Enabling the energy turnaround by

# **linking electricity, mobility and heat sector**

**Future Smart Cities Seminar**
30.11.2017

**Urs Cabalzar**
Automotive Powertrain Technologies Laboratory

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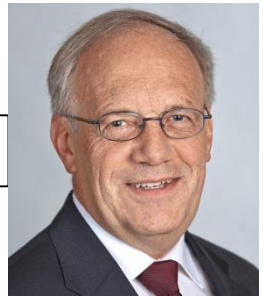
Materials Science and Technology

# Introduction Empa



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6 Departments

1 | 2 | 3 | 4 Mobility, Energy and Environment | 5 | 6

Automotive Powertrain Technologies Laboratory

- Powertrain
- Vehicle
- Exhaust Aftertreatment
- Synthetic Fuels



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# Content

- Challenges of the energy turnaround
  → linking energy sectors as one solution

- Power-to-Gas-plant “move”

- Mobility
  - $CO_2$ legislation
  - Alternative fuels & powertrains

# Content

- Challenges of the energy turnaround
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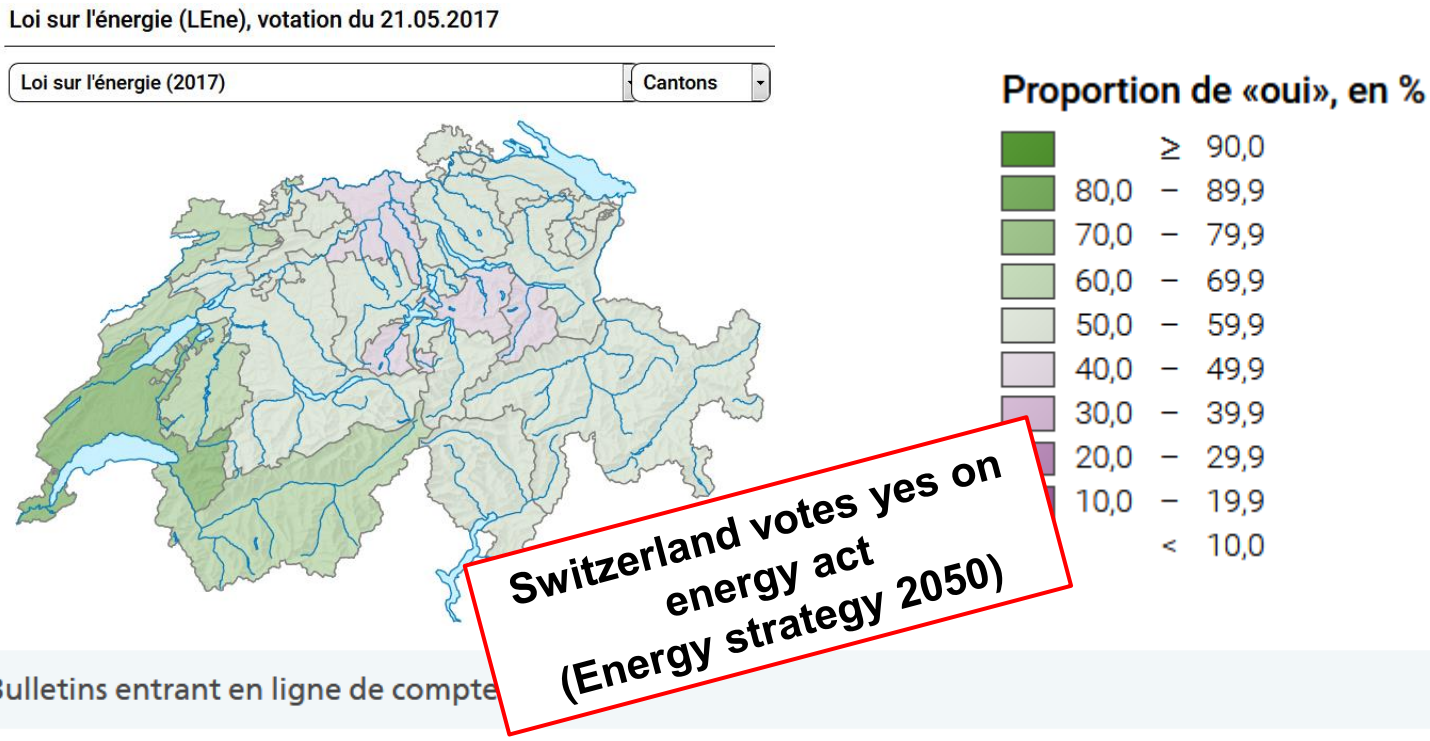
# Challenges of energy turnaround
## Energy strategy 2050




| Bulletins entrant en ligne de compte | | |
|---|---|---|
| Bulletins valables | 2'271'316 | |
| Oui | 1'322'263 | 58.2% |
| Non | 949'053 | 41.8% |

Source: admin.ch, 2017



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# Challenges of energy turnaround

## Energy strategy 2050




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# Challenges of energy turnaround
## Energy strategy 2050

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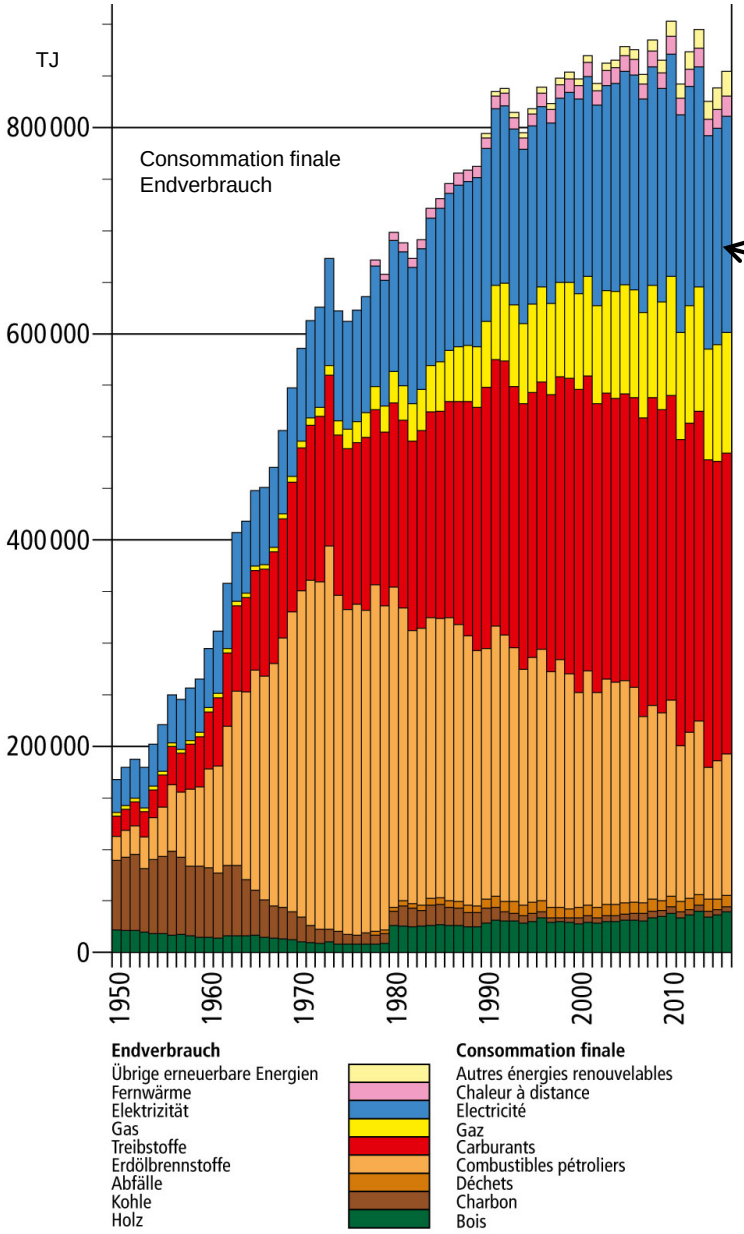
**Art. 2** Valeurs indicatives pour le développement de l'électricité issue d'énergies renouvelables

