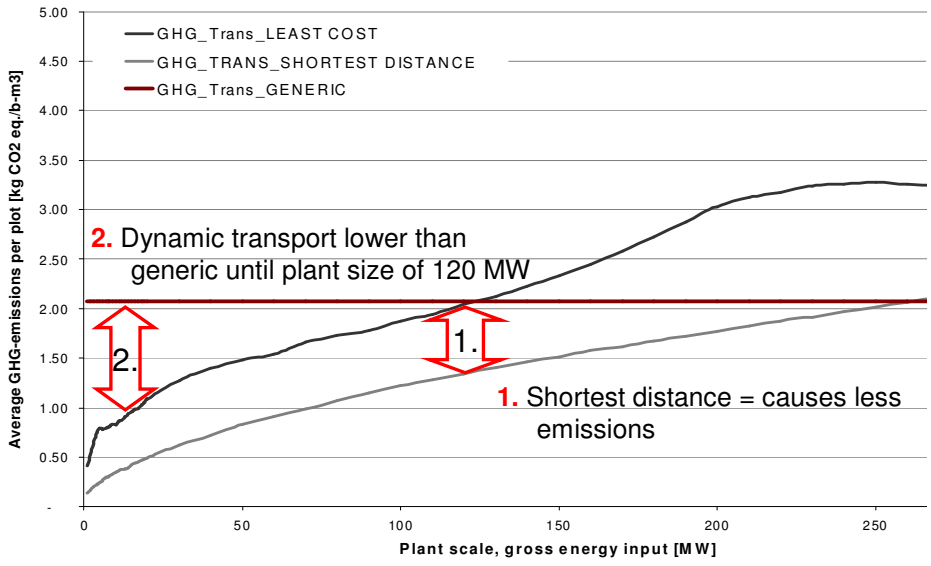
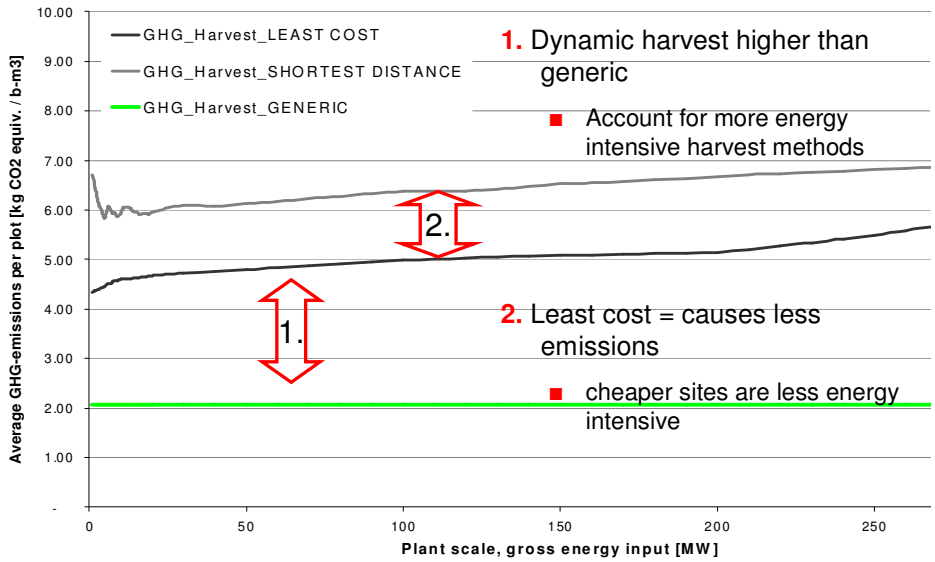


