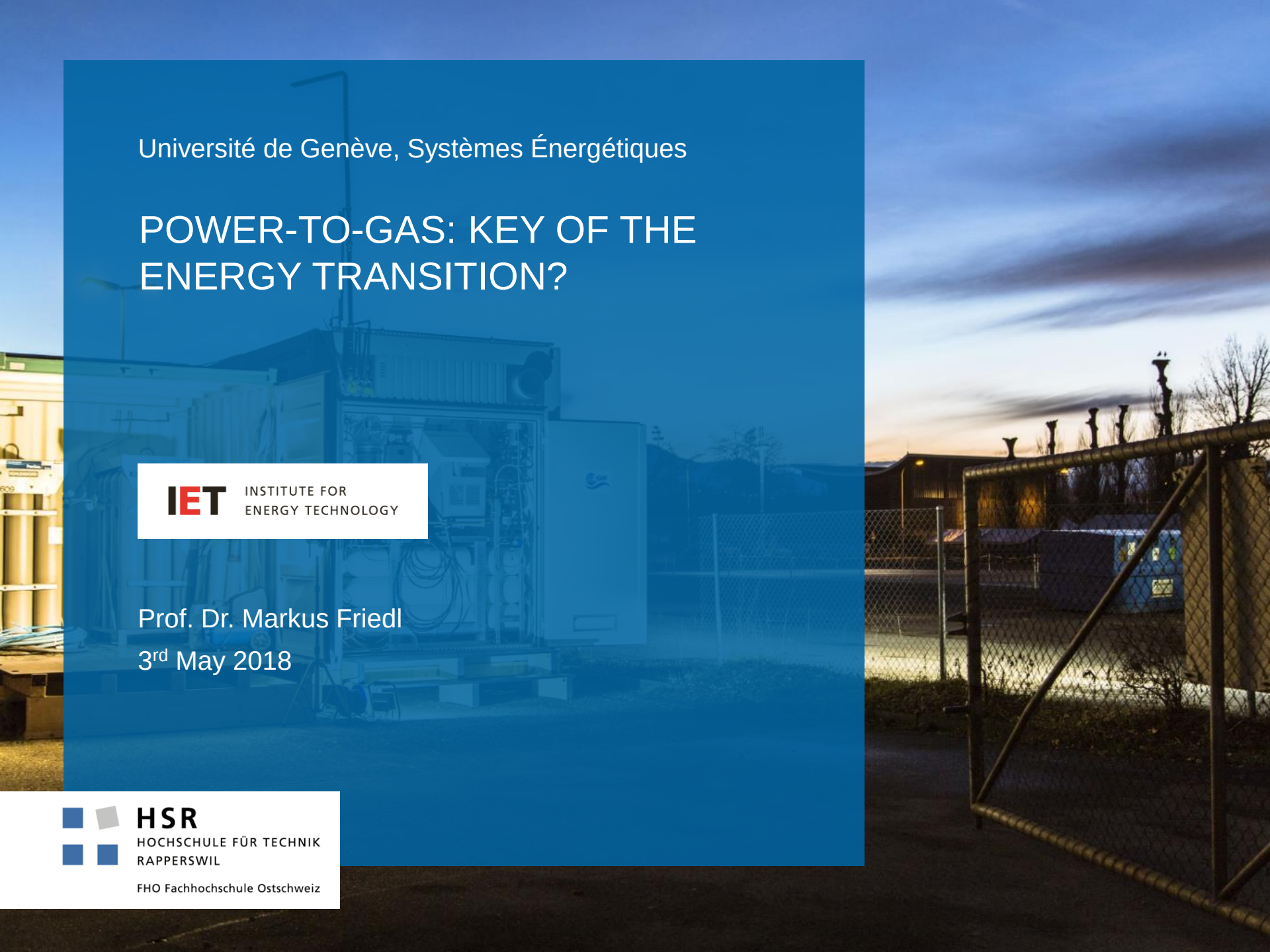
Is Switzerland’s energy supply fully based on

renewable sources possible?



Université de Genève, Systèmes Énergétiques

POWER-TO-GAS: KEY OF THE ENERGY TRANSITION?

IET INSTITUTE FOR ENERGY TECHNOLOGY

Prof. Dr. Markus Friedl

3rd May 2018

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL
FHO Fachhochschule Ostschweiz

HSR - IET

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- **Switzerland's Energy Supply**
- **What is Power-to-Gas?**
- **State of the Art**
- **Power-to-Gas Plant in Switzerland**
- **Different Technologies for Renewable Transport and Mobility**
- **Opportunities for Power-to-Gas**
- **Activities @ IET**
- **Summary**

Switzerland's Energy Supply

Energy supply = Important precondition for our wealth.

Emissions from energy supply are responsible for climate change
(87% of Switzerland's non-renewable inland CO_2 emissions)

Switzerland's goals:

- **Keep supply reliable**
- **Reduce energy consumption, efficient use of energy[1]**
- **Use renewable energy sources, particularly inland sources[1]**
- **Switch off nuclear power stations after the end of their lives[2]**
- **Reduce greenhouse gas emissions[3], fulfil Paris agreement**

1) New energy law since 1st January 2018, 2) New law on nuclear energy since 1st January 2018, 3) CO2-legislation since 1st January 2013

Switzerland's Energy Supply

- **Switzerland Year 2016**
  - Electricity Consumption: 58.2 TWh
  - Inland Net Electricity Production: 58.7 TWh
- **Where is the problem?**

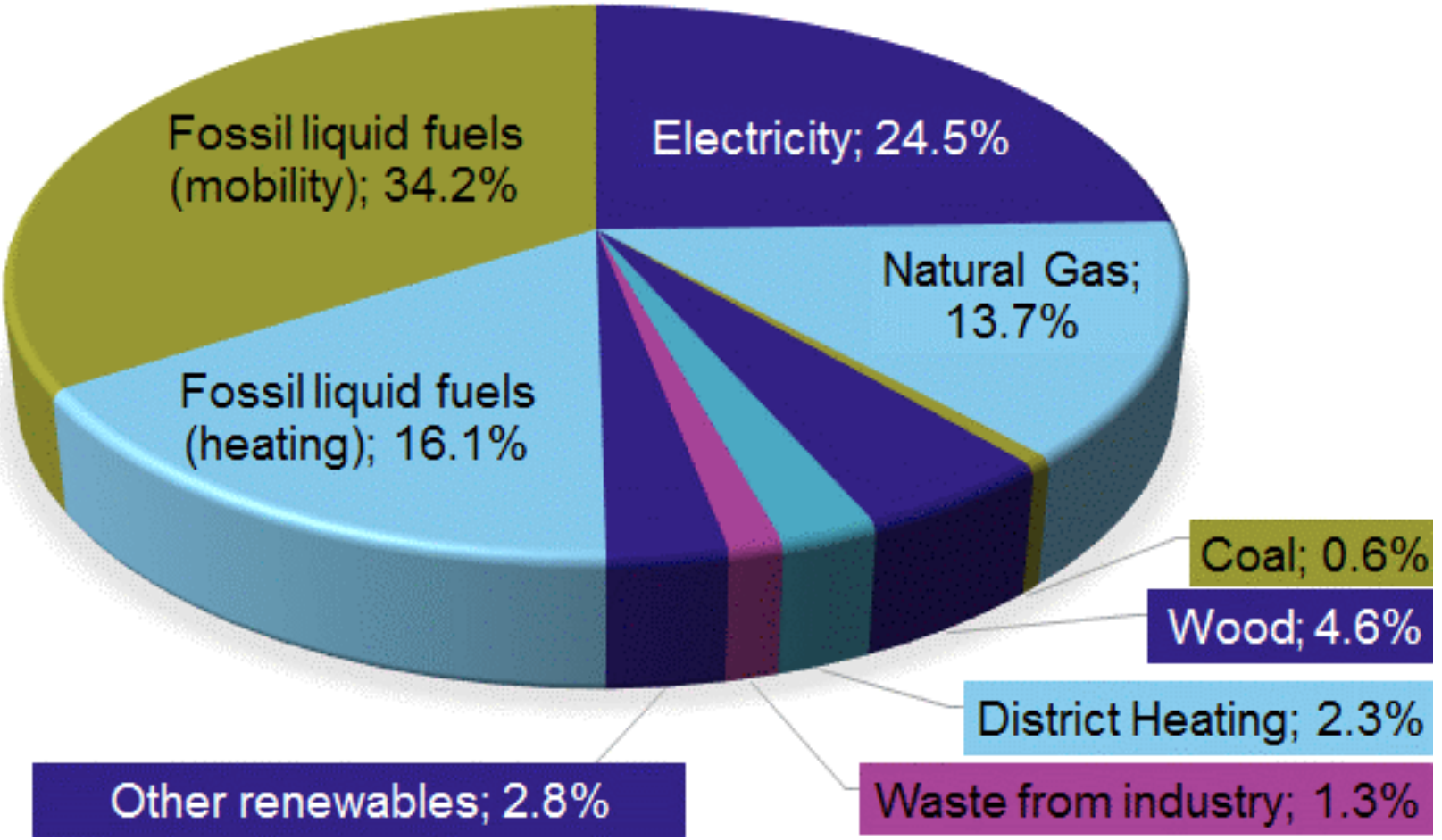
Switzerland's Energy Supply

- **Switzerland Year 2016**
  - Electricity Consumption: 58.2 TWh
  - Inland Net Electricity Production: 58.7 TWh

