biosweet
Biomass for Swiss Energy Future
Swiss Competence Center for Energy Research

IPESE Industrial Process and Energy Systems Engineering
EPFL École Polytechnique Fédérale de Lausanne

In cooperation with the CTI
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The Role of Biomass in the Swiss Energy Transition

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MOTIVATION

Potential of Renewable Energy Sources in Switzerland

Solar PV
12 TWh_{el}/year (η = 16%) – 18 TWh_{el}/year (η = 25%)

Wind
4 TWh_{el}/year

Hydro
1.5 – 3.6 TWh_{el}/year

Deep geothermal
4.4 TWh_{el}/year

Biomass
24 - 36 TWh/year

Half of it is already exploited. In Switzerland, 5% of primary energy demand. In Austria, 17% of primary energy demand.

12 TWh/year (wood from forests and wood residues)

DATA FROM:

Promotion of Biomass Technologies

- Local resource
- Renewable resource

EXAMPLES

Canton de Valais

Subsidies for wood boilers: 1000 CHF + 150 CHF/kW for new wood boilers (20 – 70 KW)

(About 50% of the boiler purchase cost)

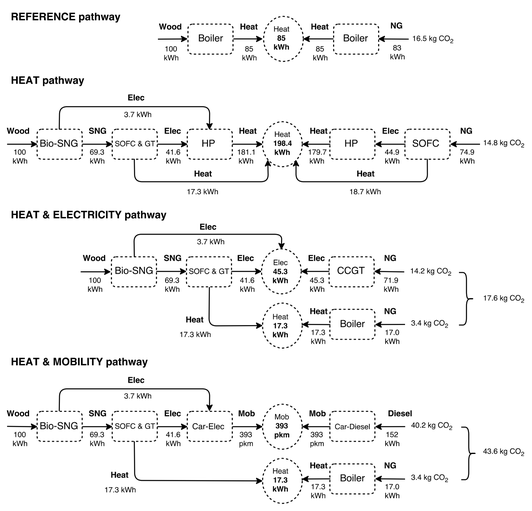
Ville de Lausanne (Pyrolysis)

La Ville veut fabriquer son combustible de chauffage

Lausanne Un biocombustible, produit à partir du bois, permettrait à Lausanne de limiter sa consommation de gaz. Elle songe a construire une raffinerie.

CO_2 MITIGATION POTENTIAL OF WOODY BIOMASS CONVERSION PATHWAYS

Reference substitution pathway and substitution pathway examples for the three considered approaches:



Fossil CO_2 emissions reduction through the substitution of natural gas, diesel or coal by biomass usage pathways for space heating and mobility (Reference value: 1.00 ≡ 0.165 $kgCO_2/kWh_{WoodyBiomass}$).