Harvest: GHG-emissions Baden (GIS) vs. generic



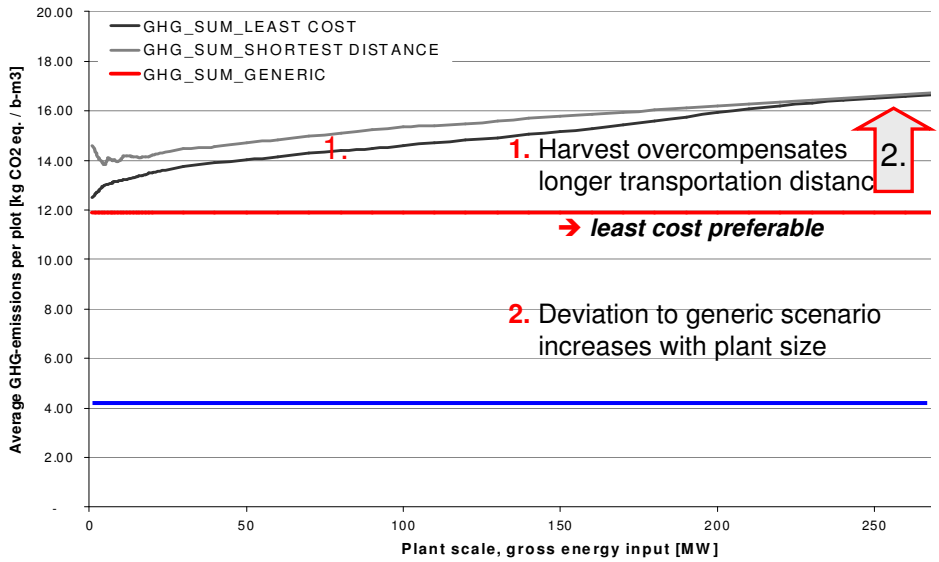
1. Dynamic harvest higher than generic

- Account for more energy intensive harvest methods

2. Least cost = causes less emissions

- cheaper sites are less energy intensive

Harvest + Transport + Production: GHG-emissions



1. Harvest overcompensates longer transportation distanc

➔ ***least cost preferable***

2. Deviation to generic scenario increases with plant size

Comparison of GIS and generic GWP (100) data for specific plant sizes

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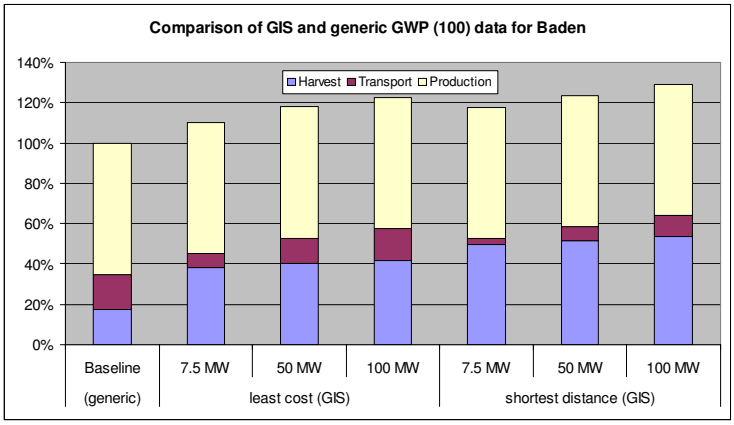

- GIS always higher than generic, due to underestimation of harvest
  - Variation: 10 – 29 %

Conclusions

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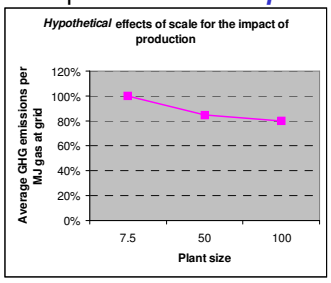
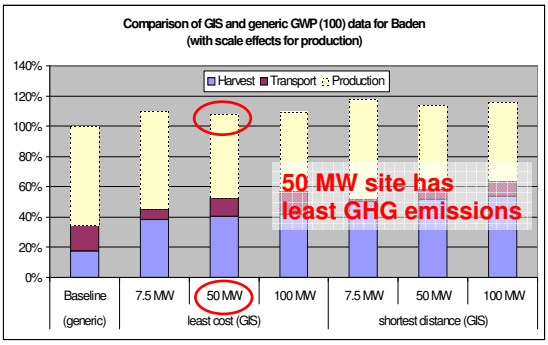
- SNG from Baden tends to be **better than imported natural gas**
- **Plant size matters** from an environmental perspective, since the impacts of transport and production vary
- **GIS: Least cost scenario performs better** than shortest distance
- **Significant differences** exist between the generic and the dynamic impacts of **harvest**
- To determine an optimal plant scale, a **better understanding of the impact of scale on production is needed**
- Gasification of biomass is a **promising technology** but to be successful **costs have to be lowered**