1 S'agissant de la production indigène moyenne d'électricité issue d'énergies renouvelables, énergie hydraulique non comprise, il convient de viser un développement permettant d'atteindre au moins 4400 GWh en 2020 et au moins 11 400 GWh en 2035.

2 S'agissant de la production indigène moyenne d'électricité d'origine hydraulique, il convient de viser un développement permettant d'atteindre au moins 37 400 GWh en 2035. Pour les centrales à pompage-turbinage, seule la production provenant de débits naturels est comprise dans ces valeurs indicatives.

3 Le Conseil fédéral peut fixer des valeurs indicatives intermédiaires supplémentaires, globalement ou pour des technologies données.

Consommation d'énergie 1950-2016 en TJ
Energieverbrauch 1950-216 in TJ




**41'000TJ -> 11.4 TWh**
Goal for new renewables for 2035

Source: BFE, Schweizerische Energiestatistik 2016



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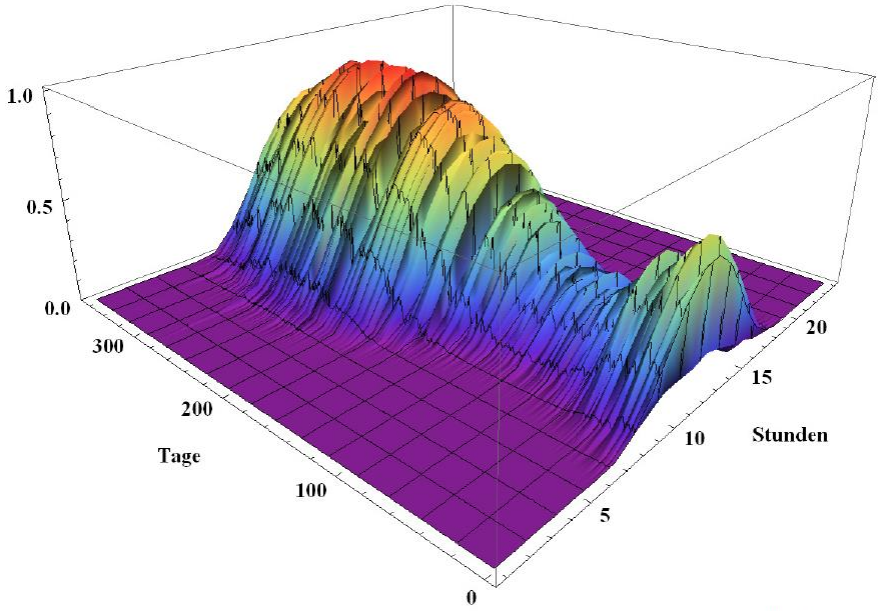
# Challenges of energy turnaround

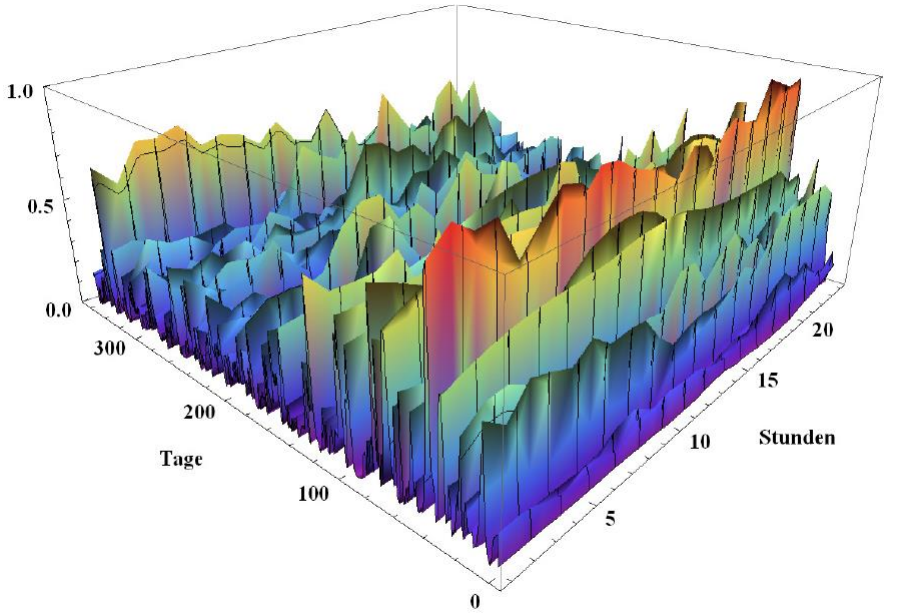
## Electricity from renewable sources




*Quelle: Prognos 2012*

**Photovoltaic**

Strong surplus in summer




*Quelle: Prognos 2012*

**Wind energy**

Stochastic production



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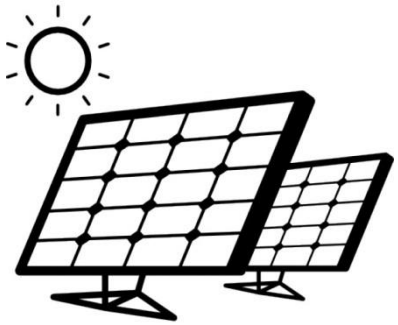
# Challenges of energy turnaround
## Electricity from renewable sources