- **We have to replace 20.2 TWh nuclear electricity with renewable electricity production.**
  - New photovoltaics (PV)/year: ca. 0.3 TWh /a
  - If electricity consumption, new PV, wind and hydro constant, we need 67 years to replace nuclear electricity. (20.2 TWh/(0.3 TWh/a)
  - Accelerated new PV, wind, hydro and geothermal production → replacement seems possible.
- **Where is the problem?**
  - Only 25% of our Energy End Use is electricity.
  - The electricity is not generated at the same time as we need it → Storage

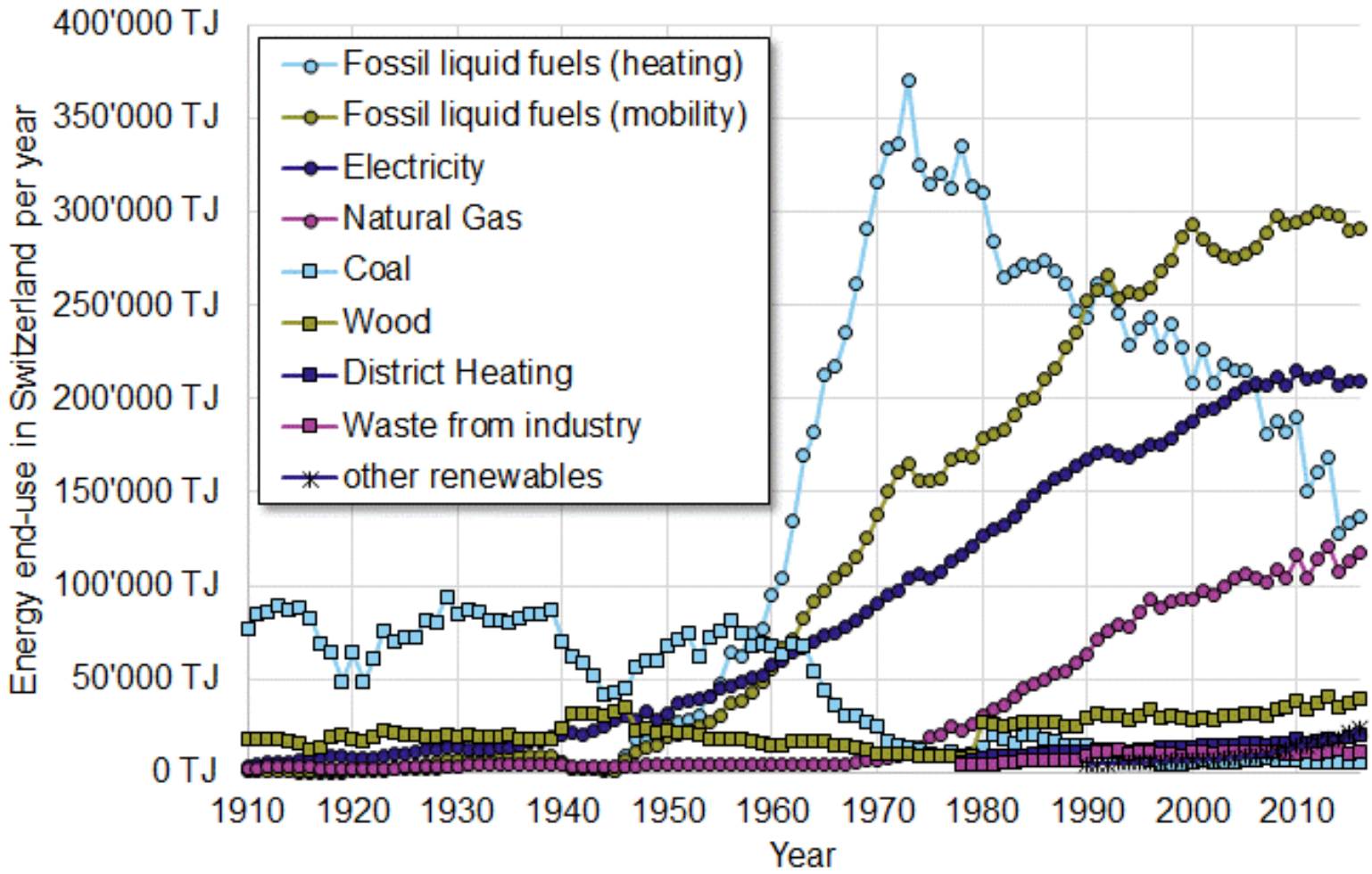
Energy End Use

Switzerland's Energy End Use



Final Energy Consumption 2016, Source: Swiss Federal Office of Energy, Gesamtenergiestatistik 2016

Switzerland's Energy End Use

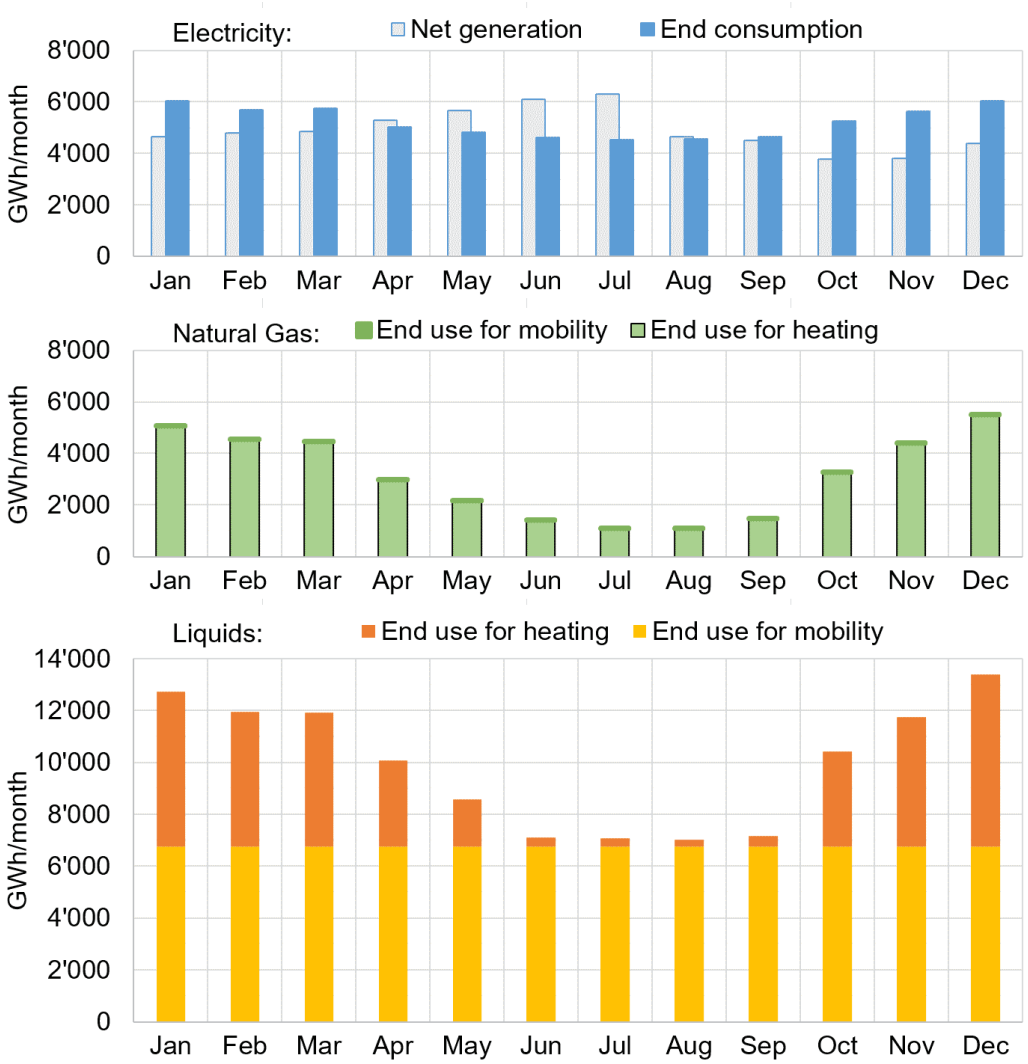


Switzerland's Energy End Use 2016, Source: Swiss Federal Office of Energy, Gesamtenergiestatistik 2016