Outlook

- Next LCA: Now that we have a LCA for SNG, we are **ready to investigate the best use of wood** (direct combustion, CHP or SNG)
- Optimal plant size: An Empa PhD thesis is currently dedicated to the estimation of up-scaling of technology in LCA

Just to provide an ***example*** what it could look like…





With kind support of

ccem.ch

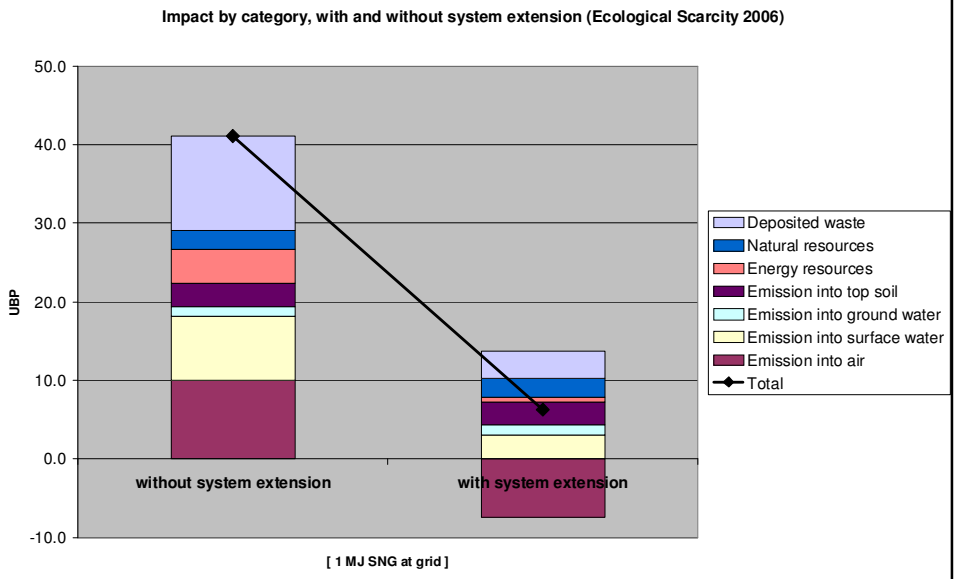
Conzepte Technik Umwelt

Thank you for your attention!

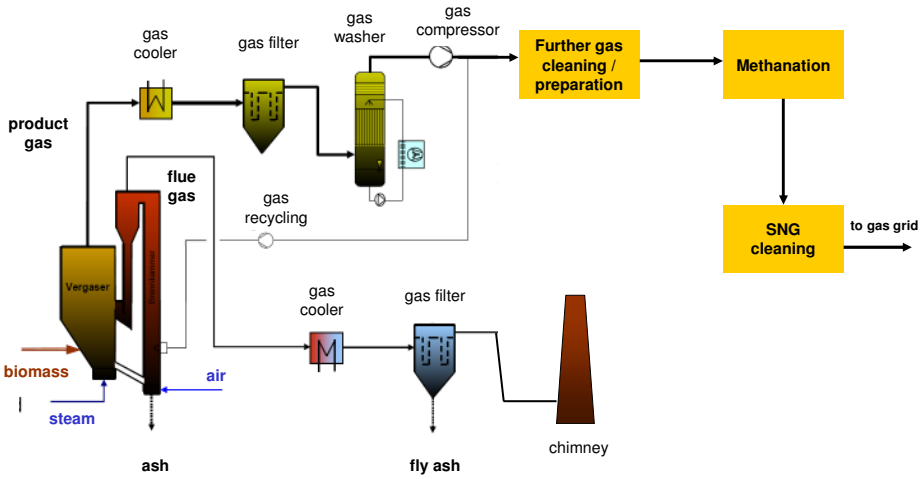
Questions?

