Environmental impacts of the CO_2 methanation value chain

Implications on mobility with passenger cars

Source: Frank Brüderli

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66th Discussion Forum: LCA of mobility solutions: Approaches and findings
30 August 2017, Alumni Pavillon, ETH Zürich, Switzerland

Hegemony of diesel finally crumbling?

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Mainstream natural gas Volkswagens are still a ways away.

VW looks to natural gas as it pivots away from diesel

NATURAL GAS VW COULD HELP KEEP FLEET EMISSIONS LOW, BUT NO WORD YET ON TIMING

MAY 4, 2017

Stuttgart judge demands diesel bans from 2018, ruling retrofits will not tackle pollution

31/07/2017 in Manufacturer News

A Stuttgart judge has ruled that retrofitting illegally polluting diesel vehicles will not solve the German region's air quality crisis and demanded a diesel ban be implemented in the city from January 2018.

The ruling means Stuttgart's government must rewrite its Air Quality Plan (AQP), as the current version is inadequate and will not protect people's health in the shortest time possible.

Air quality in the region is illegally poor, regularly breaching limits for toxic gas nitrogen dioxide (NO_2) and dangerous coarse particles (PM_{10}). The levels are some of the worst in Germany.

Production of synthetic natural gas

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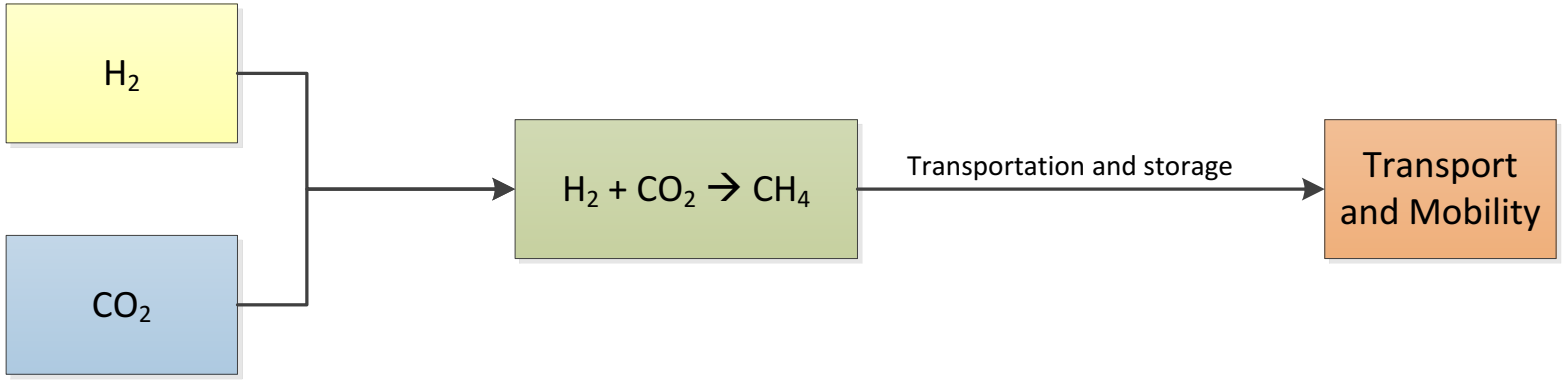
Power-to-Gas process uses excess power from renewable sources to produce hydrogen (H_2). H_2 is then converted to **synthetic natural gas** (SNG, methane) using the process of **methanation**, which can be used to power vehicles.



NRP 70 Energy Turnaround: Sustainability assessment of the CO_2 methanation value chain: environmental impacts and socio-economic drivers and barriers
NRP 70 Energy Turnaround: Renewable Methane for Transport and Mobility (RMTM)
Project partners:

- Hochschule für Technik Rapperswil (HSR), Institut für Energietechnik (IET)
- Zurich University of Applied Sciences (ZHAW), Institute of Chemistry and Biotechnology (ICBT) and Institute of Natural Resource Sciences (IUNR)
- University St. Gallen, Institute of Operations Research and Computational Finance
- École Polytechnique Fédérale de Lausanne (EPFL), Institut des Sciences et Ingénierie Chimiques (ISIC)
- Swiss Federal Laboratories for Materials Science and Technology (EMPA), Department of Mobility, Energy and Environment