Wind turbine: 5 MW

1’000 $m^2$ PV: 0.15 MW

=

=



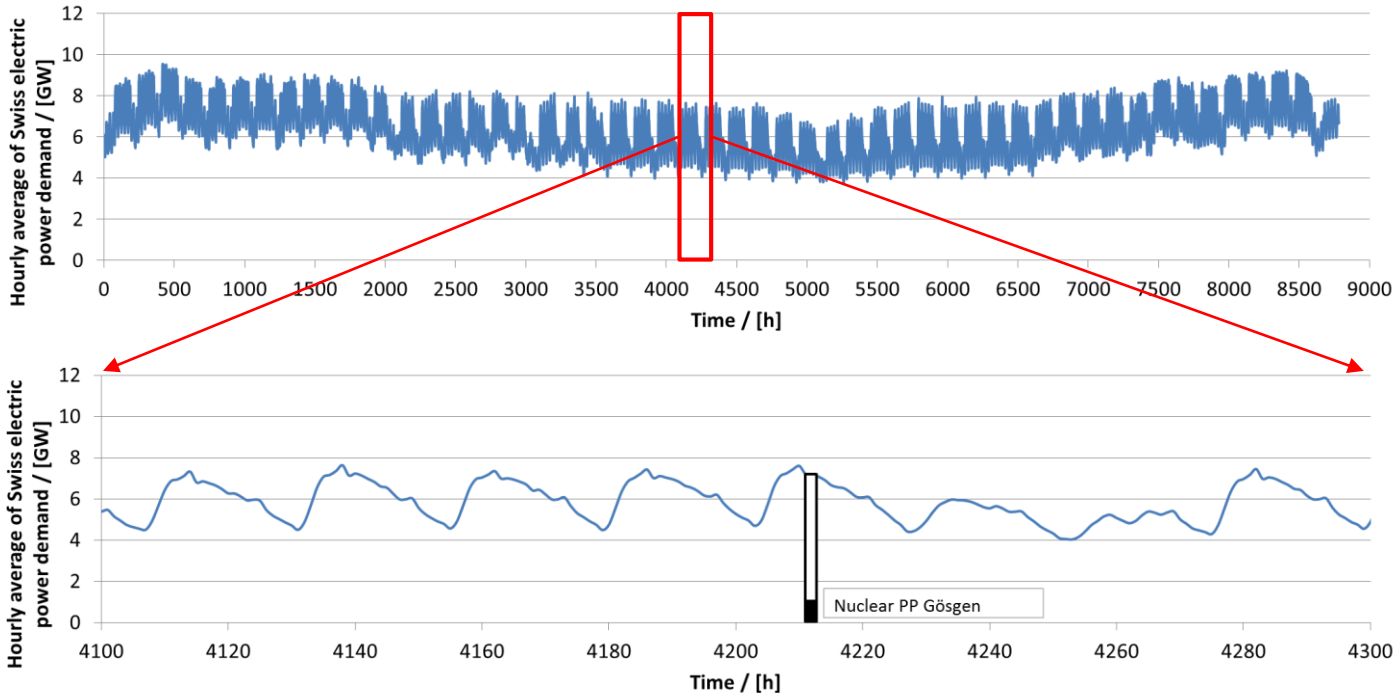
**P = 1’000 MW**
h = 8’000 h/a
E = 8’000 GWh/a

**P = 640 x 5 = 3’200 $MW_p$**
h = 2’500 h/a
E = 8’000 GWh/a

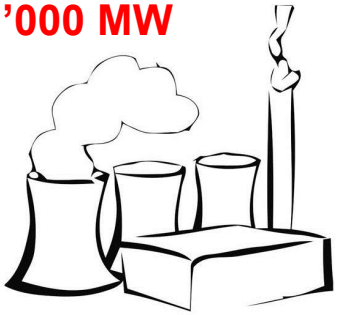
**P = 60’000 x 0.15 = 8’000 $MW_p$**
h = 1000 h
E = 8’000 GWh/a

# Challenges of energy turnaround

## Electricity from renewable sources




**P = 1’000 MW**



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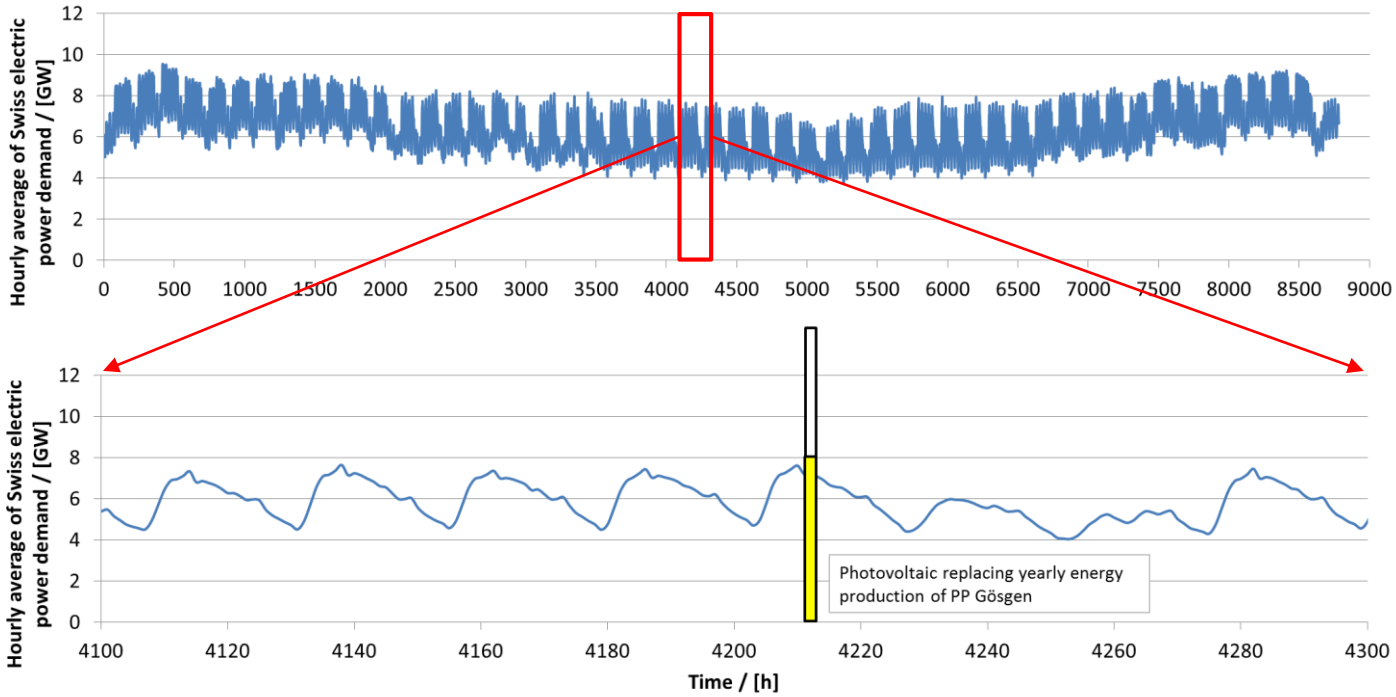
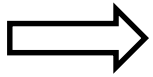
# Challenges of energy turnaround