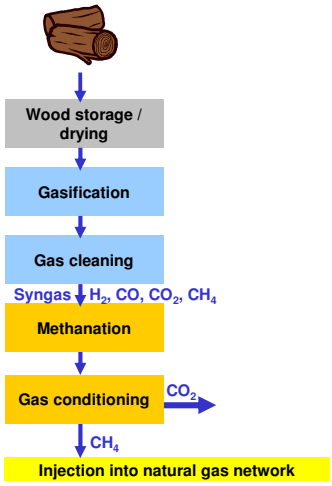
Bernhard.Steubing@empa.ch

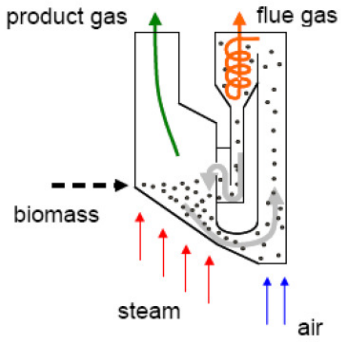
Impact by category, with and without system extension (UBP)



How is wood converted into Synthetic Natural Gas (SNG)?







Quelle: Hofbauer, H. 2003

How is wood converted into Synthetic Natural Gas (SNG)?

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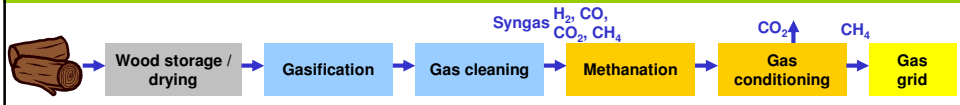
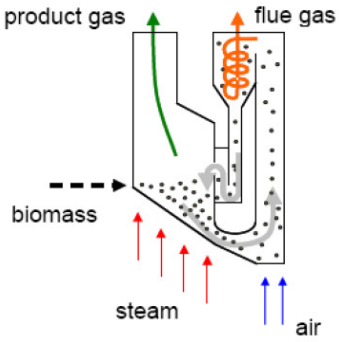
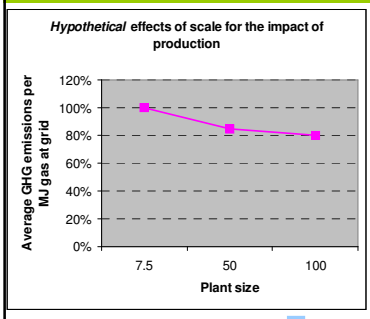
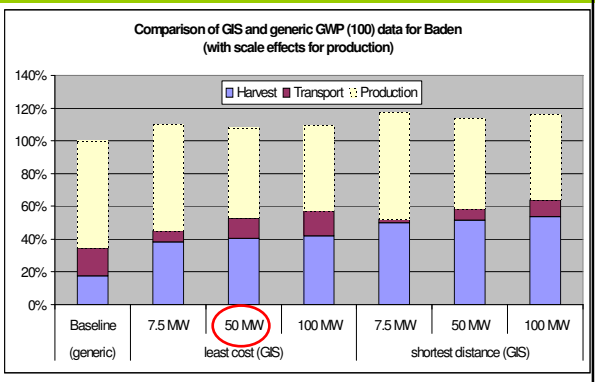




Quelle: Hofbauer, H. 2003

Estimation of the optimal plant scale with **hypothetical** effects of scale





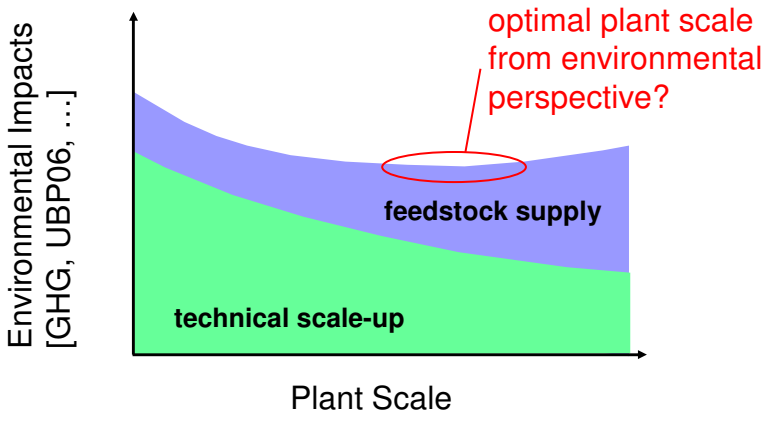
Assumptions:

- 15% less environmental impact, when up-scaling from 7.5 MW to 50 MW
- 5% less environmental impact, when up-scaling from 50 MW to 100 MW

➔ the 50 MW plant has now the smallest environmental footprint

Finding the optimal plant scale from an environmental perspective

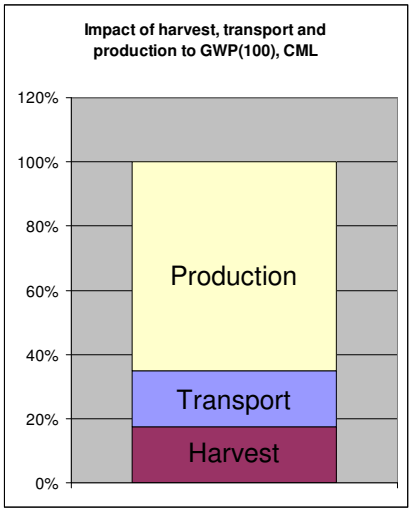
- Upscaling of Environmental Impacts (EMPA-EPFL)



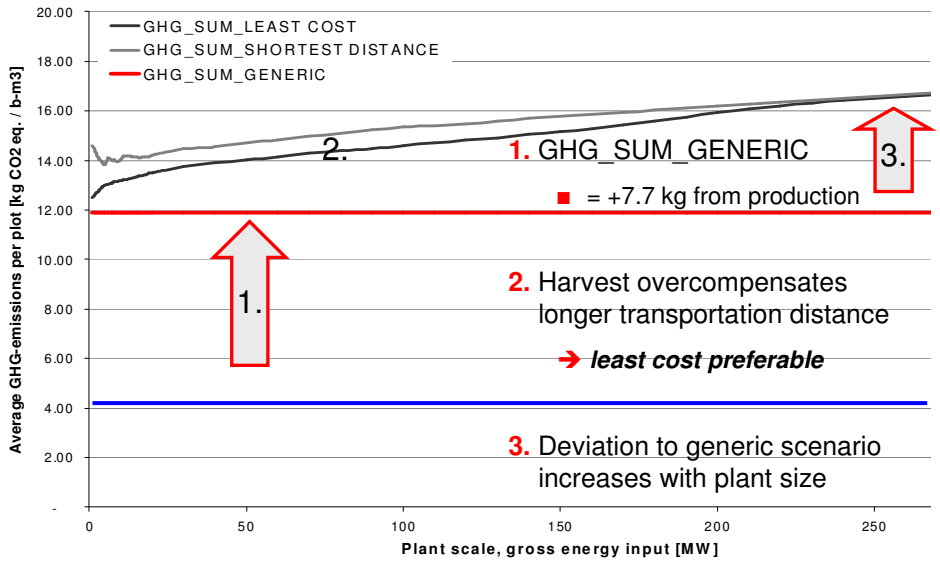
LCA research questions

- Is SNG from the Energy-Hub in Baden better from an environmental perspective than imported natural gas?
- What is the influence of transport in the LCA?
- What is the influence of plant scale and plant location on transport and harvest intensity?
  - Eclépens vs. Baden
  - What is the influence of the applied search algorithm?
  - What are the respective environmental impacts (GHG-emissions)?
- How accurate is the generic LCI of “methane from wood” in comparison to the dynamic spatial approach (Baden)?
  - What are the contributions of transport and harvest in relation to the overall impacts?

The impact of harvest, transport and production



Harvest + Transport + Production: GHG-emissions



FRAGEN

- Wie ist das genau mit der FU? (SNG? + H+E? muss gleich sein wie bei Erdgas?)
- Was gehört in eine typische LCA Präsentation?
  - Goal and Scope
  - System boundaries and Functional Unit
  - Life Cycle Inventory
  - Impact Assessment
- Outlook: die anderen LCA Fragestellungen vorstellen…

Research Questions (of this presentations)

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1. What is the influence of plant scale and plant location on transport and harvest intensity?
   - Eclepens vs. Baden
   - What is the influence of the applied search algorithm?
   - What are the respective environmental impacts (GHG-emissions)?
2. How accurate is the generic LCI of “methan from wood” in comparison to the dynamic spatial approach (Baden)?
   - What are the contributions of transport and harvest in relation to the overall impacts?