Goal and scope of the project

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Quantification of the environmental impacts of **vehicles powered by synthetic natural gas (SNG)** in comparison with conventional vehicles

4 different vehicle types

- Petrol powered car
- Diesel powered car
- Natural gas powered car
- Electric car

4 sets of scenarios for production synthetic PtG natural gas

- Electricity source
- Hydrogen electrolysis efficiency
- CO_2 source
- Methanation (work in progress)

Framework

- Geographic: Switzerland
- Temporal: Actual state of research, 2015

Functional Unit

- 1 kilometre driven by car (1 vehicle kilometre)

Scenarios for synthetic natural gas production

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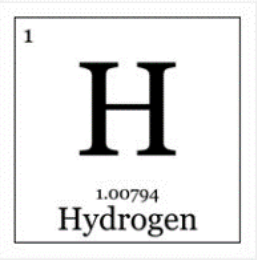
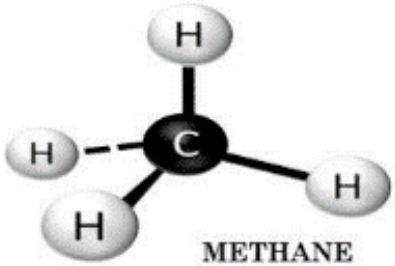
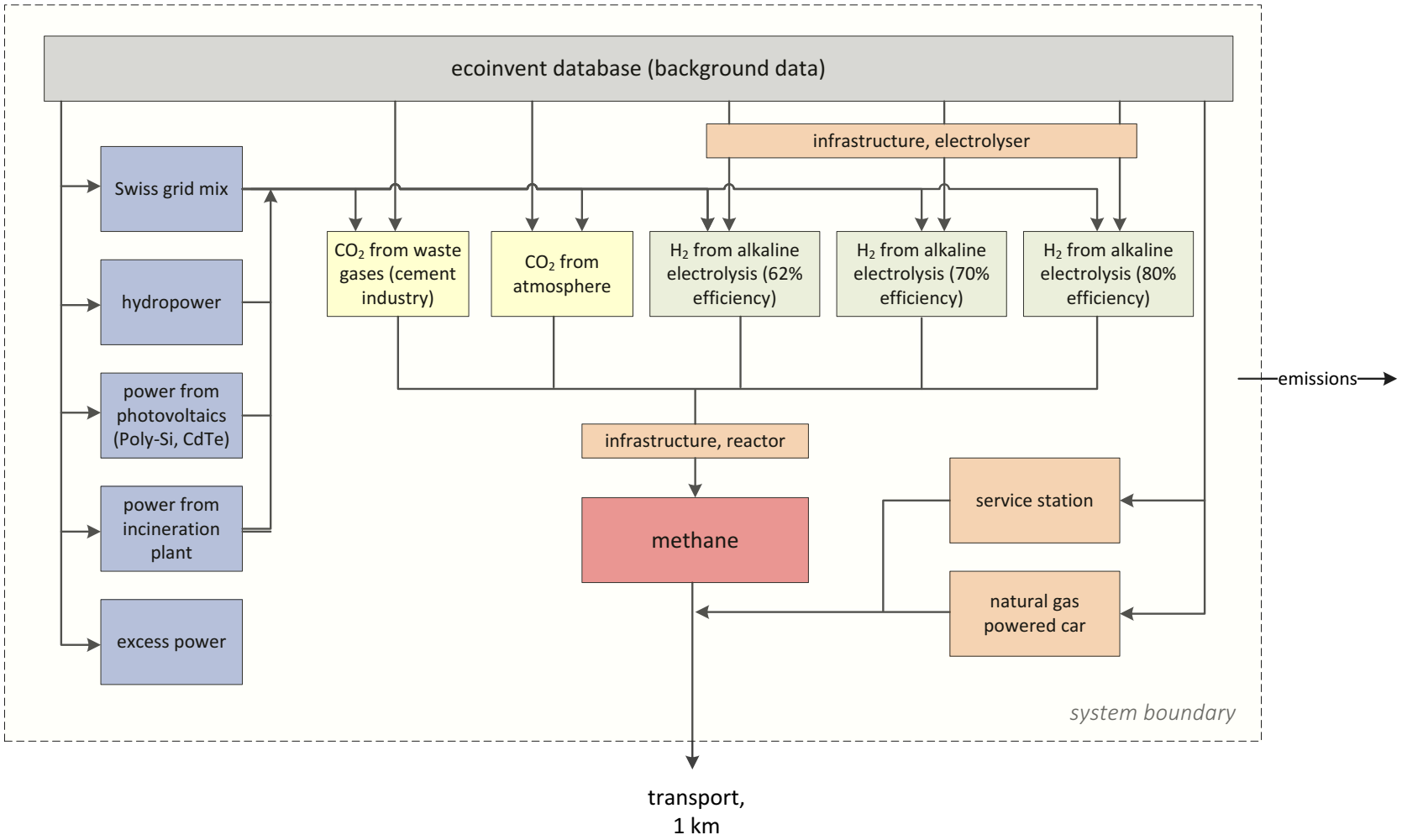