Technological Revolution

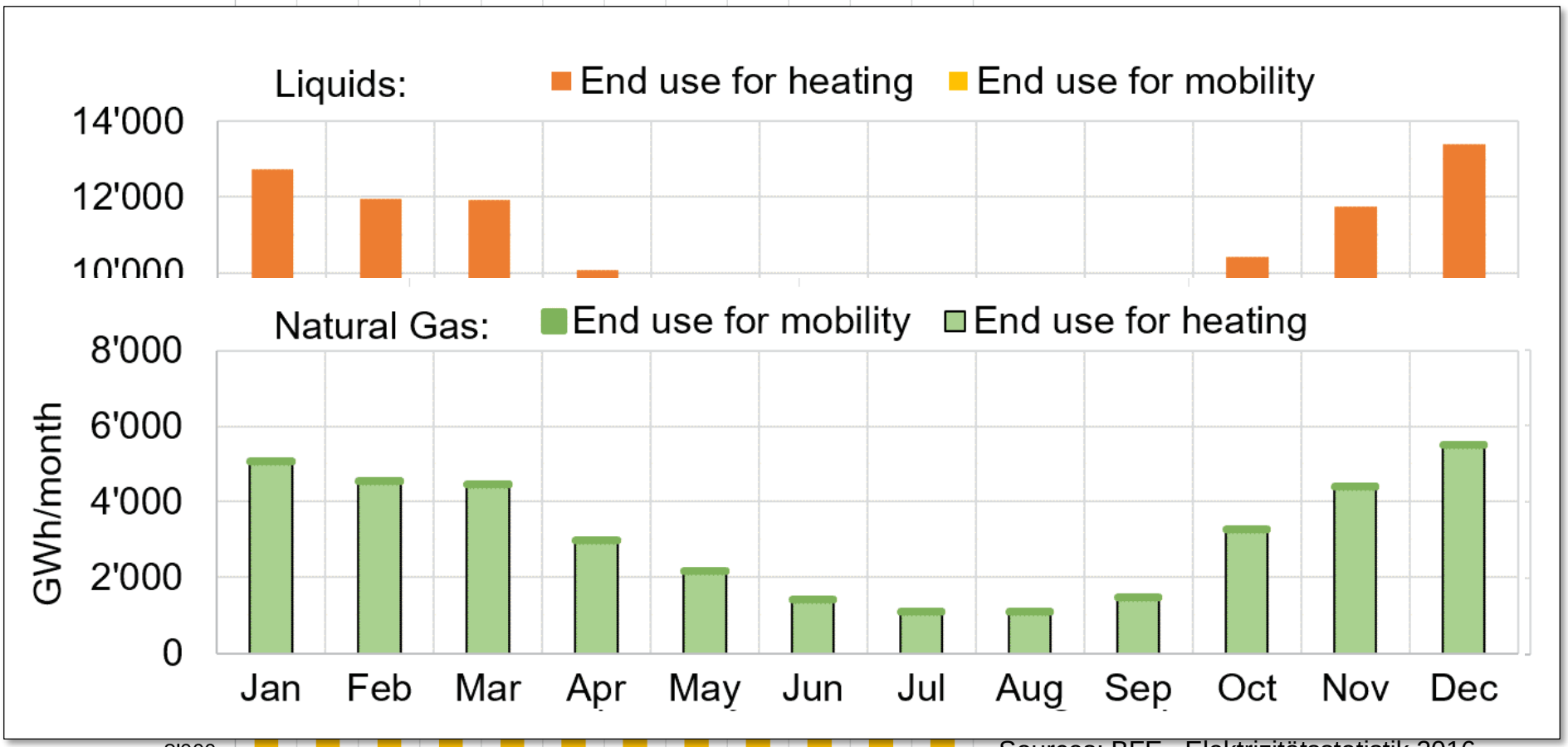
Gotthardrampe im Bau vermutlich bei Giornico Biaschina TI, Bildquelle: Sendung "Die Schweizer" Teil 4 des Schweizer Fernsehens vom 28. November 2013

Switzerland's Energy Supply



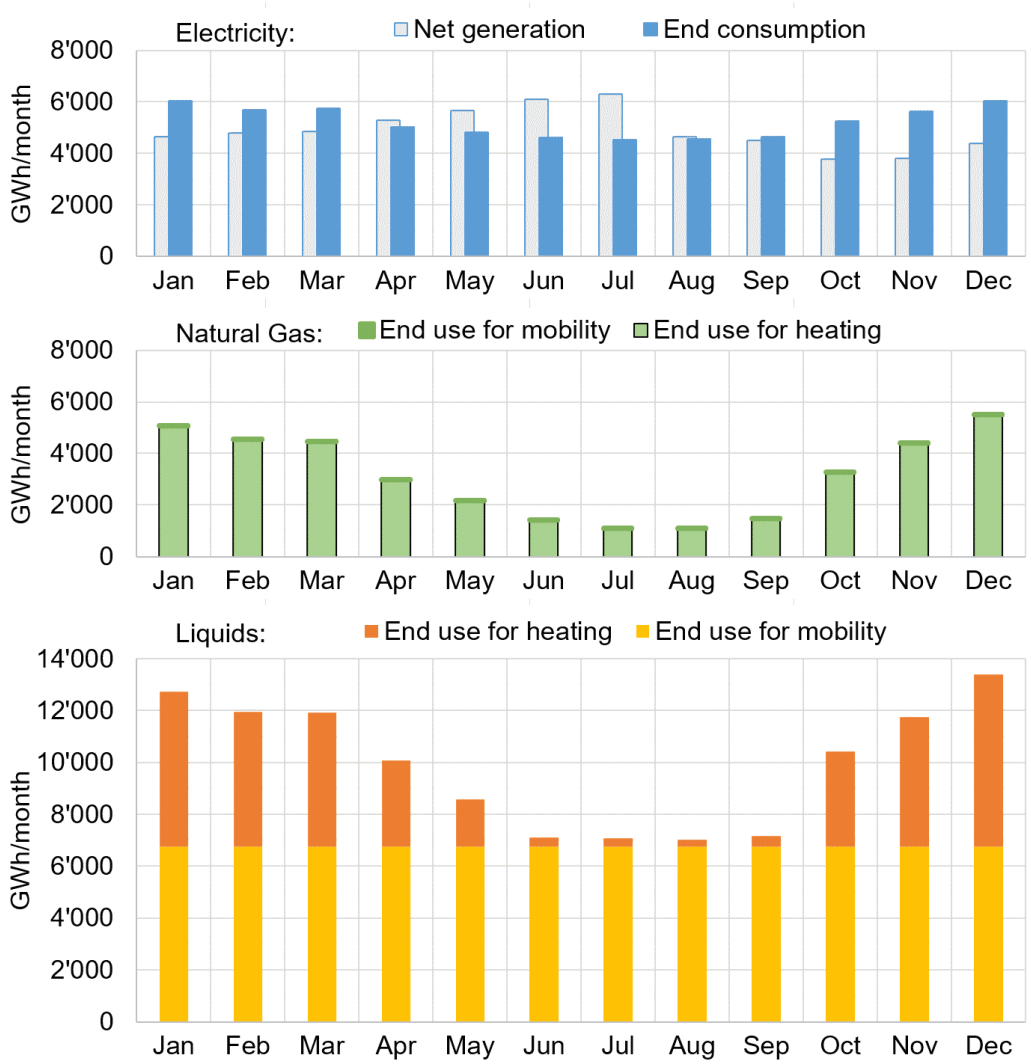
Statistics for 2016
Sources: BFE «Elektrizitätsstatistik 2016» und «Gesamtenergiestatistik 2016», VSG Jahresstatistik Ausgabe 2016

Switzerland's Energy Supply



Sources: BFE «Elektrizitätsstatistik 2016» und «Gesamtenergiestatistik 2016», VSG Jahresstatistik Ausgabe 2016

Switzerland's Energy Supply



Future changes:

- 1/3 of electricity generation disappears (nuclear)
- Massive development of production capacities for renewable Electricity of which most will be BIPV
- More surplus electricity generation in summer
- What are we going to do with our demand for fossil liquids?

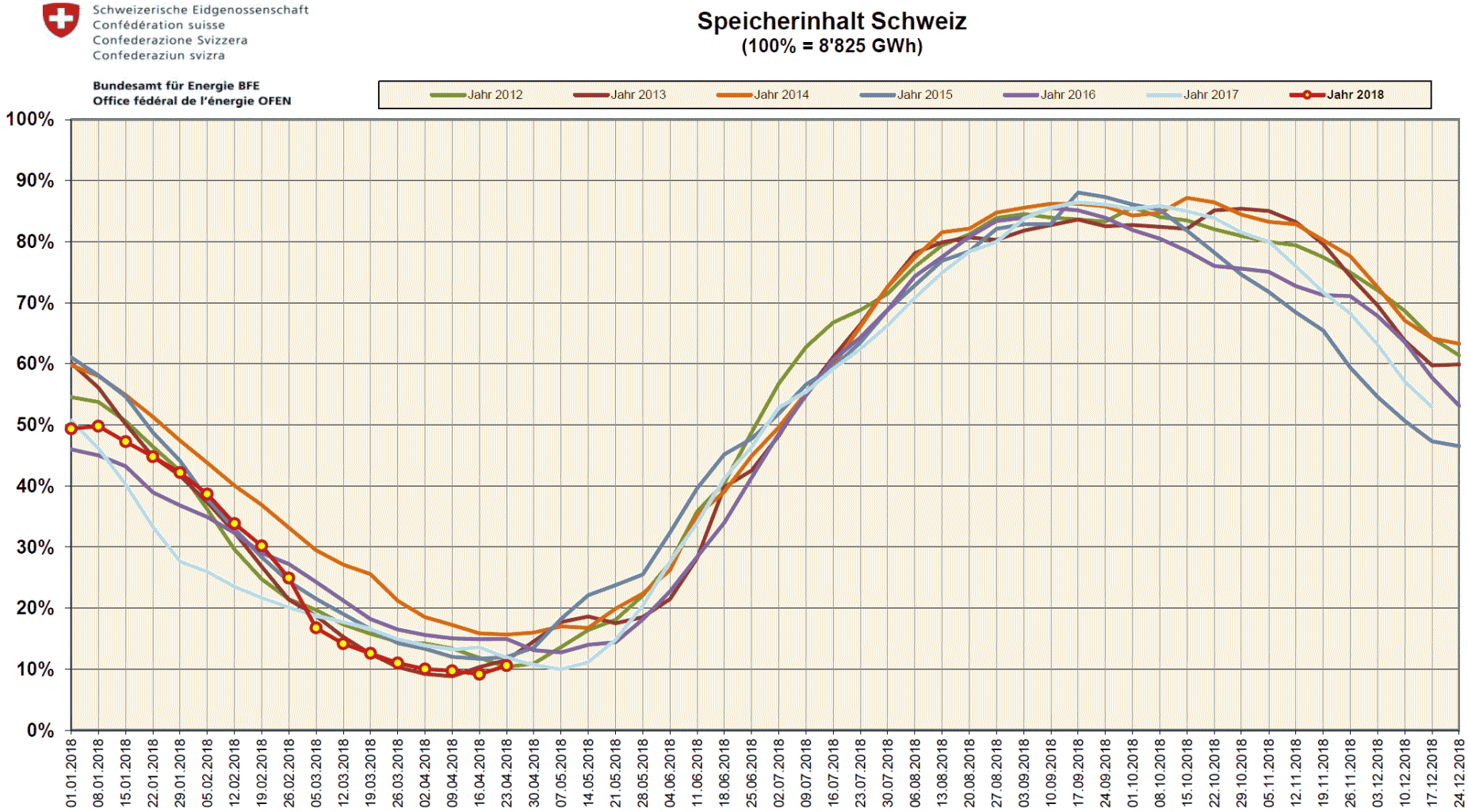
Statistics for 2016
Sources: BFE «Elektrizitätsstatistik 2016» und «Gesamtenergiestatistik 2016», VSG Jahresstatistik Ausgabe 2016