## Electricity from renewable sources

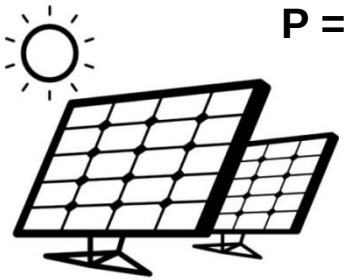



P = 1’000 MW





P = 8’000 $MW_p$



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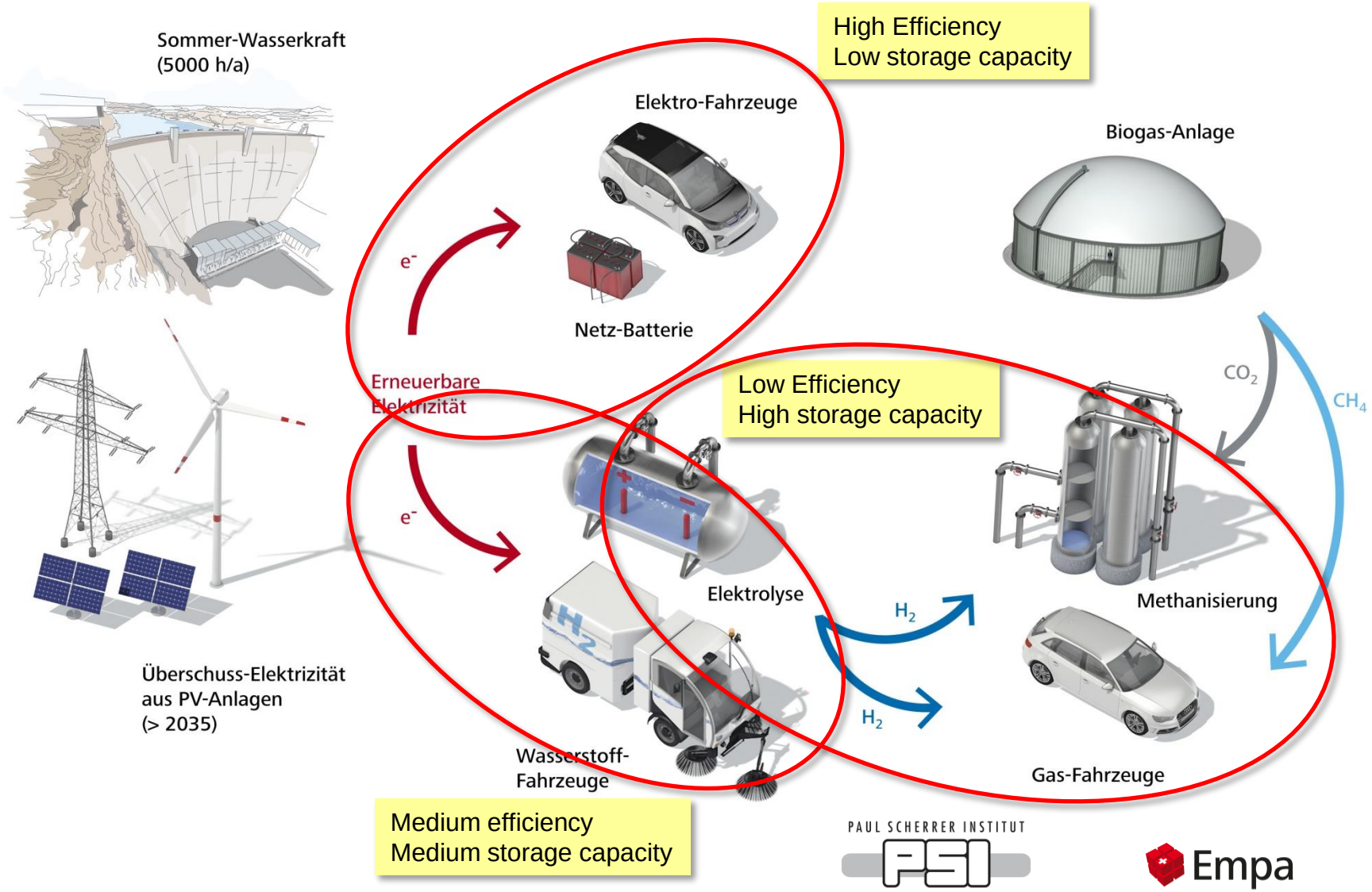
- Power-to-Gas-plant “move”
- Mobility
  - $CO_2$ legislation
  - Alternative fuels & powertrains

# Power-to-Gas plant “move”

## Linking electricity and mobility sector




PAUL SCHERRER INSTITUT PSI

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# Power-to-Gas plant “move”

## Linking electricity and mobility sector



**Inaugurated November 2015**
(located on Empa Campus)



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# Power-to-Gas plant “move”

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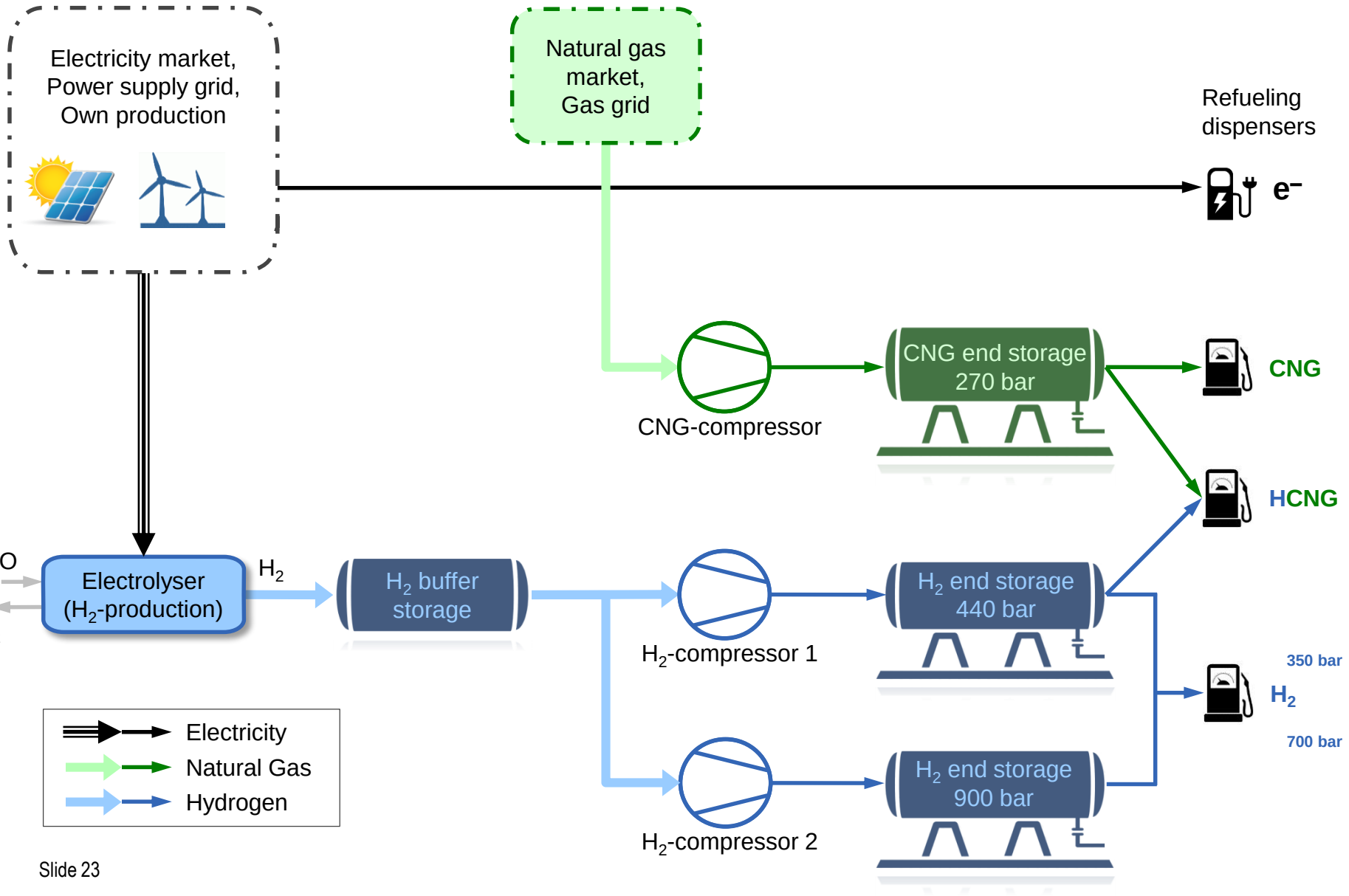