Set of scenarios	Scenario
Electricity source	Swiss power mix (grid mix) Poly-Si photovoltaics Cadmium telluride photovoltaic Hydropower Municipal solid waste incineration Excess power from photovoltaic production
Hydrogen production	Electrolysis efficiency: 62% Electrolysis efficiency: 70% Electrolysis efficiency: 80%
CO_2 source	Industrial waste gases (e.g. from cement production) Atmosphere
Methanation	Catalytic Biogenic (under revision)

System boundaries and schematic representation of the production system



Blue: Scenario set electricity source
Green: Scenario set electrolysis efficiency
Grey: Background data

Yellow: Scenario set CO_2 source
Orange: Infrastructure and vehicle

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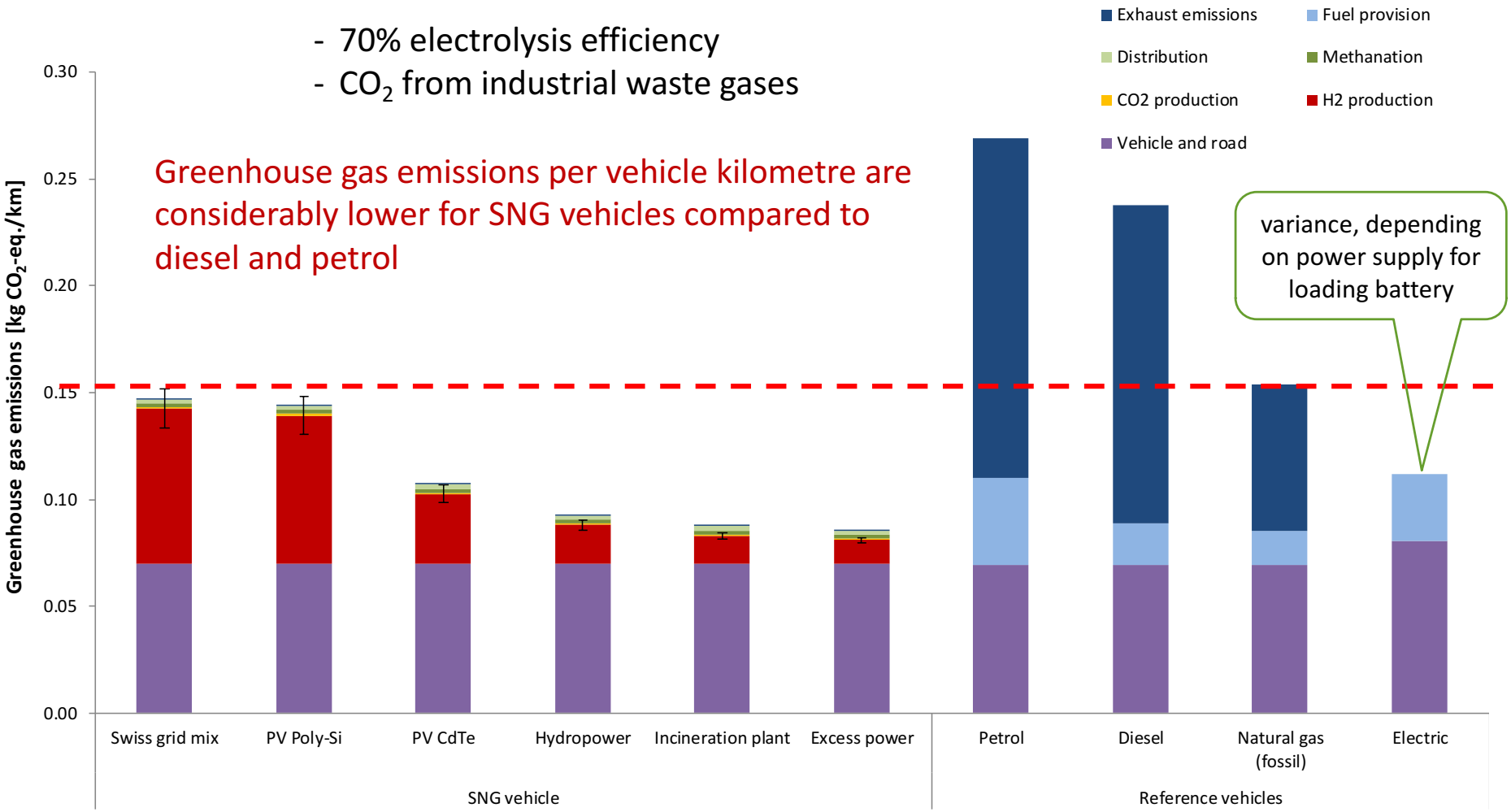
Greenhouse gas emissions per vehicle kilometre