Switzerland's Energy Supply

A renewable supply of energy is possible:

- **Consideration all forms of energy**
- **Massive development of additional renewable energy production**
- **Key component are storage technologies:**
  short term (Supercapacitors, Batteries, Pumped Hydro)
  seasonal (Barrier lakes hydro power, Power-to-Gas)

Level of Swiss Barrier Lakes 2012 to 2018



Source: Swiss Federal Office of Energy (SFOE), accessed 3rd May 2018

Switzerland's Energy Supply

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- **Consideration all forms of energy**
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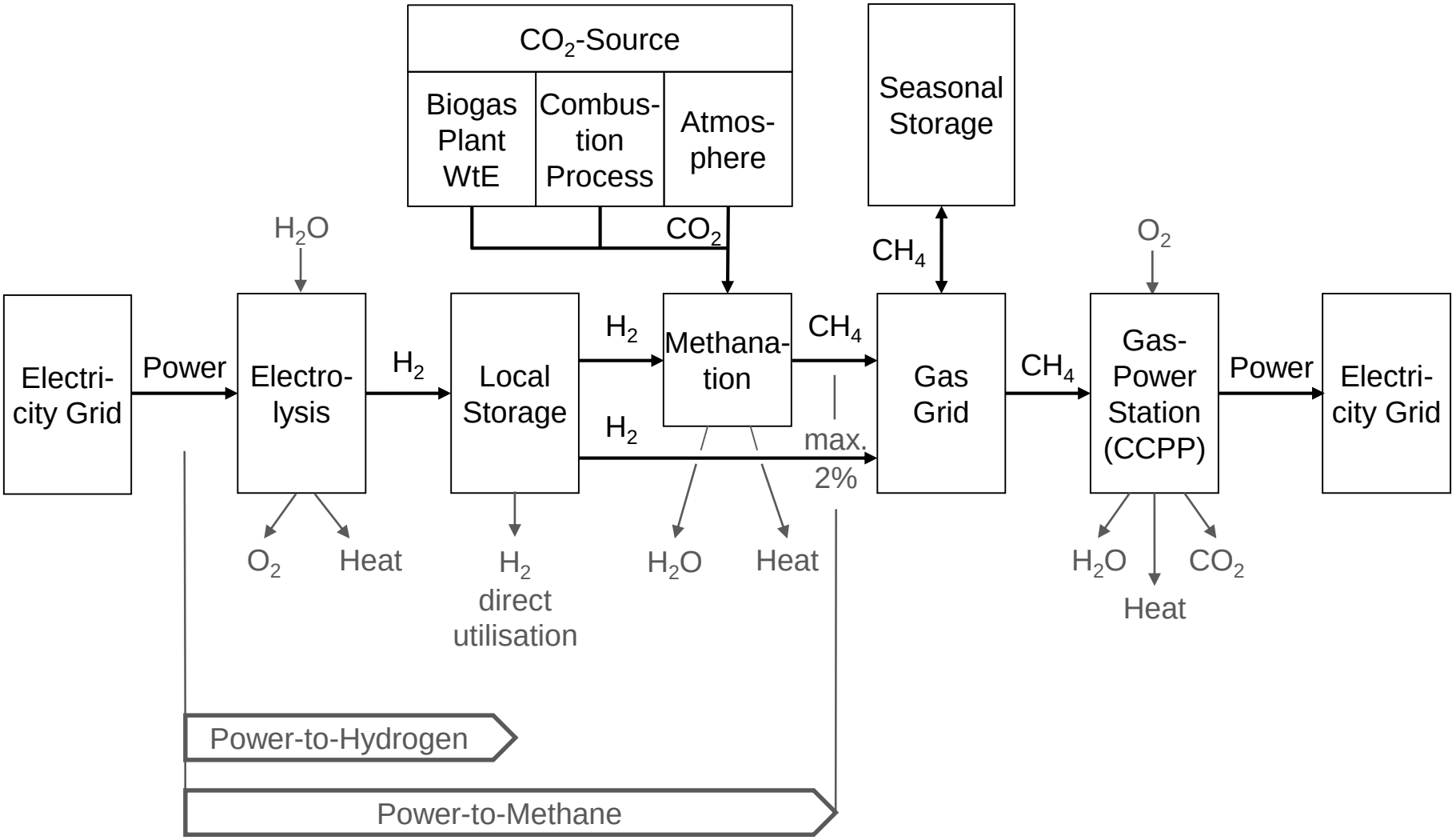
- **Key component are storage technologies:**
  short term (Supercapacitors, Batteries, Pumped Hydro)
  seasonal (Barrier lakes hydro power, Power-to-Gas)
- **Coordination between the different forms of energy (convergence of the grids, sector coupling, flexibility)**

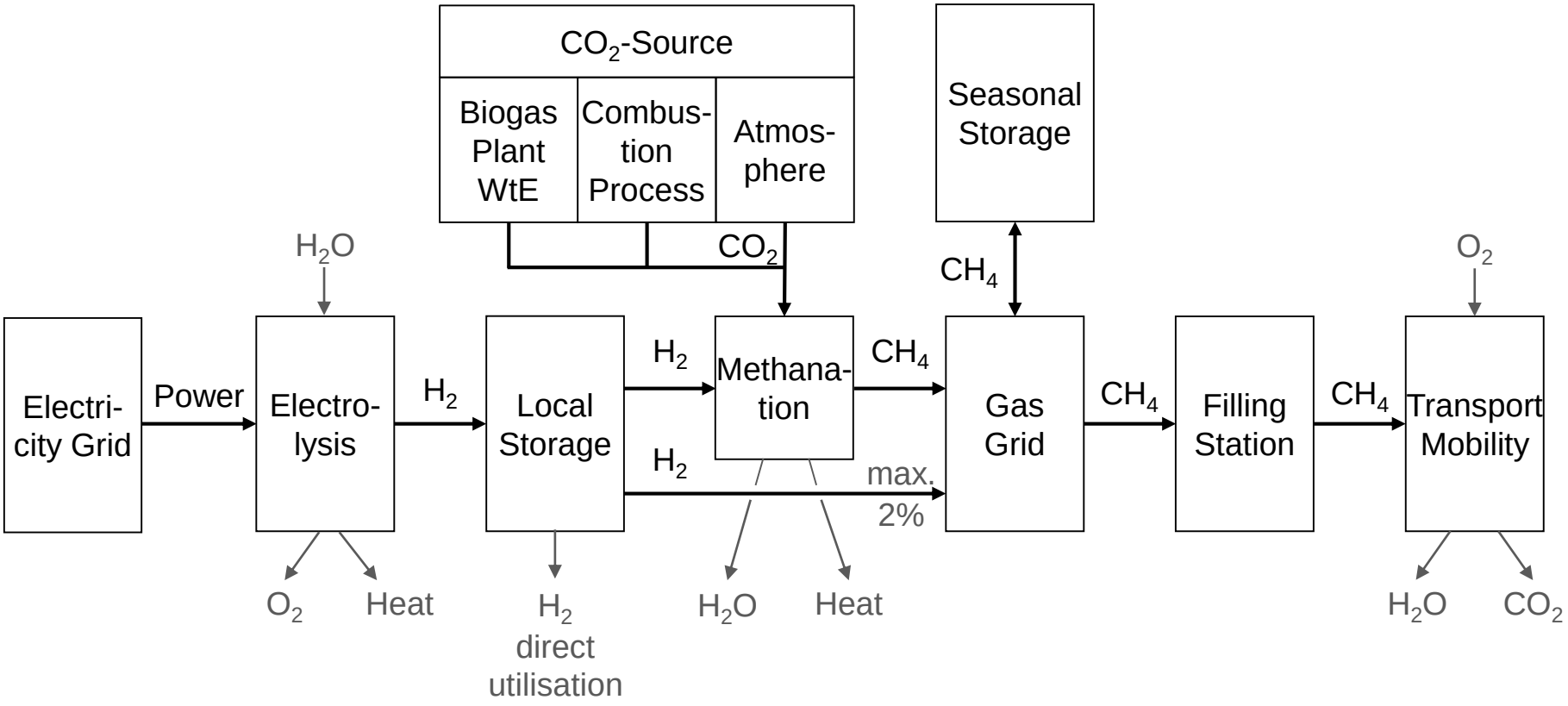
Surplus of renewable electricity in the Summer:

- **Power-to-Gas uses this surplus for the production of renewable gas.**

What is Power-to-Gas?