# Power-to-Gas plant “move”

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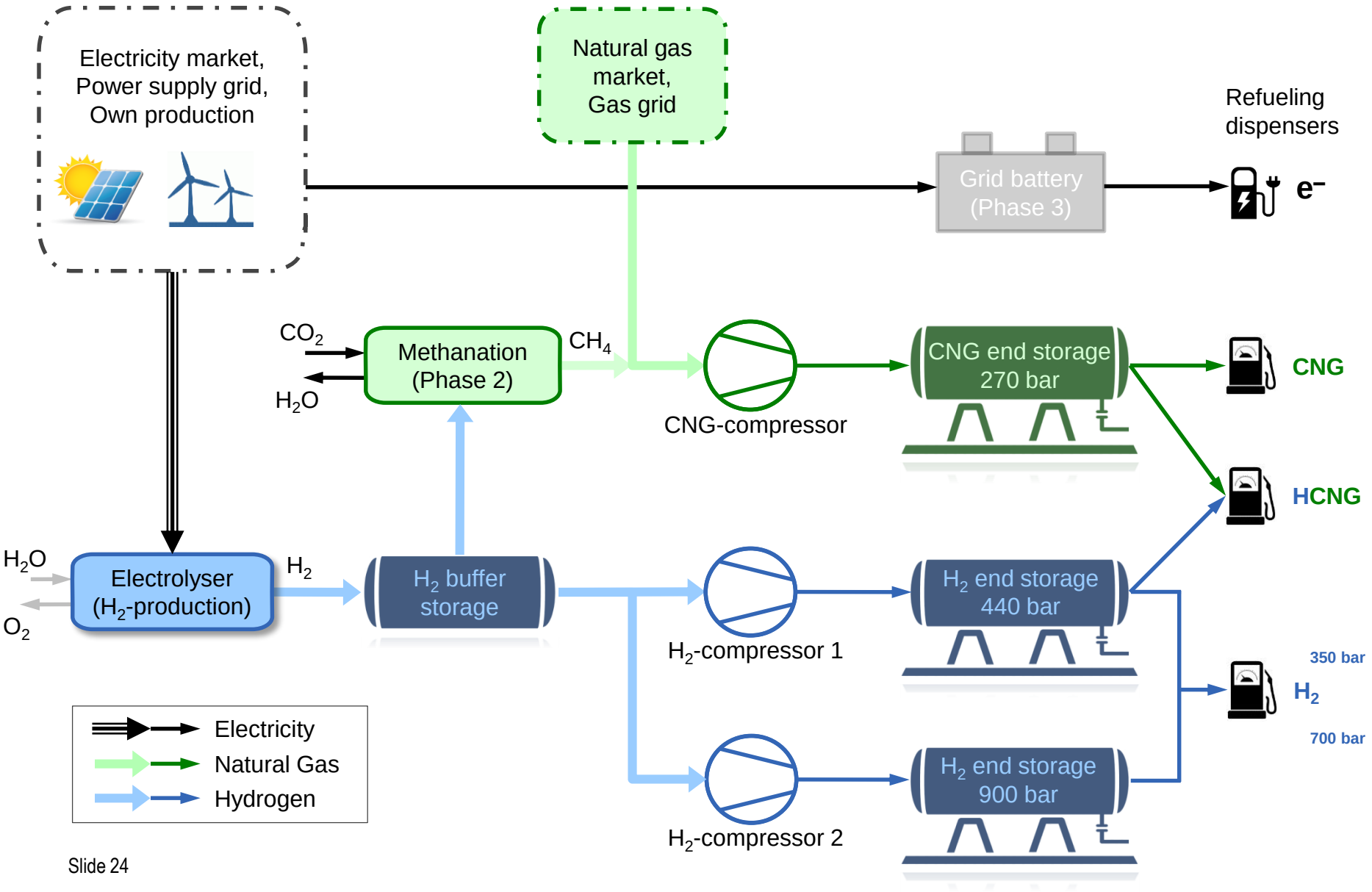
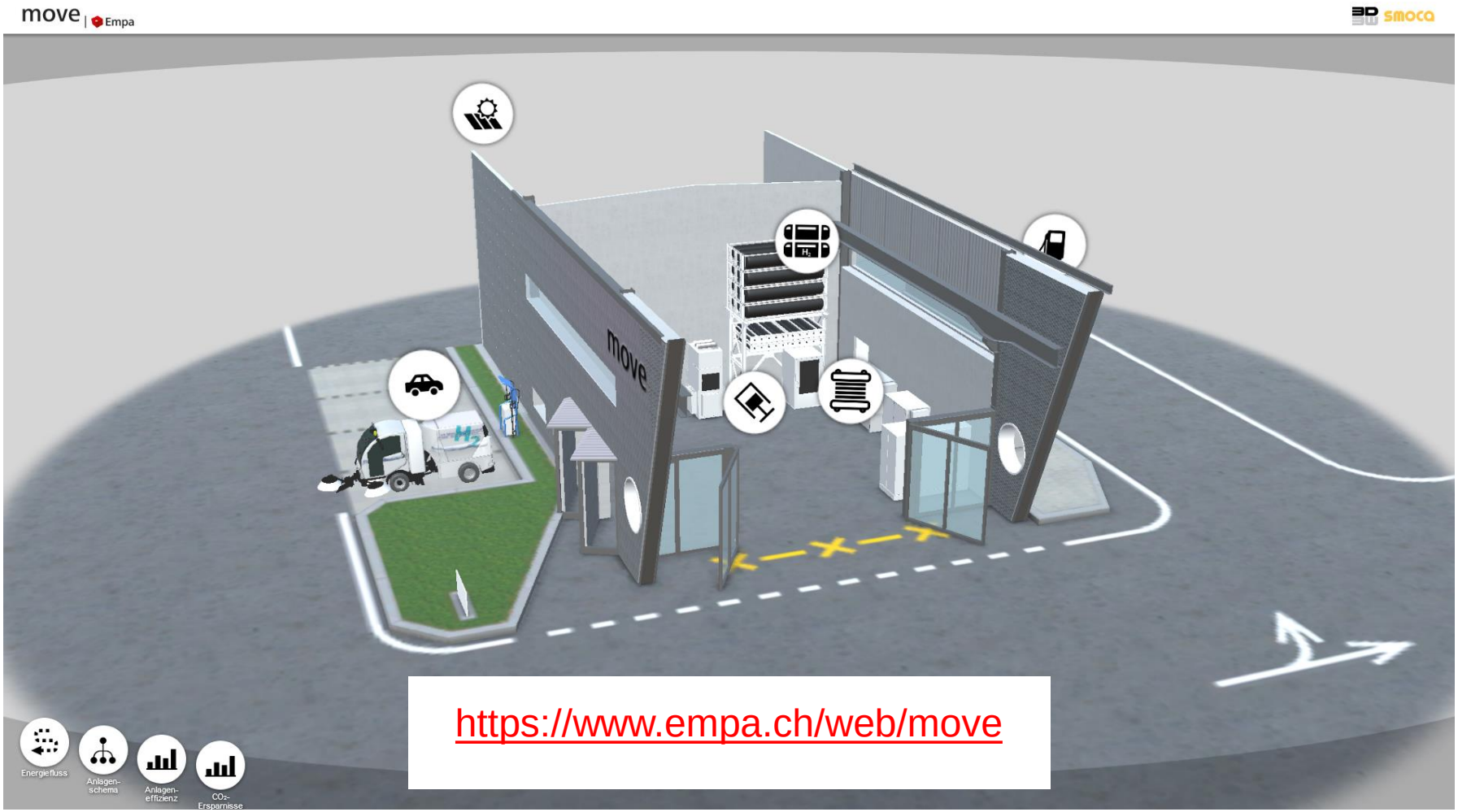