GIS approaches and comparison to generic data

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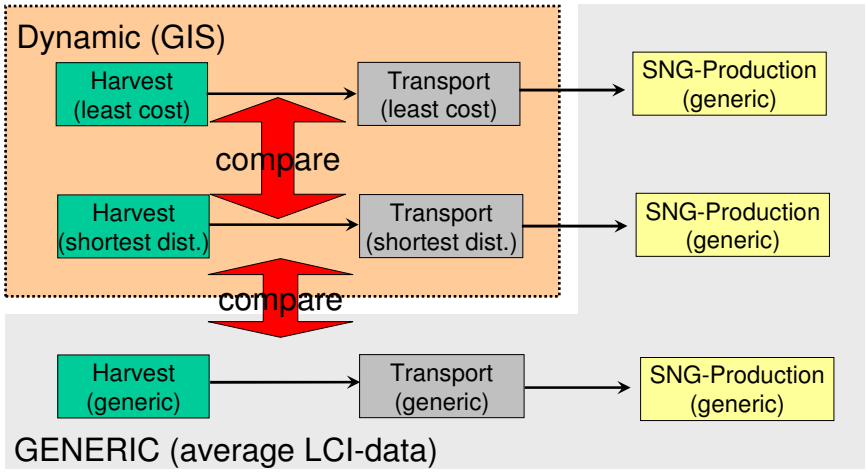
Least cost approach:
- least costly sites first

Shortest distance approach:
- nearest sites first



Process contribution to GWP (100)

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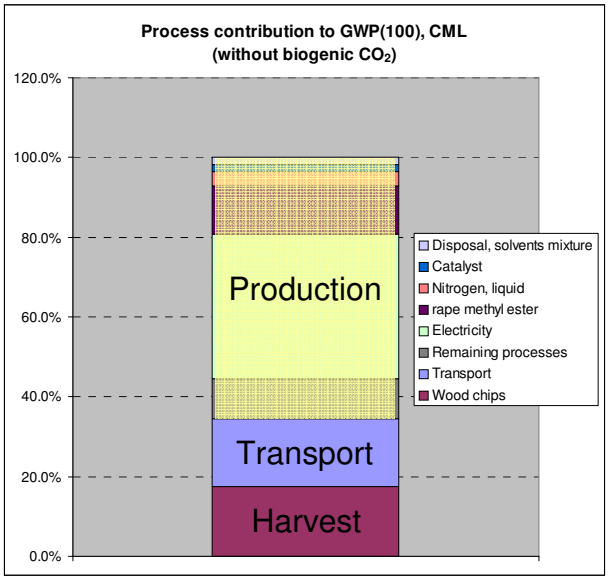

Task 5.2: Environmental Performance

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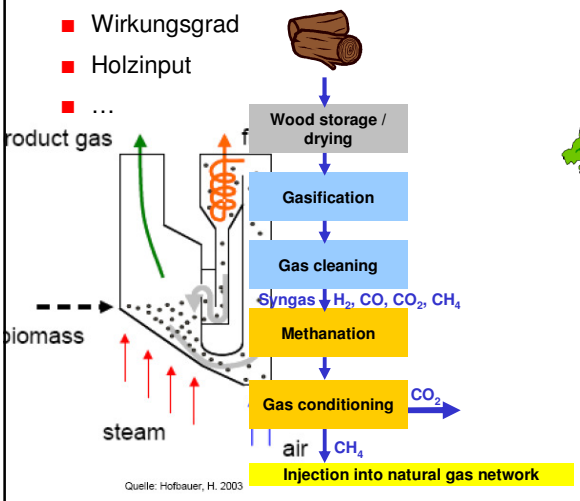
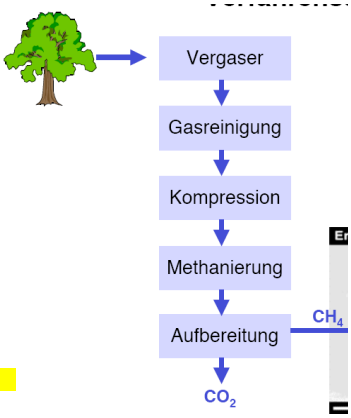
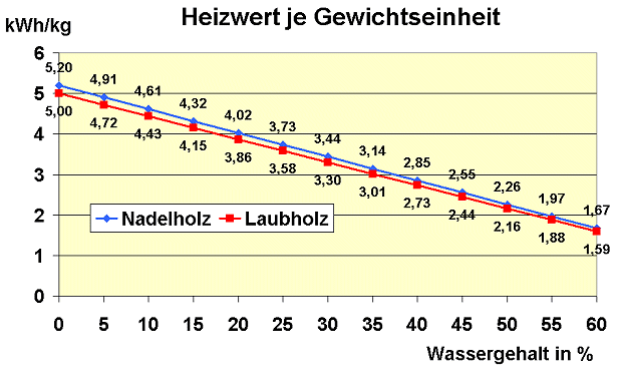
- Comparative Life Cycle Assessment (LCA) for selected scenarios of biogas production using 2nd generation methanation
- Goals:
  - Demonstrating the environmental performance of 2nd gen. methanation **compared to other** 1st and 2nd gen. technologies;
  - Assessment of **optimal pathways in a spatial context** using GIS (urban – rural; plateau – alps)
  - Study the **consequences of plant scale** on impacts considering transport distance and “ecology of scale”.