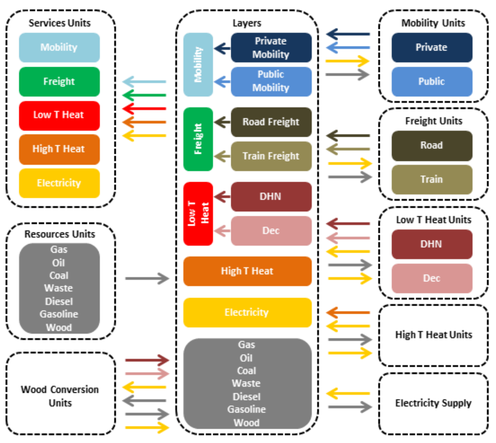
			Transport & Heat			
Biomass to Fuel	Fuel to X	Elec. to Transport	Car-Diesel Boiler(Natural gas)	Car-CNG Boiler(Natural gas)	Car-Elec(CCGT) Boiler(Natural gas)	Car-Elec(Supercritical coal) Boiler(Natural gas)
–	Boiler	–	1.00	1.00	1.00	1.00
HTG	Car-CNG	–	1.07	1.02	0.51	0.88
Bio-SNG	Car-CNG	–	1.07	1.01	0.46	0.86
Bio-SNG & Electrolysis	Car-CNG	–	2.19	2.04	0.71	1.68
FT	Car-Diesel	–	0.70	0.65	0.23	0.53
FT & Electrolysis	Car-Diesel	–	1.35	1.26	0.44	1.04
HTG	Cogen eng	Car-Elec	2.32	2.19	0.99	1.86
Bio-SNG	Cogen eng	Car-Elec	2.38	2.24	1.03	1.91
Bio-SNG & Electrolysis	Cogen eng	Car-Elec	5.31	5.01	2.34	4.28
FT	Cogen eng	Car-Elec	1.21	1.15	0.54	0.98
FT & Elec	Cogen eng	Car-Elec	2.35	2.22	1.05	1.90
HTG	SOFC	Car-Elec	2.77	2.60	1.03	2.17
Bio-SNG	SOFC	Car-Elec	2.86	2.68	1.07	2.24
Bio-SNG & Electrolysis	SOFC	Car-Elec	6.48	6.08	2.44	5.08
HTG	SOFC & GT	Car-Elec	3.47	3.24	1.21	2.68
Bio-SNG	SOFC & GT	Car-Elec	3.60	3.36	1.26	2.79
Bio-SNG & Electrolysis	SOFC & GT	Car-Elec	8.30	7.76	2.91	6.43
HTG	SOFC & GT & CCS	Car-Elec	4.16	3.94	1.96	3.40
Bio-SNG	SOFC & GT & CCS	Car-Elec	4.34	4.11	2.06	3.55
Bio-SNG & Electrolysis	SOFC & GT & CCS	Car-Elec	10.12	9.59	4.88	8.30
HTG	CCGT	Car-Elec	2.70	2.51	0.88	2.07
Bio-SNG	CCGT	Car-Elec	2.78	2.59	0.90	2.13
Bio-SNG & Electrolysis	CCGT	Car-Elec	6.28	5.86	2.04	4.81
HTG	CCGT & CCS	Car-Elec	3.17	3.00	1.50	2.59
Bio-SNG	CCGT & CCS	Car-Elec	3.28	3.11	1.57	2.69
Bio-SNG & Electrolysis	CCGT & CCS	Car-Elec	7.52	7.14	3.68	6.19
BIGCC		Car-Elec	2.45	2.33	1.19	2.01
CFB-SOFC-GT		Car-Elec	4.16	3.88	1.35	3.19
CFB-SOFC-GT & CCS		Car-Elec	5.99	5.72	3.33	5.07
Torrefaction	Supercritical plant	Car-Elec	2.46	2.29	0.80	1.88

List of considered technologies

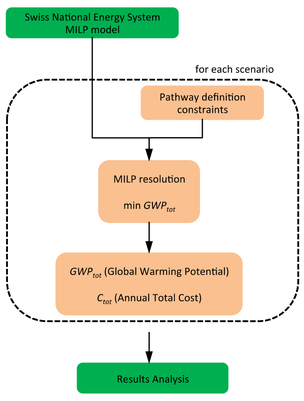
Technology
Hydrothermal gasification (HTG)
Conventional gasification and methanation (Bio-SNG)
Bio-SNG with electrolysis
Fischer-Tropsch synthesis (FT)
FT with electrolysis
Integrated Gasifier-SOFC-GT System (CFB-SOFC-GT)
CFB-SOFC-GT with CCS (CFB-SOFC-GT & CCS)
Biomass Integrated Gasification Combined Cycle (BIGCC)
Torrefaction
Wood boiler
Oil boiler
Gas boiler
Gas cogeneration engine (Cogen. eng.)
Oil cogeneration engine (Cogen. eng.)
Solid Oxide Fuel Cell (SOFC)
Hybrid cycle SOFC and Gas Turbine (SOFC & GT)
SOFC & GT with CCS (SOFC & GT & CCS)
Combined Cycle Gas Turbine (CCGT)
CCGT with CCS (CCGT & CCS)
Supercritical plant
Heat pump
Car-Diesel
Car-CNG
Car-Electric