# Power-to-Gas plant “move”

## Linking electricity and mobility sector




https://www.empa.ch/web/move



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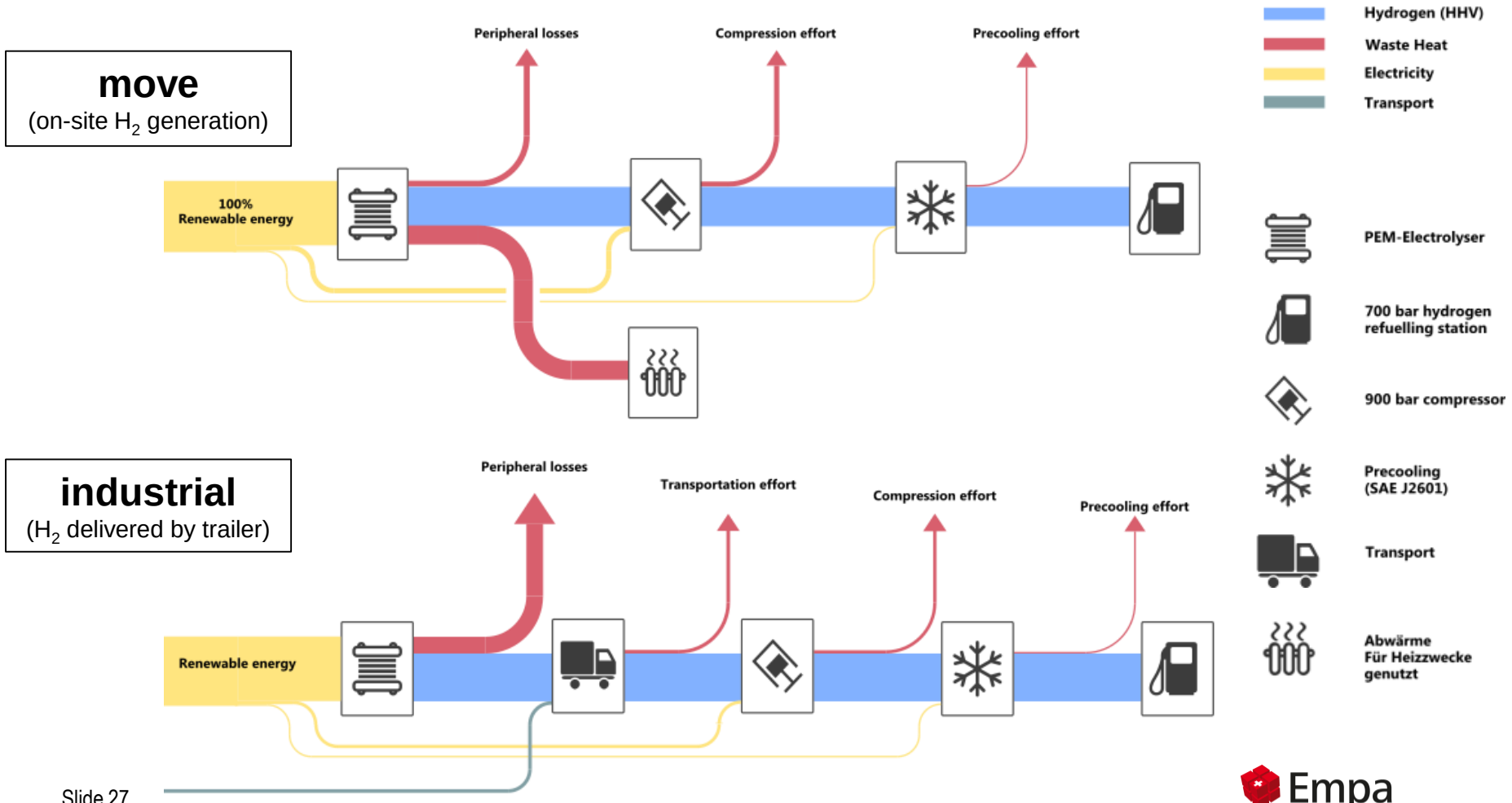
# Power-to-Gas plant “move”
## Projects