- 70% electrolysis efficiency
- CO_2 from industrial waste gases

Greenhouse gas emissions per vehicle kilometre are considerably lower for SNG vehicles compared to diesel and petrol



Error bars indicate the variance due to change in electrolysis efficiency from 70% to 64% and 80%

Total environmental impacts according to ecological scarcity 2013

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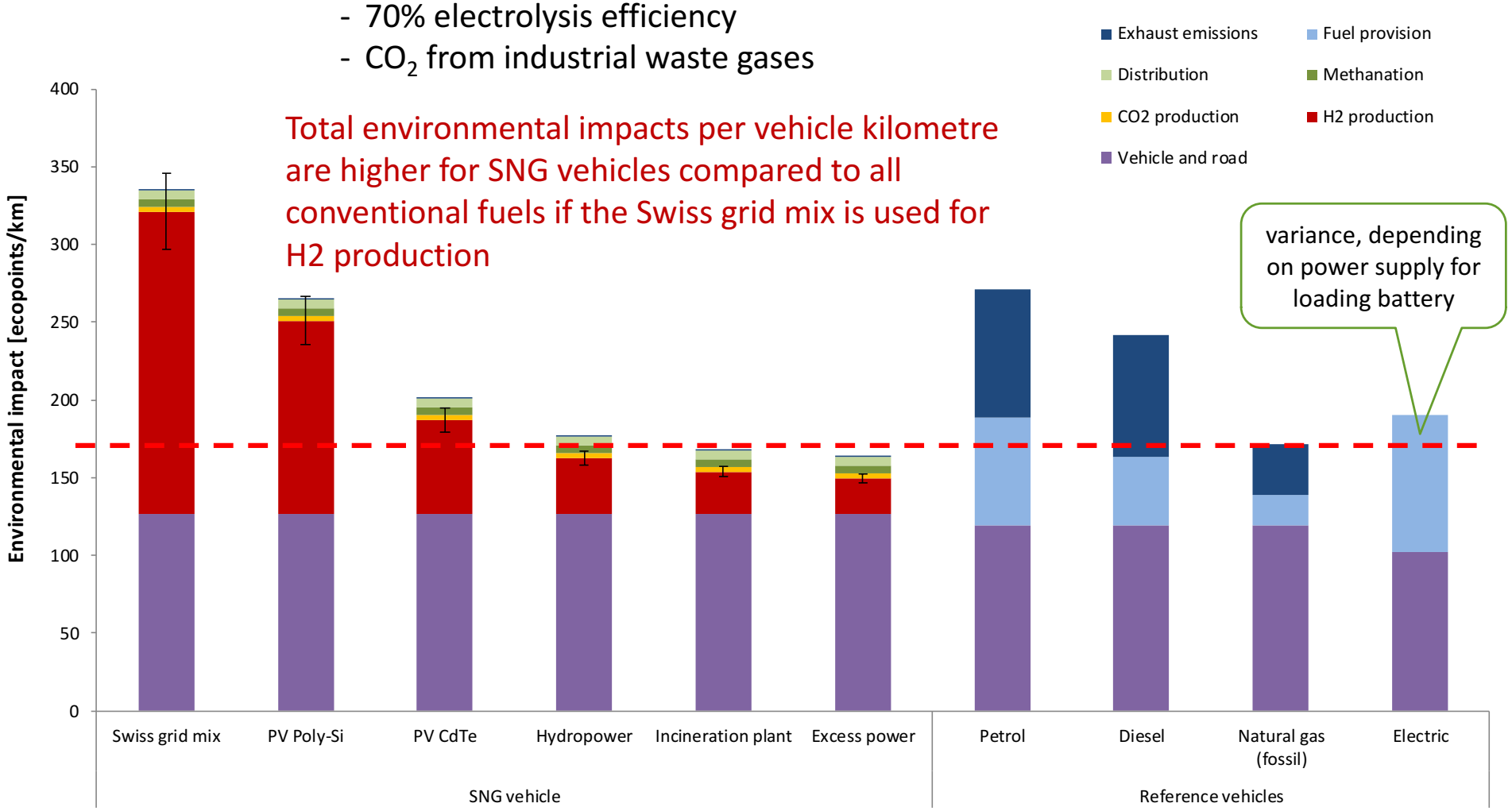
- 70% electrolysis efficiency
- CO_2 from industrial waste gases