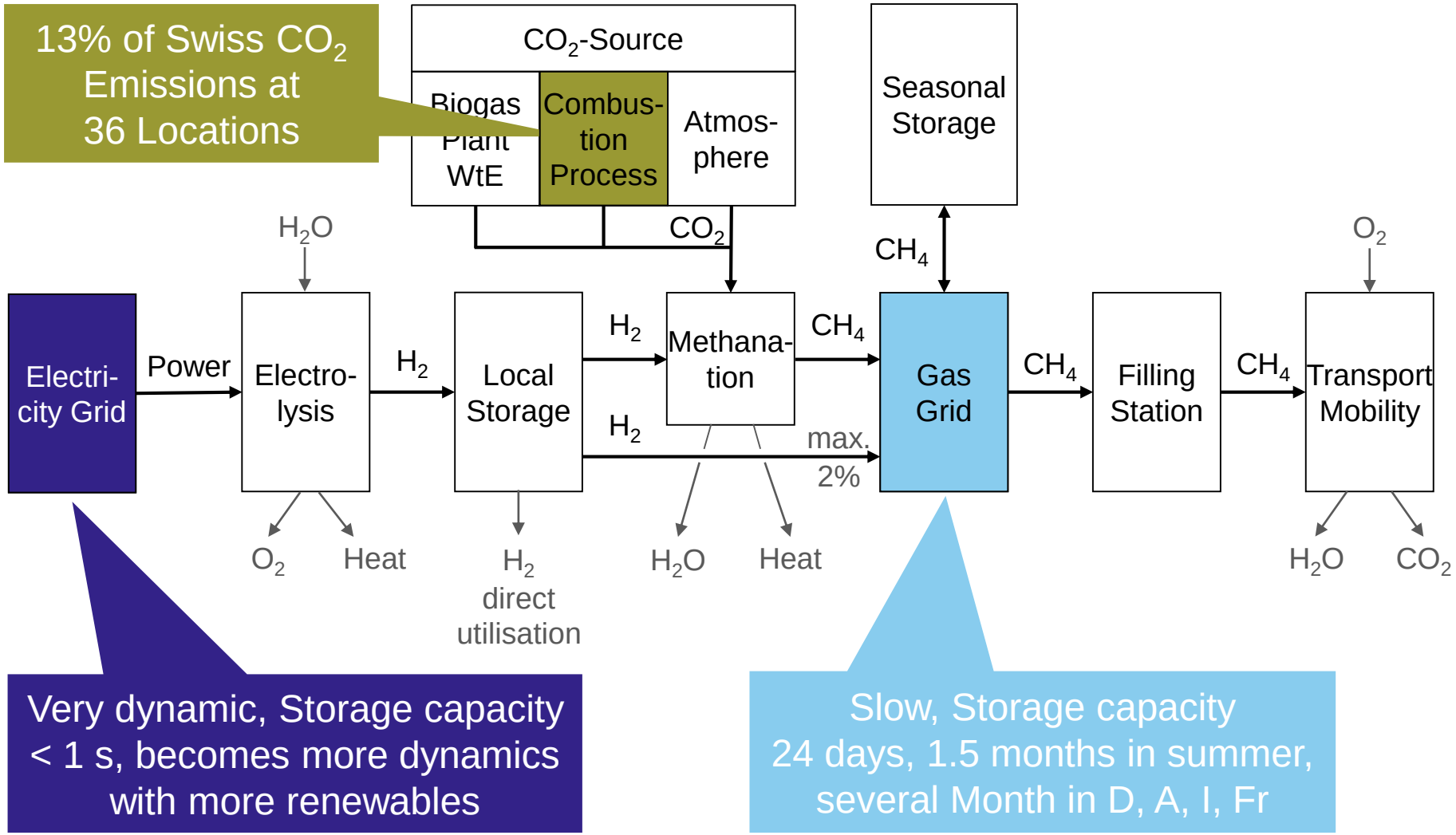


What is Power-to-Gas?



1. Required infrastructure and technologies exist today.
2. Production costs of synthetic methane > Costs for exploiting fossil methane
3. Emissions of synthetic methane < Emissions of fossil methane.
   Condition 3. is fulfilled, if electricity is renewable.

The Role of Power-to-Gas in Switzerland's Energy Supply



The Role of Power-to-Gas in Switzerland's Energy Supply

IET INSTITUTE FOR ENERGY TECHNOLOGY

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL
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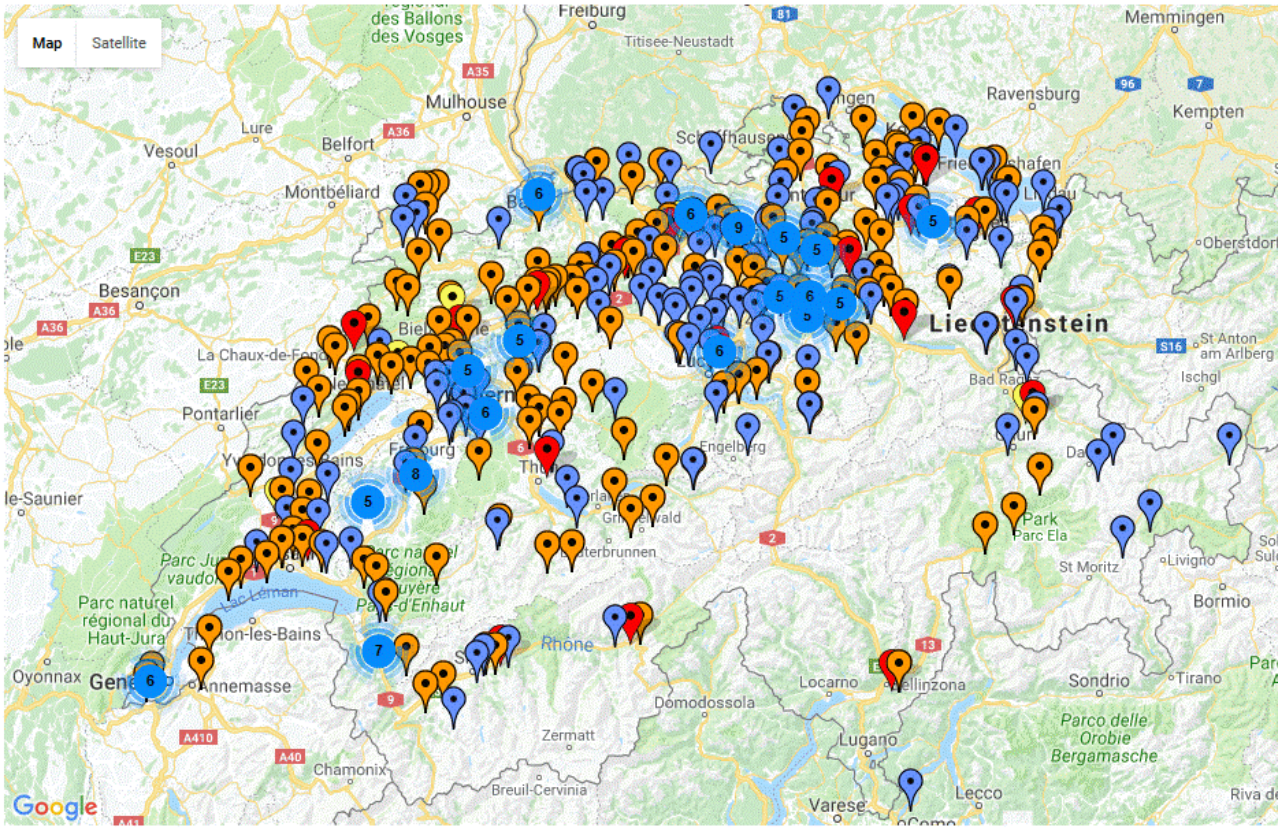
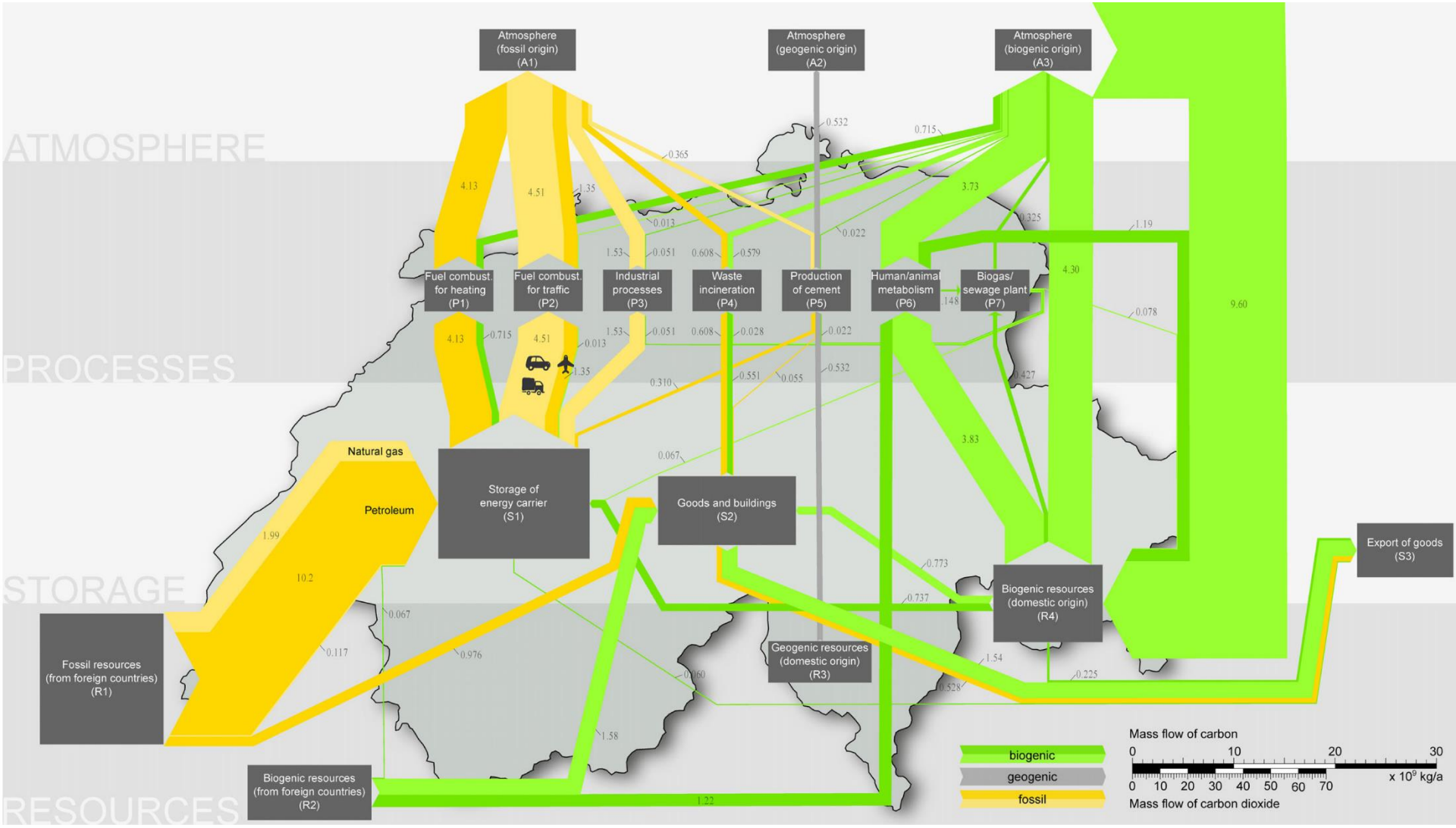
70 NRP Energy Turnaround
National Research Programme