OPTIMAL USE OF BIOMASS IN LARGE-SCALE ENERGY SYSTEMS: INSIGHTS FOR ENERGY POLICY

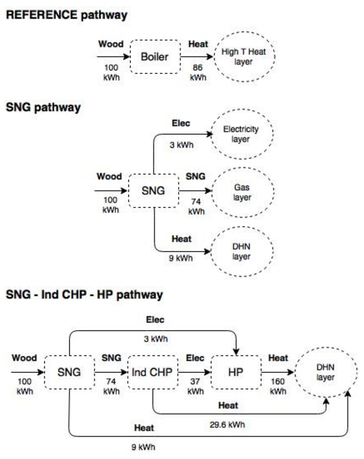
Graphical representation of the modelling framework.



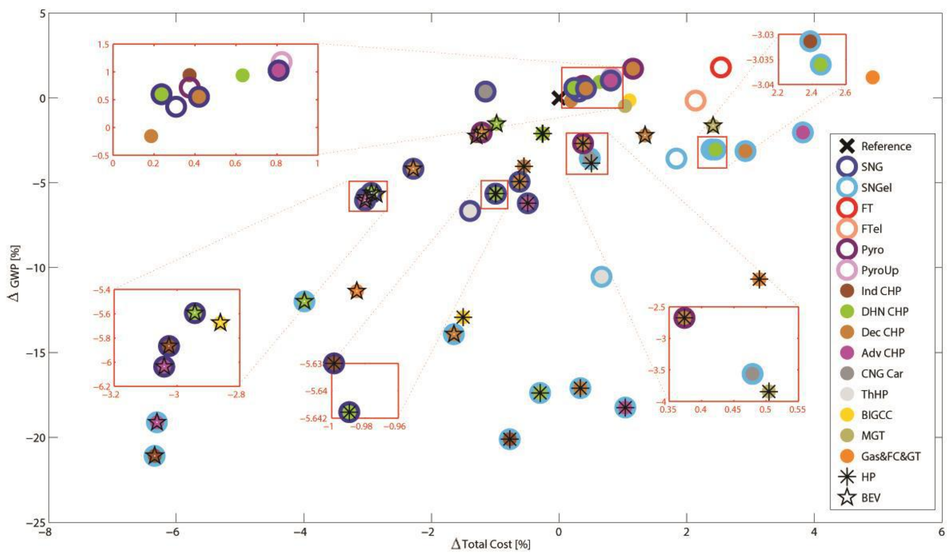
Scenario evaluation methodology.



Example of biomass conversion pathways: "Reference", "SNG", and "SNG – Ind CHP – HP" pathways.

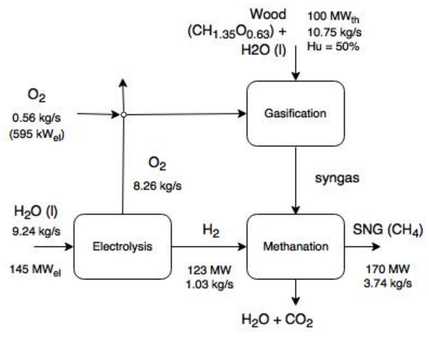


Annual GWP impact and Total Cost relative values for the 56 scenarios compared to the Reference scenario.

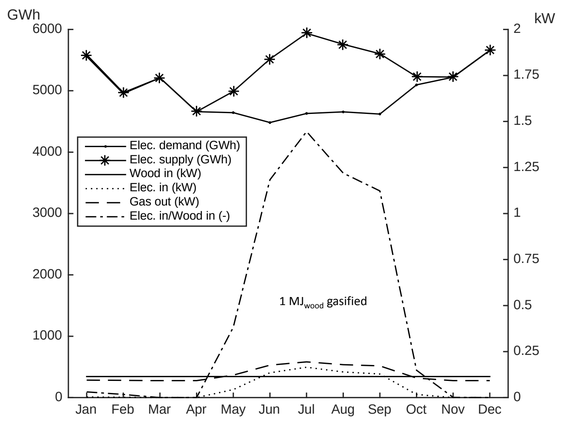


WOODY BIOMASS FOR RENEWABLE ELECTRICITY STORAGE

- Future energy scenarios contemplate an important deployment of PV panels.
- Excess electricity during summer months. Need to store it.
- Gasification-Methanation of woody biomass combined with hydrogen production allows to store excess electricity.