Total environmental impacts per vehicle kilometre are higher for SNG vehicles compared to all conventional fuels if the Swiss grid mix is used for H2 production



Error bars indicate the variance due to change in electrolysis efficiency from 70% to 64% and 80%

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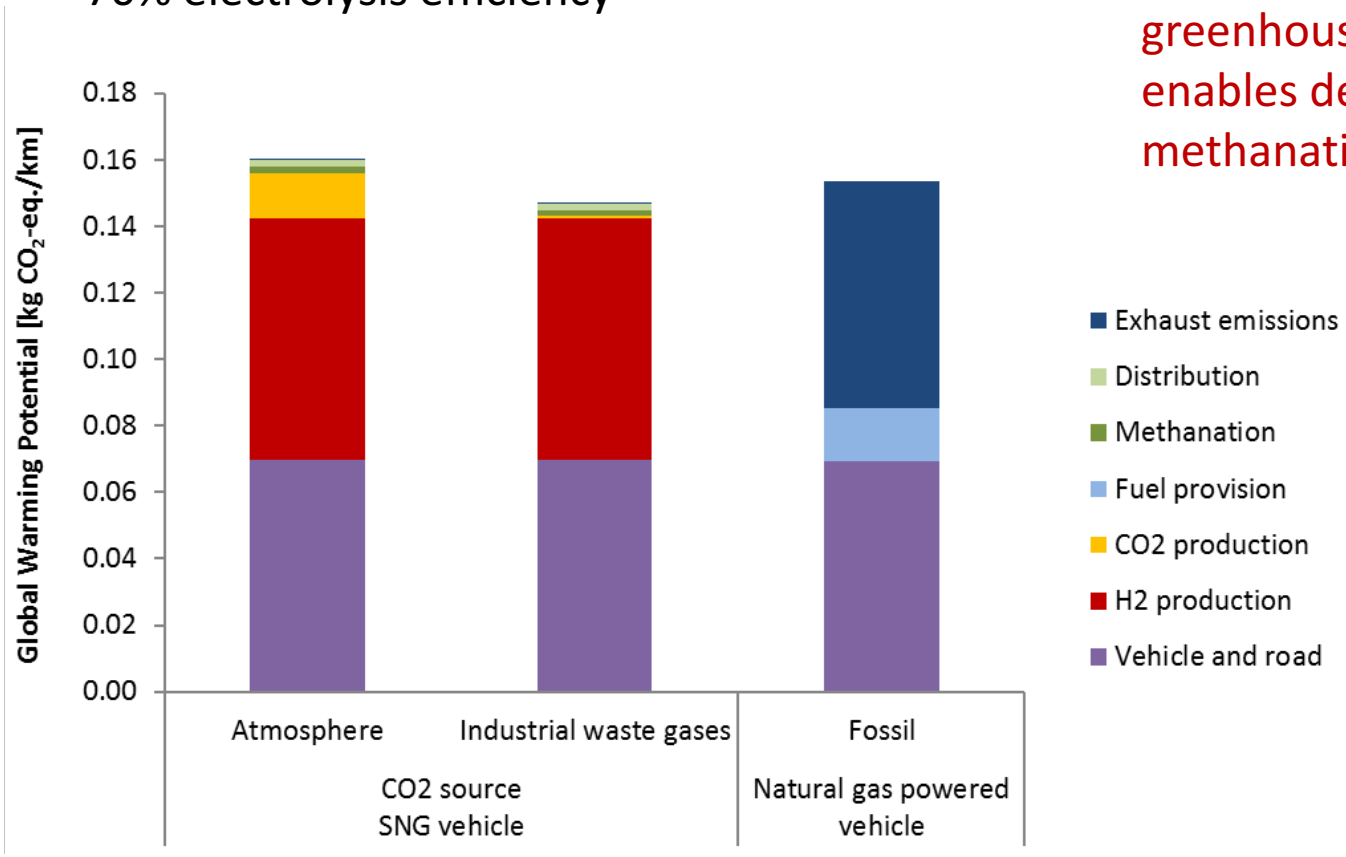
Scenario CO_2 source