- Sankey-diagram of hydrogen pathway



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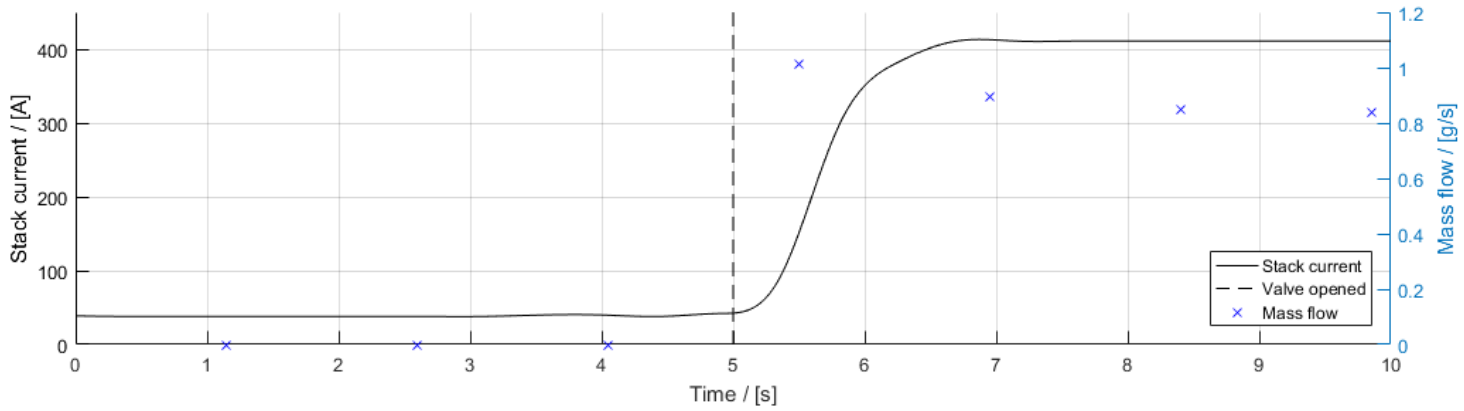
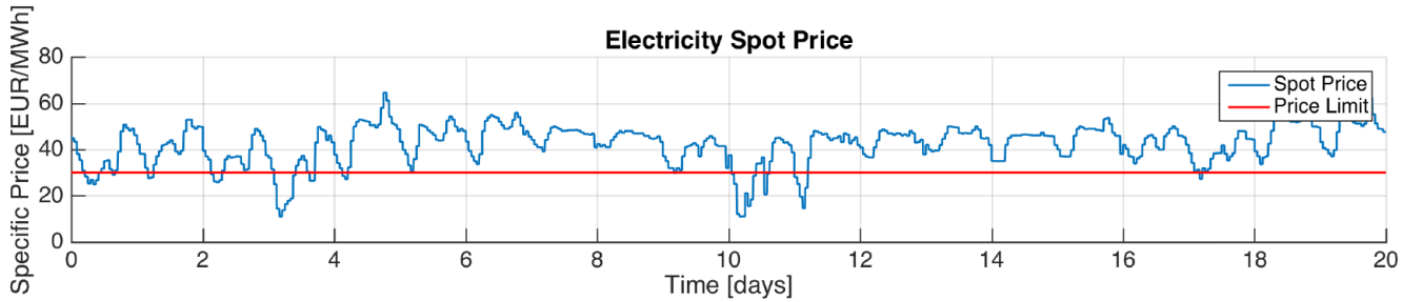
# Power-to-Gas plant “move”
## Projects

- System dynamics




- Operation strategy / storage sizing



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# Mobility – $CO_2$ legislation
## Energy strategy 2050




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# Mobility – $CO_2$ legislation
## Energy strategy 2050

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Loi sur l'énergie

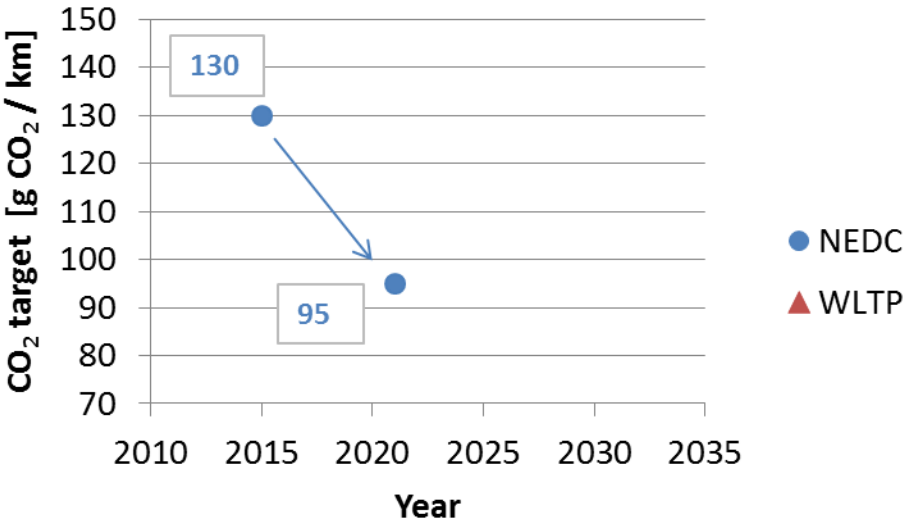
*Art. 10* Principe

1 Les émissions de $CO_2$ des voitures de tourisme mises en circulation pour la première fois doivent être réduites, d'ici à fin 2015, à 130 g de $CO_2$/km en moyenne, et d'ici à fin 2020, à 95 g de $CO_2$/km en moyenne.

2 Les émissions de $CO_2$ des voitures de livraison et des tracteurs à sellette d'un poids total allant jusqu'à 3,50 t (tracteurs à sellette légers) mis en circulation pour la première fois sont réduites en moyenne à 147 g de $CO_2$/km d'ici à fin 2020.

# Mobility – $CO_2$ legislation

## Emission limits in the EU



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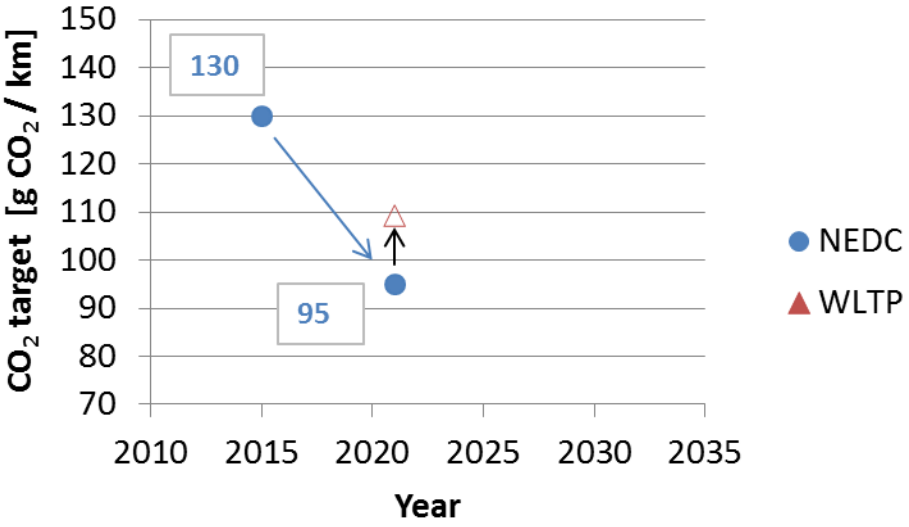
# Mobility – $CO_2$ legislation