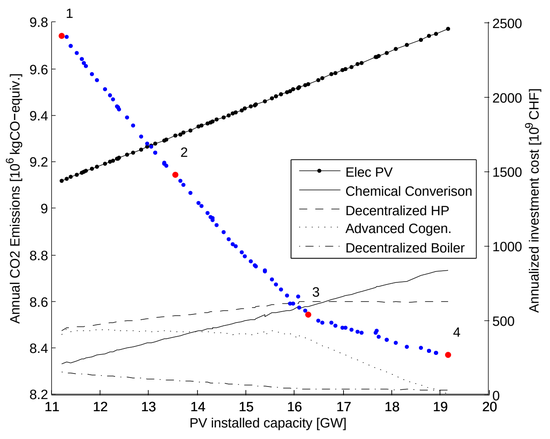


Behavior of the bio-SNG with electrolysis system considering electricity demand and supply profiles of the "New Energy Policies" scenario in 2050.



Design of new energy scenarios. Goal:
Minimizing energy dependency of Switzerland
By:

- Increasing PV installed capacity.
- Use of bio-SNG & elec. for electricity storage.
- Not allowing import and export of electricity.



- 38% reduction in the CO_2 emissions respect to the NEP scenario.
- Investment of 0.287 CHF in decentralized heat pumps and 0.622 CHF in the bio-SNG with electrolysis system for every CHF invested in PV capacity

New Energy Policies Scenario for 2050

Input / Output data		NEP	F1P1	F1P2	F1P3	F1P4
Vehicle types	Battery electric vehicles	21.9	85.0	84.8	84.1	85.0
	Hybrid vehicles	15.3	15.0	15.0	15.3	12.2
	Natural gas vehicles	2.1	0.0	0.0	0.2	1.6
	Hydrogen vehicles	4.4	0.0	0.1	0.3	0.7
	Gasoline/Diesel vehicles	56.3	0.0	0.1	0.1	0.5
Technology mix for distributed heating [%]	Electric heat pump	18.7	27.6	33.2	39.4	39.3
	Thermal heat pump	0.0	0.0	0.0	0.0	0.0
	Cogeneration	7.7	7.7	7.7	7.7	7.7
	Advanced cogeneration	0.3	1.2	1.1	1.0	0.0
	Boiler	25.6	15.7	10.2	4.1	5.2
	Solar	46.1	46.1	46.1	46.1	46.1
	Electric heater	1.6	1.6	1.6	1.6	1.6
Installed capacity PV [GW]		11.21	11.21	13.55	16.28	19.16
Installed capacity SNG [GW_{WoodIn}]		0.00	0.37	0.70	1.07	1.50
Natural gas import [GWh]		16257	9671	5200	0	0
Equivalent CO_2 emissions [10^6 tonnes]		13.6	9.7	9.1	8.5	8.4
Total cost [10^9 CHF]		30.1	37.9	38.0	38.1	38.0

CONCLUSIONS

- The CO_2 mitigation potential of woody biomass highly depends on the conversion pathway and the fuel-technology pathway that is substituting. Values can be up to 10 times higher than the reference case.
- Scenarios considering only chemical conversion technologies (e.g. Fisher-Tropsch) perform worse than the reference scenario in terms of Annual GWP impact and Annual Total Cost. Deployment of chemical conversion technologies must be accompanied by the promotion of efficient technologies such as heat pumps, cogeneration and electric mobility.
- The use of bio-SNG & Electrolysis systems to store excess electricity from PV panels offers the possibility to reduce to zero the natural gas imports in Switzerland.

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