- Swiss electricity mix at grid for H_2 production
- 70% electrolysis efficiency



CO_2 collection from atmosphere causes higher greenhouse gas emissions but enables decentralised methanation

The separation of the CO2 from atmosphere only causes minor greenhouse gas emissions compared to the hydrogen production

Conclusions

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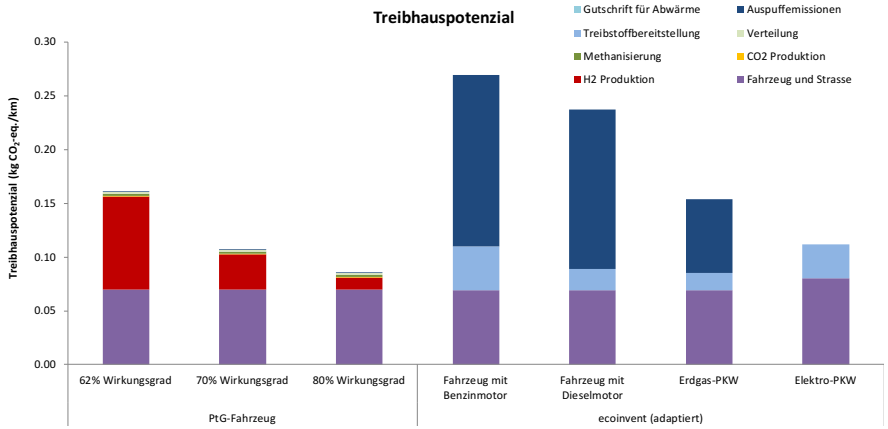
- Mobility fuelled by synthetic natural gas causes lower greenhouse gas emissions per vehicle km than diesel and petrol fuelled vehicles
- Total environmental impacts per vehicle km for synthetic PtG natural gas are higher compared to conventional natural gas unless excess power is used for methanation
- Depending on the used electricity source, the GHG emissions and the total environmental impacts per vehicle kilometre can be reduced by 42% and 51%, respectively.
- The GHG emissions of the separation of CO2 from the atmosphere are of minor importance for the total greenhouse gas emissions per vehicle kilometre.