- Map Power-to-Gas
  - Selected Swiss CO_2 sources
    - Bio- and sewer-gas plants with electricity generation
    - Bio gas production with feed into natural gas grid
    - Sewage treatment plants
    - Waste incineration plants
    - Cement manufacturing plants
  - Natural gas infrastructure
    - Natural gas grid (high pressure)
    - Natural gas stations
    - Power-to-Methane facilities
    - Power-to-Hydrogen facilities
  - Selected power plants
    - River power plants
    - Pumped storage hydro power stations
    - Wind power stations
    - Nuclear power plants
  - Research and Development
    - Research projects Switzerland
    - Selected manufacturer of electrolysers (worldwide)

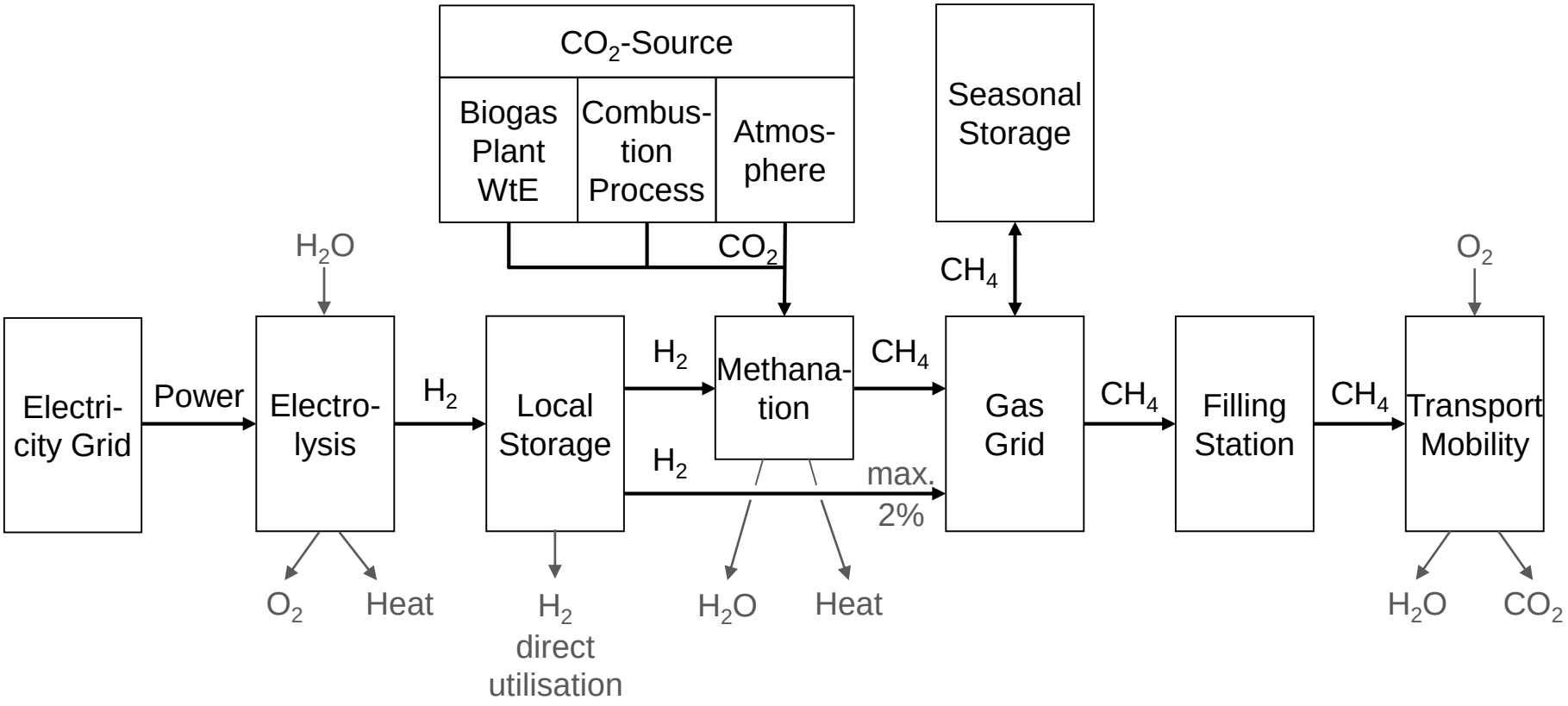


Carbon Flows through Switzerland

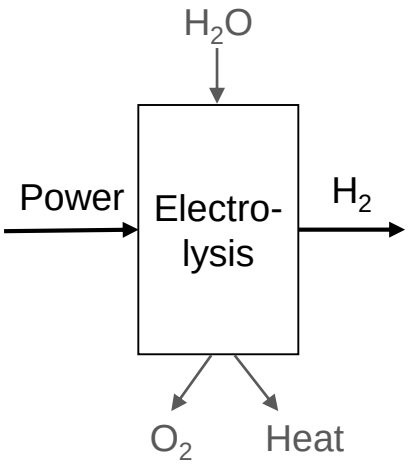
Source: Meier, B., Ruoss, F. and Friedl, M., «Investigation of Carbon Flows in Switzerland with the Special Consideration of Carbon Dioxide as a Feedstock for Sustainable Energy Carriers», Energy Technology 2017 5 7 – 14



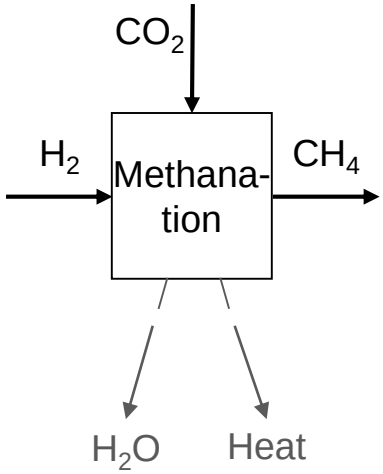
State of the Art



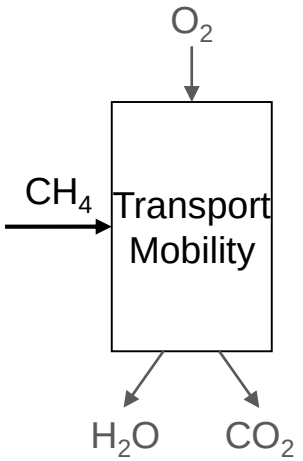
State of the Art



- Traditional: alkaline electrolysis
- New: PEM electrolysis
- Future: High temperature electrolysis = SOEC