Technology perspective: SNG from wood

- How it works
  - Wirkungsgrad
  - Holzinput
  - …

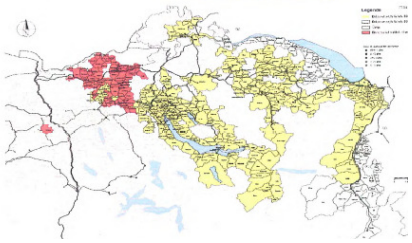






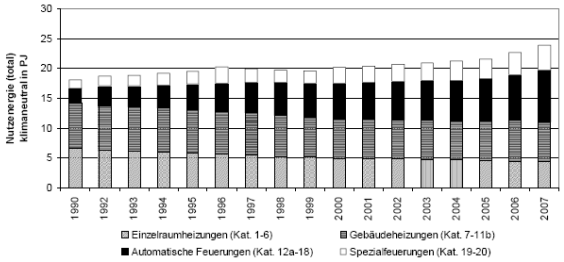
Waldholz Region Baden-Zurzach

Einzugsgebiet, ca. 60% vom vermarktbaren Waldholz



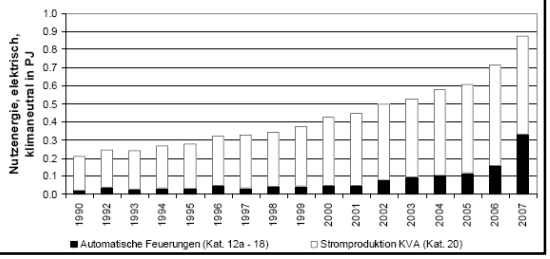
	Kategorie 1-19 (ohne KVA)		Kategorie 1-20	
Waldholz	2.02	65%	2.02	58%
Holzpellets	0.17	6%	0.17	5%
Restholz	0.66	21%	0.66	19%
Altholz	0.26	8%	0.63	18%
Alle Holzbrennstoffe	**3.11**	**100%**	**3.48**	**100%**

Tabelle 3.1 Anteile verschiedener Holzbrennstoffe am effektiven Holzumsatz 2007:
in Millionen Kubikmeter Holzfestmasse



Energy wood use is increasing; larger installations are main drivers

CHP nimmt zu!!