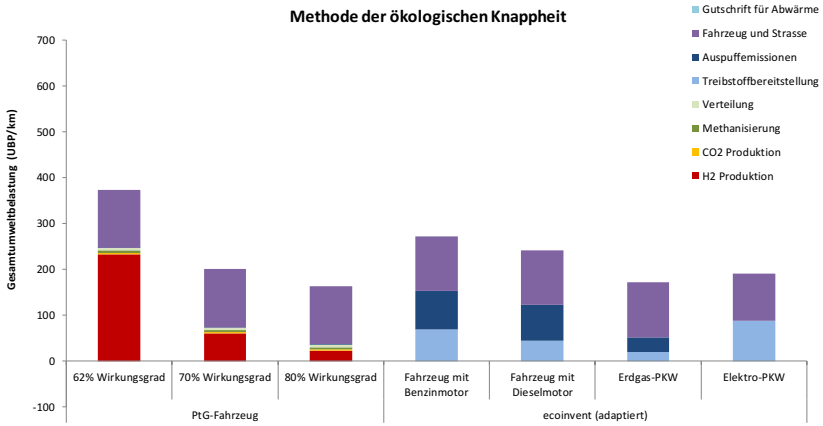
Outlook: Calculation tool

Parameter	62% Wirkungsgrad	70% Wirkungsgrad	80% Wirkungsgrad	Fahrzeug mit Benzinmotor	Fahrzeug mit Dieselmotor	Erdgas-Auto	Elektro-Auto
Stromquelle H_2-Elektrolyse	CH Strommix	Photovoltaik CdTe	Überschussstrom				
Wirkungsgrad H_2-Elektrolyse	62%	70%	80%				
CO_2-Quelle	Abgase	Abgase	Abgase				
Stromquelle CO_2-Bereitstellung	CH Strommix	CH Strommix	CH Strommix				
Stromquelle Methanisierung	CH Strommix	CH Strommix	CH Strommix				
Gutschrift für Abwärmenutzung	nein	nein	nein				
Stromquelle Batterieladung Elektroauto							CH Strommix

Kommentar:
- für alle gelb markierten Zellen per Dropdown-Me

Ergebnisse für die einzelnen Prozesse (pro Kilometer)		PtG-Fahrzeug			ecoinvent (adaptiert)				PtG-Fahrzeug			ecoinvent (adaptiert)			
		62% Wirkungsgrad	70% Wirkungsgrad	80% Wirkungsgrad	Fahrzeug mit Benzinmotor	Fahrzeug mit Dieselmotor	Erdgas-PKW	Elektro-PKW	62% Wirkungsgrad	70% Wirkungsgrad	80% Wirkungsgrad	Fahrzeug mit Benzinmotor	Fahrzeug mit Dieselmotor	Erdgas-PKW	Elektro-PKW
		kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	UBP	UBP	UBP	UBP	UBP	UBP	UBP
H_2 Produktion	0.0126 kg	0.09	0.03	0.01	0	0	0	0	233	60	23	0	0	0	0
CO_2 Produktion	0.06948 kg	0.001	0.001	0.001	0	0	0	0	3	3	3	0	0	0	0
Methanisierung	0.0336 m3	0.002	0.002	0.002	0	0	0	0	5	5	5	0	0	0	0
Verteilung	0.0336 m3	0.002	0.002	0.002	0	0	0	0	6	6	6	0	0	0	0
Treibstoffbereitstellung	1 km	0	0	0	0.04	0.02	0.02	0.03	0	0	0	70	44	20	88
Auspuffemissionen	1 km	0.000	0.000	0.000	0.16	0.15	0.068	0.000	0	0	0	83	79	33	0
Fahrzeug und Strasse	1 km	0.07	0.07	0.07	0.07	0.07	0.07	0.08	127	127	127	119	119	119	102
Gutschrift für Abwärme	1 km	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0
Total	1 km	0.161	0.11	0.09	0.269	0.237	0.154	0.112	374	201	163	271	242	171	190
		161	107	85	60%										





- Variable electricity source
- H_2 production efficiency
- CO_2 source
- Methanation process
- Credit for waste heat

- Work in progress
- Available on request, maybe online

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Questions?

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References and data sources

- ecoinvent Centre. (2015). *Ecoinvent Data v3.2, Swiss Centre for Life Cycle Inventories*. Zürich.
- Zah, R., Spielmann, M., & Ruiz, S. (2015). Analyse Der Umwelt-Hotspots von Strombasierten Treibstoffen - Finaler Bericht, (Journal Article), 1–68.
- Vehicle data with real consumption, compiled by Christian Bach, EMPA
- CO_2 collecting data from atmosphere, Climeworks AG, Zurich

ecoinvent Centre