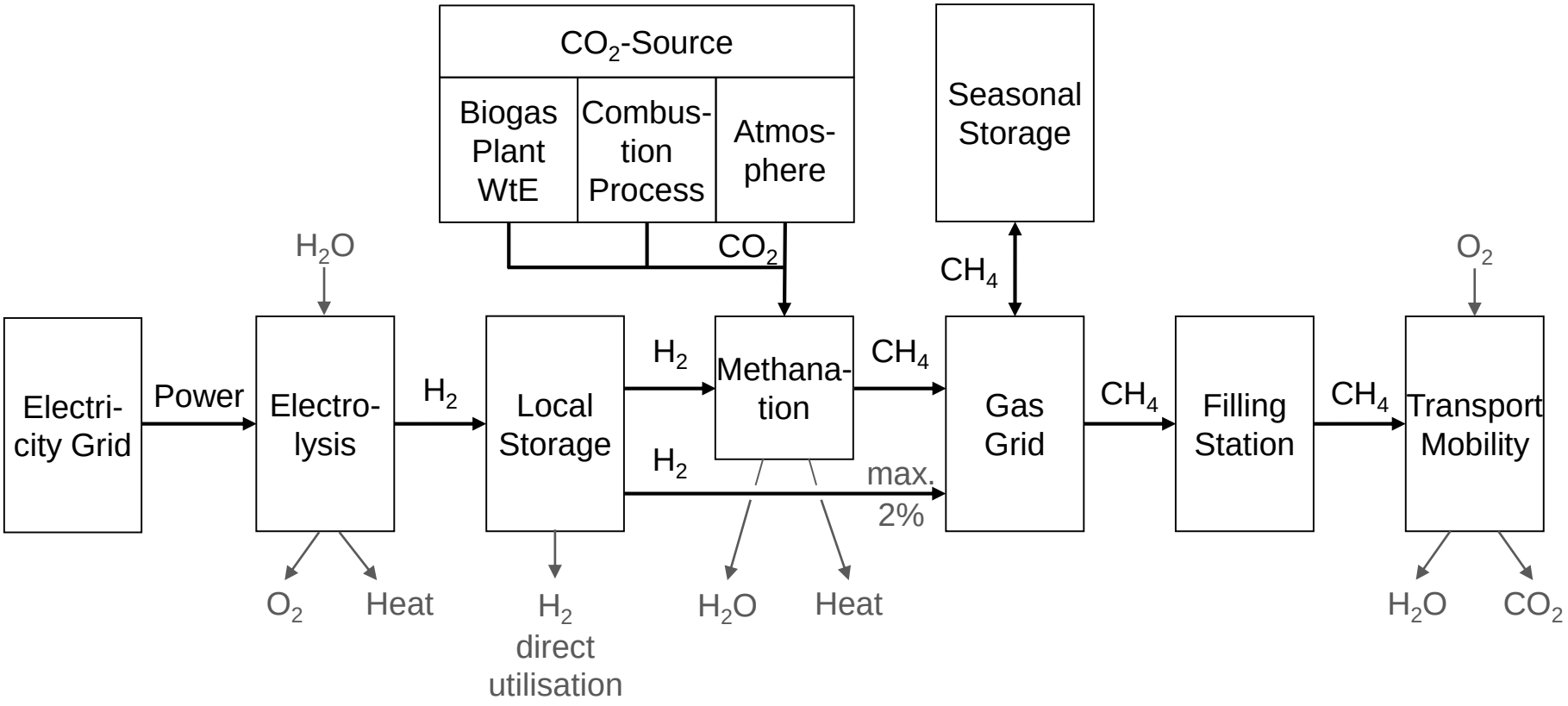
- Catalytic methanation, 300°C, since 2013 commercially available
- Biological methanation, 50°C, at market entry



Commercially available

- 24 Car models
- Utility vehicles
- Trucks
- Busses

State of the Art



Existing Plants in Switzerland and nearby (Selection)

Project	Place	Electrolyser	Output	Status	WEB
Audi e-gas	Werlte	$6\ MW_{el}$	$270\ Nm^3/h$ CNG	In operation since 2015	
Hybrid-werk Aarmatt	Solothurn	$350\ kW_{el}$	Hydrogen	In operation since 2016	
IBAarau, Coop, H2 Energy	Aarau und Hunzen-schwil	$175\ kW_{el}$	Hydrogen	In operation, hydrogen for Switzerland's first public hydrogen filling station	
Move	EMPA, Dübendorf	$175\ kW_{el}$	Hydrogen		
ESI Platform	PSI, Villigen	$100\ kW_{el}$	Hydrogen Methane		

New Plants in Switzerland and nearby (Selection)

Project	Place	Electrolyser	Output	Status	WEB
STORE& GO	Falken-hagen (D)	2 MW_{el}	ca. 51 Nm^3/h CNG	Commissioning, ready for operation in May	www.storeandgo.info
STORE& GO	Solothurn (CH)	350 kW_{el}	ca. 30 Nm^3/h CNG	Under construction, Opening September 2018	www.storeandgo.info
STORE& GO	Troia (I)	200 kW_{el}	LNG	Under construction, commissioning in June 2018	www.storeandgo.info
HEPP	Rapperswil (CH)	14.6 kW_{el} 5 - 10 kW_{el}	ca. 1 Nm^3/h CNG	Under construction, Opening 4th October 2018	www.iet.hsr.ch
Limeco	Dietikon	2 MW_{el}	ca. 90 Nm^3/h CNG	Construction starts in 2018, production 2019	https://www.swisspower.ch/themen-und-standpunkte/aus-abfall-und-abwasser-macht-das-hybridkraftwerk-sauberes-gas
	Laufenburg	k.A.	Audi E-diesel, sowie Wachse	Production starts early 2019	http://ineratec.de/audi-intensiviert-forschung-bei-synthetischen-kraftstoffen/
EMPA	Gösgen	5 MW_{el}			
PtG BW	Grenzach-Wyhlen	1 MW_{el} ind. 300 kW_{el} F&E	Hydrogen	Permissions granted	http://www.ptg-bw.de/

Different Technologies for Renewable Transport and Mobility

	Electric Mobility	Hydrogen Mobility	Methane Mobility
Fuel Production	no transformation from electricity	Easy in Power-to-Hydrogen	Additional methanation
Efficiency	High	Medium	Low
Available models	More and more passenger cars	2 passenger cars	24 passenger cars, trucks, busses
Existing infrastructure	Building up	One public filling station in CH	140 public filling station in CH
Time for charging/filling	Slow	Quick	Quick
Range	Good for passenger cars	Good for passenger cars	Good for passenger cars, trucks, busses
Embodied energy	With large battery twice of an ICE car	Medium	Normal
Storability	Short term with large efficiency		Short term (grid) and long term

Opportunities of Power-to-Gas

Power-to-Gas …

- **… connects to infrastructures: Grids for Electricity and Gas**
- **… provides a service to the electricity grid (reserve power supply)**
- **… is operated**
  - when a lot of renewable electricity is in the European grid
  - when electricity prices are low.
- **… allows to increase the share of renewable gas considerably.**
  - Potential of biomass is limited
  - Goal of the gas industry until 2030: 30% renewable gas for heating
  - Transport und mobility renewable (together with electric mobility)
- **Power-to-Gas is a new technology close to profitability.**

Risks

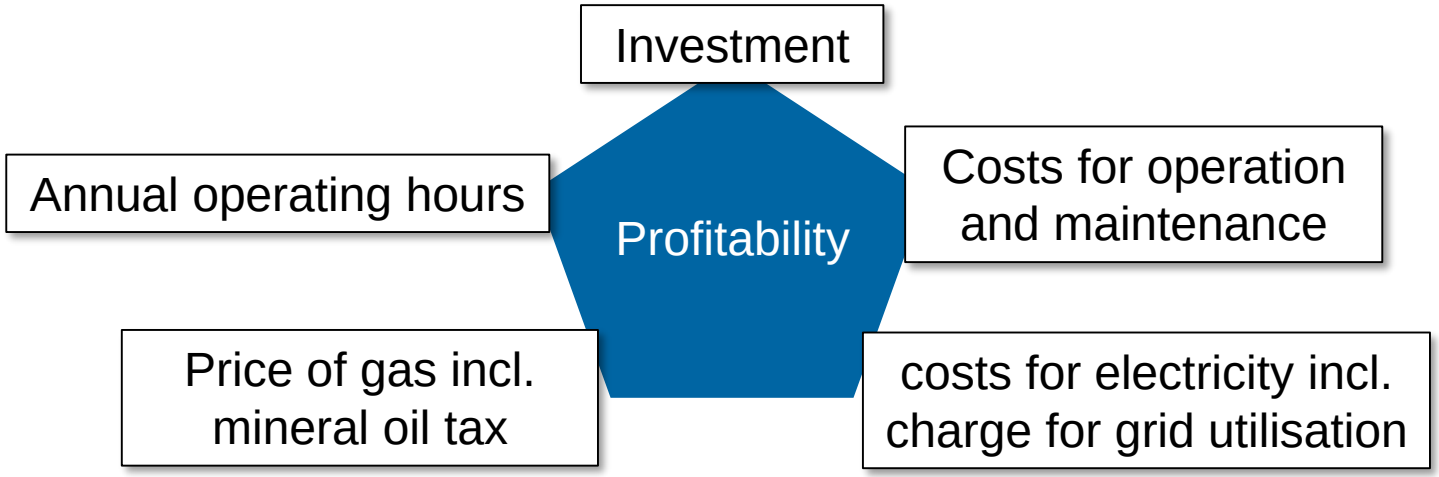
- **Infrastructure operating less than 8’000 hours per year:**
- **Political framework conditions:**

  Established before Power-to-Gas was around.