Verbrauchergruppe / Jahr	2007	Anteil	2000	Anteil	1990	Anteil
Haushalte	15'835	52%	16'805	61%	20'372	72%
Land- / Forstwirtschaft	557	2%	537	2%	423	1%
Industrie / Gewerbe	7'470	24%	5'407	20%	4'307	15%
Dienstleistungen	5'369	17%	4'373	16%	2'884	10%
Elektrizität	596	2%	64	0%	35	0%
Fernwärme	867	3%	498	2%	285	1%
Alle Anlagenkategorien (ohne KVA) Wert für Gesamtenergiestatisitk	30'693	100%	27'684	100%	28'306	100%

Tabelle 4.1 ***Bruttoverbrauch Holz 1990, 2000 und 2007 nach Verbrauchergruppen***
in TJ, effektive Jahreswerte (ohne KVA)

Verbrauchergruppe / Jahr	2007	Anteil	2000	Anteil	1990	Anteil
Haushalte	15'835	46%	16'805	55%	20'372	67%
Land- / Forstwirtschaft	557	2%	537	2%	423	1%
Industrie / Gewerbe	7'470	22%	5'407	18%	4'307	14%
Dienstleistungen	5'369	16%	4'373	14%	2'884	9%
Elektrizität	1'923	6%	1'030	3%	631	2%
Fernwärme	3'102	9%	2'334	8%	1'918	6%
Alle Anlagenkategorien (inkl. KVA)	34'255	100%	30'487	100%	30'535	100%

Tabelle 4.2 ***Bruttoverbrauch Holz 1990, 2000 und 2007 nach Verbrauchergruppen***
in TJ, effektive Jahreswerte (inkl. KVA)

Consumer group	
Households	46%
Industry	22%
Service sector	16%
District heating	9%
Electricity production	6%
Agriculture / Forestry	2%
Total	100%

SNG technology applied

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Evolution of the technology

- 1960's / 70's: methane from coal
- 2000: methane from wood, PSI
- 2004: Güssing, pilot, 10 kW
- 2008: Güssing, industrial pilot, 1 MW

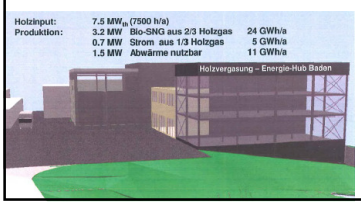
Possible future projects:

- Baden, 7.5 MW
- Eclépens, 20 MW
- Sweden, 100 MW gas output!

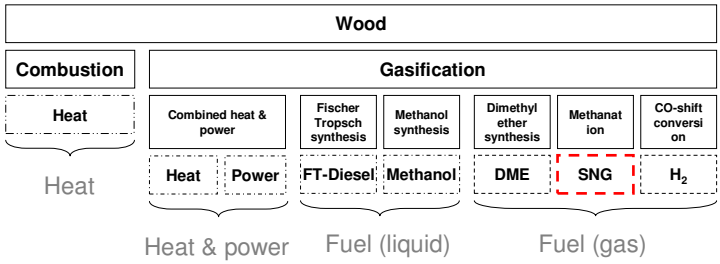
CHP plant, 8 MW

Güssing

SNG pilot, 10 kW

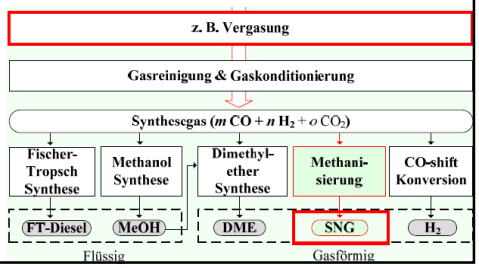


Introduction: energetic use of wood



Introduction: energetic use of wood

1. Direct incineration
2. Gasification
   - CHP
   - methane
   - dimethylether (DME)
   - methanol
3. Ethanol / biodiesel production (?)



Technology perspective: SNG from wood

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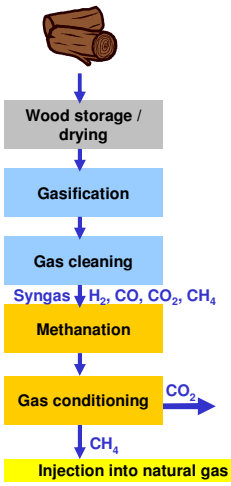
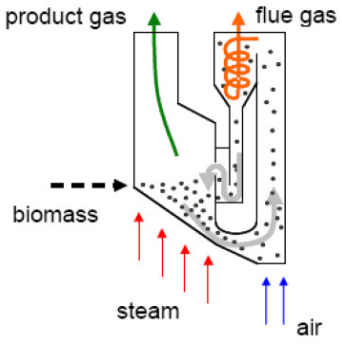
- How it works





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