  Undergo changes with uncertainties for the future.

  - Power-to-Gas installations pay fees for utilisation of the electricity grid, pumped hydro storage and battery storage don’t.
  - Renewable fuels are exempt from CO2-tax (when used for heating) and from mineral oil tax (when used for mobility) until 2020. What happens after this?
  - Which prise is assigned to the emission of CO_2?

Perspectives



Ingredients for a working Business-Case:

- **Renewable electricity at the same location**
- **Electric power of at leas 1 MW**
- **At least 5000 annual operating hours**
- **Income from services stabilising the electricity grid**
- **Income from selling CO_2-neutral gas «Swiss Made» for mobility**
- **Subsidies as P&D Project of SFOE**

Power-to-Gas Team


Friedl


Meier


Ruoss


Schmidlin


Moebus


Stadler


Gorre


de Sousa


Angst


Lydement


Steiner


Leonhard

Pilot- und Demonstration Plant Power-to-Gas HSR

ENERGIE ZürichseeLinth

erdgas regio

erdgas

EWJR ELEKTRIZITÄTSWERK JONA-RAPPERSWIL AG

Audi

CLIMEWORKS

ETOGAS
smart energy conversion

In Zusammenarbeit mit der KTI

Energie
Swiss Competence Centers for Energy Research

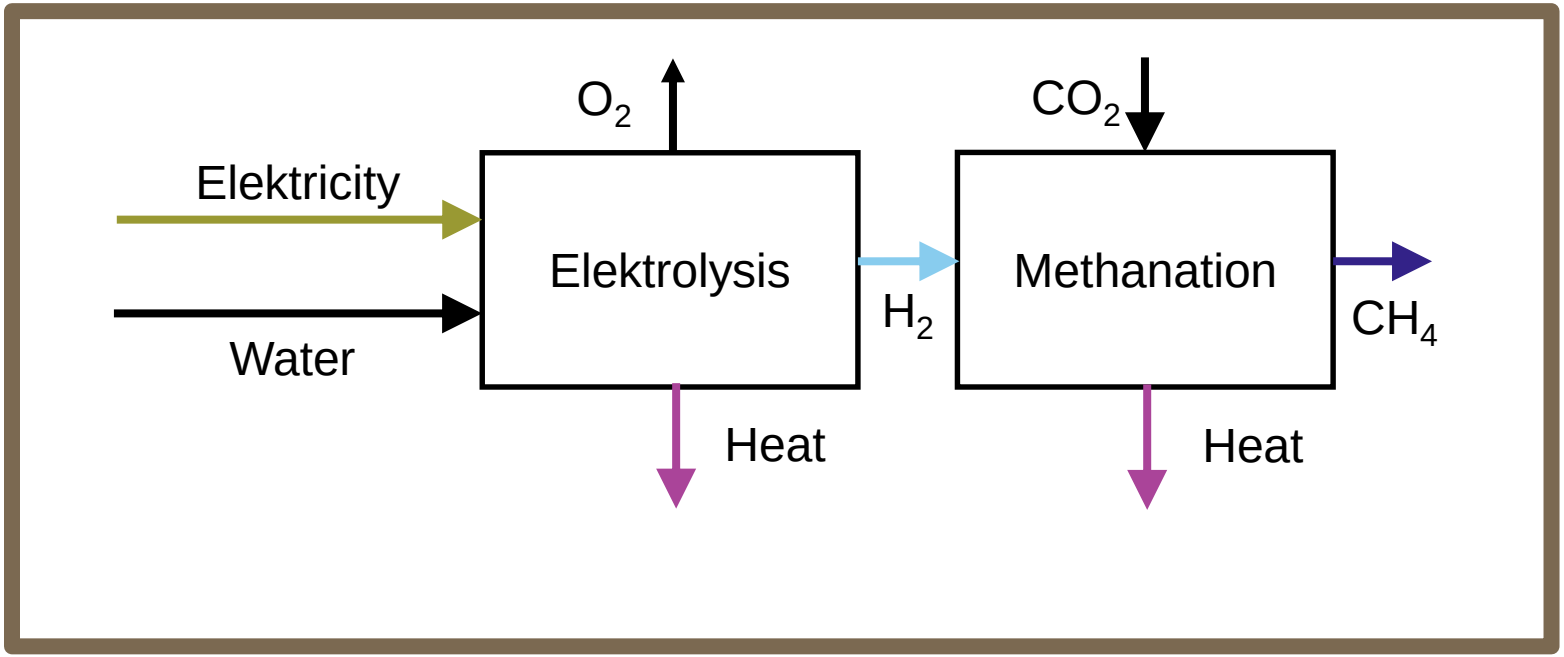
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Kommission für Technologie und Innovation KTI

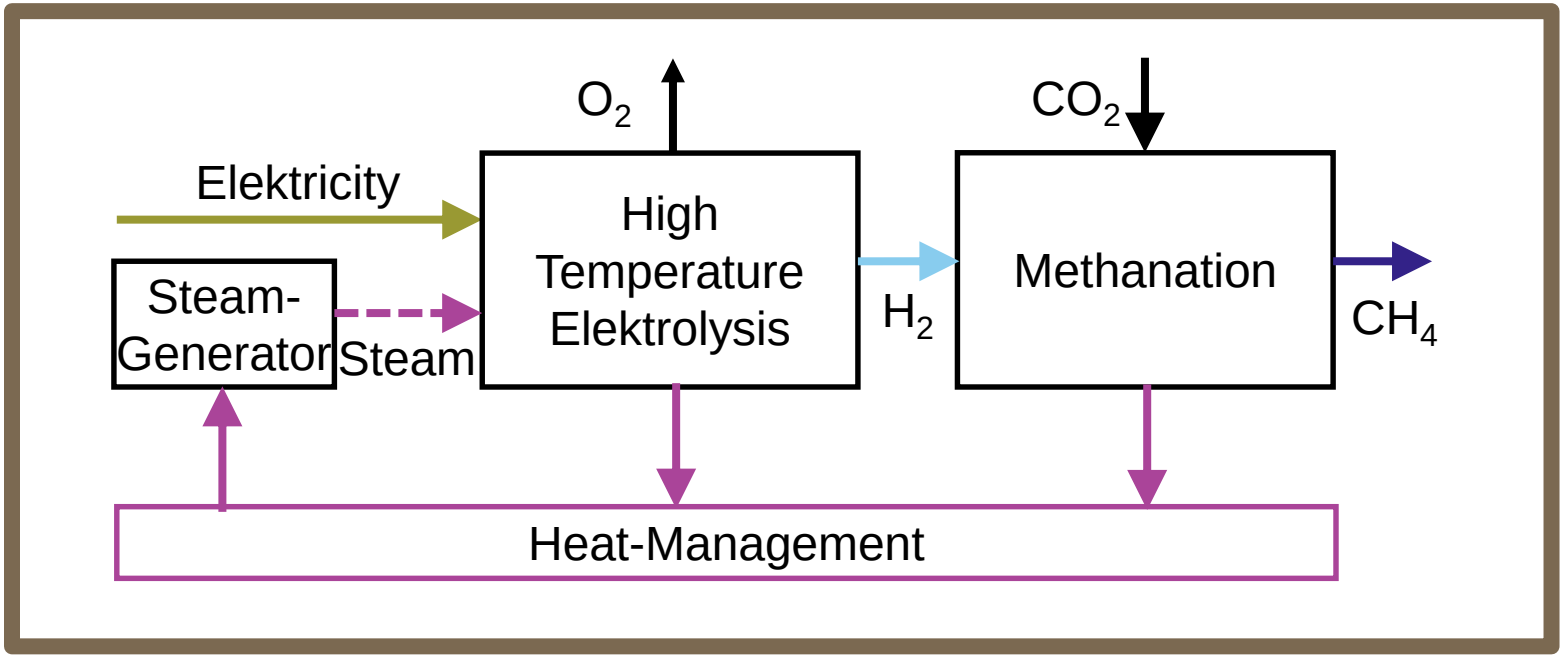
Storage
Swiss Competence Centers for Energy Research

High Efficiency Power-to-Gas Pilot (HEPP)

High Efficiency Power-to-Gas Pilot (HEPP)



High Efficiency Power-to-Gas Pilot (HEPP)



Power-to-Gas @ IET

Projects aF&E

High Efficiency Power-to-Methane Pilot HEPP

SNF Project: Carbon Flows in the Energy Transition

Horizon 2020

Services

Scientific Consulting Hybridwerk Aarmatt

Feasibility Studies

Expert Talks Power-to-Gas

Network

Exchange of Experience Power-to-Gas

Education

Student Projects

ARO

Partner of

Summary

Power-to-Gas …

- **… uses existing infrastructure …**
- **… and existing technologies.**

Power-to-Gas has to play an important role …

- **… in a sustainable energy supply (Electricity, heat, fuels)**
- **… in a sustainable transport and mobility.**

IET is leading the implementation of Power-to-Gas in Switzerland.