## Emission limits in the EU



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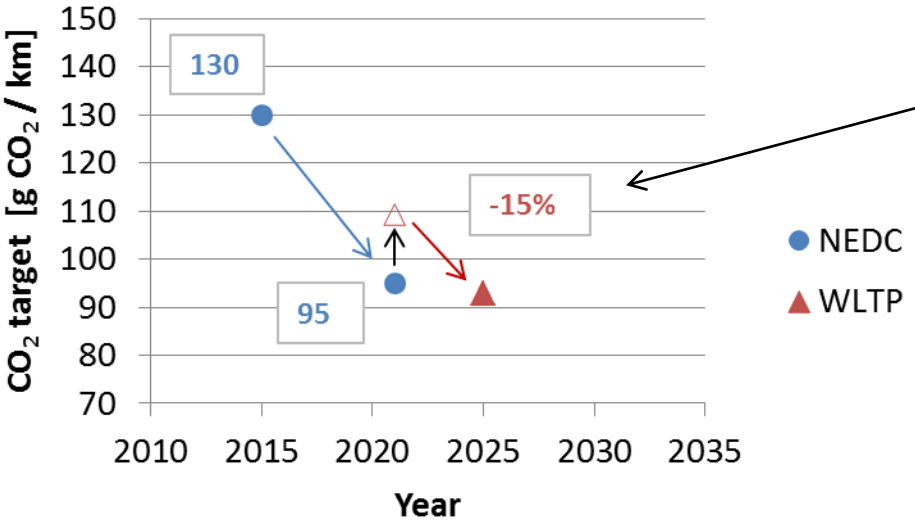
# Mobility – $CO_2$ legislation
## Emission limits in the EU




Proposed targets for 2025/2030 were presented on 8th of November 2017 by the European Commission



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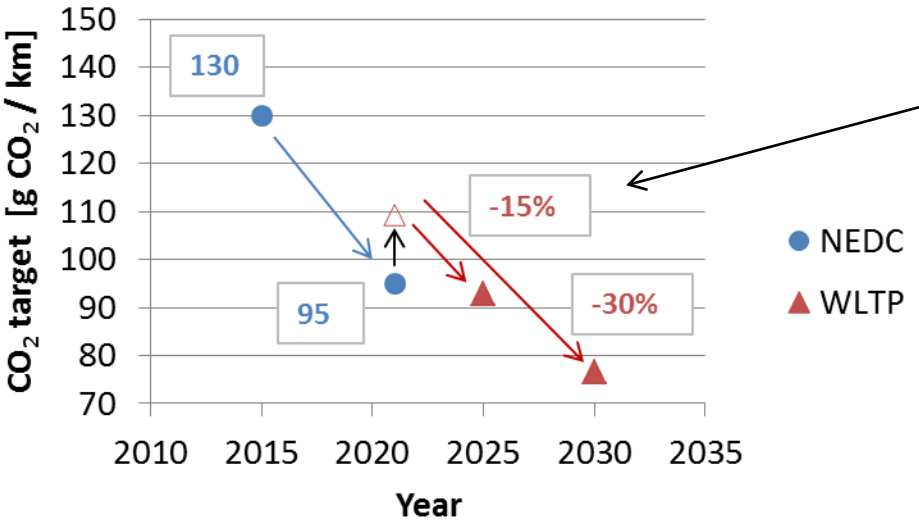
# Mobility – $CO_2$ legislation
## Emission limits in the EU




P 2016 argets for 2025/2030 were presented on 8th of November 2017 b

EU-Ø$_{2016}$ = 118 g $CO_2$/km

CH-Ø$_{2016}$ = 134 g $CO_2$/km

Hypothetical penalty per vehicle:

(134 – 95) * 142.50 = **5'558 CHF**

| Financial penalty | |
|---|---|
| EU | 95 € / g |
| CH | 142.50 CHF / g |

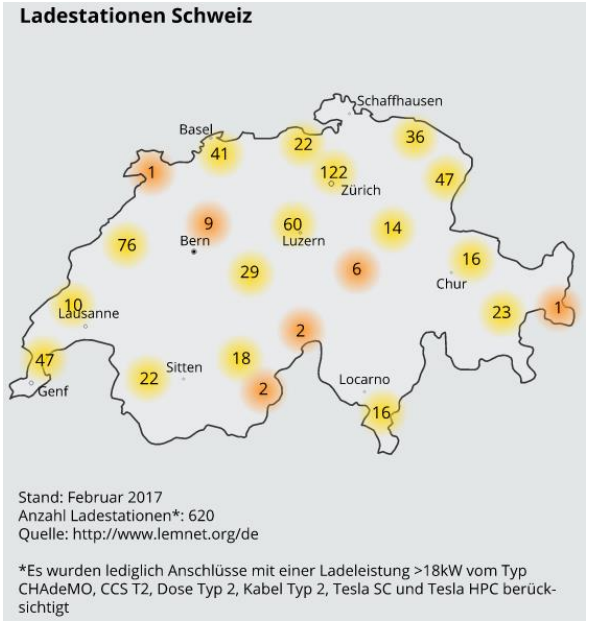
Invest in PtG-plants instead of paying penalties **(e.g. Audi e-gas)**

**Options for car manufacturers / importers:**

- Development of conventional powertrains (optimization of gas exchange, lowering friction, …)
- Combine fleets, Eco-innovations, Super credits, …
- Electrification (HEV, PHEV, BEV, …)
- **Alternative Fuels (biofuels, electricity-based fuels, …)**

# Mobility – Alternative fuels & powertrains
## Status infrastructure

Electric




Hydrogen


Natural Gas / Biogas


Data retrieved February 2017



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# Mobility – Alternative fuels & powertrains

## Status $H_2$-mobility

**Launch of hydrogen refueling infrastructure by Coop**
(initiative in the context of their strategy “CO2-neutral by 2023”)


**Station in Hunzenschwil**
Open since November 2016


**ESORO Fuel Cell Truck**
Prototype



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# Mobility – Alternative fuels & powertrains

## Status $H_2$-mobility


Hyundai ix35 FC

| | |
|---|---|
| Power | 100 kW / 136 PS |
| Torque | 300 Nm |
| Range | up to 600 km |
| Fuel cons. | 1 $kg_{H2}$/100km |
| $CO_2$ | 0 g/km (local) |
| Price | 66‘990 CHF |


Hyundai Fuel Cell SUV

Toyota Mirai


Mercedes GLC Fuel Cell


Honda Clarity FC



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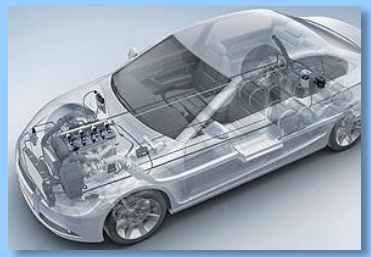
# Mobility – Alternative fuels & powertrains

## Status $CH_4$-mobility

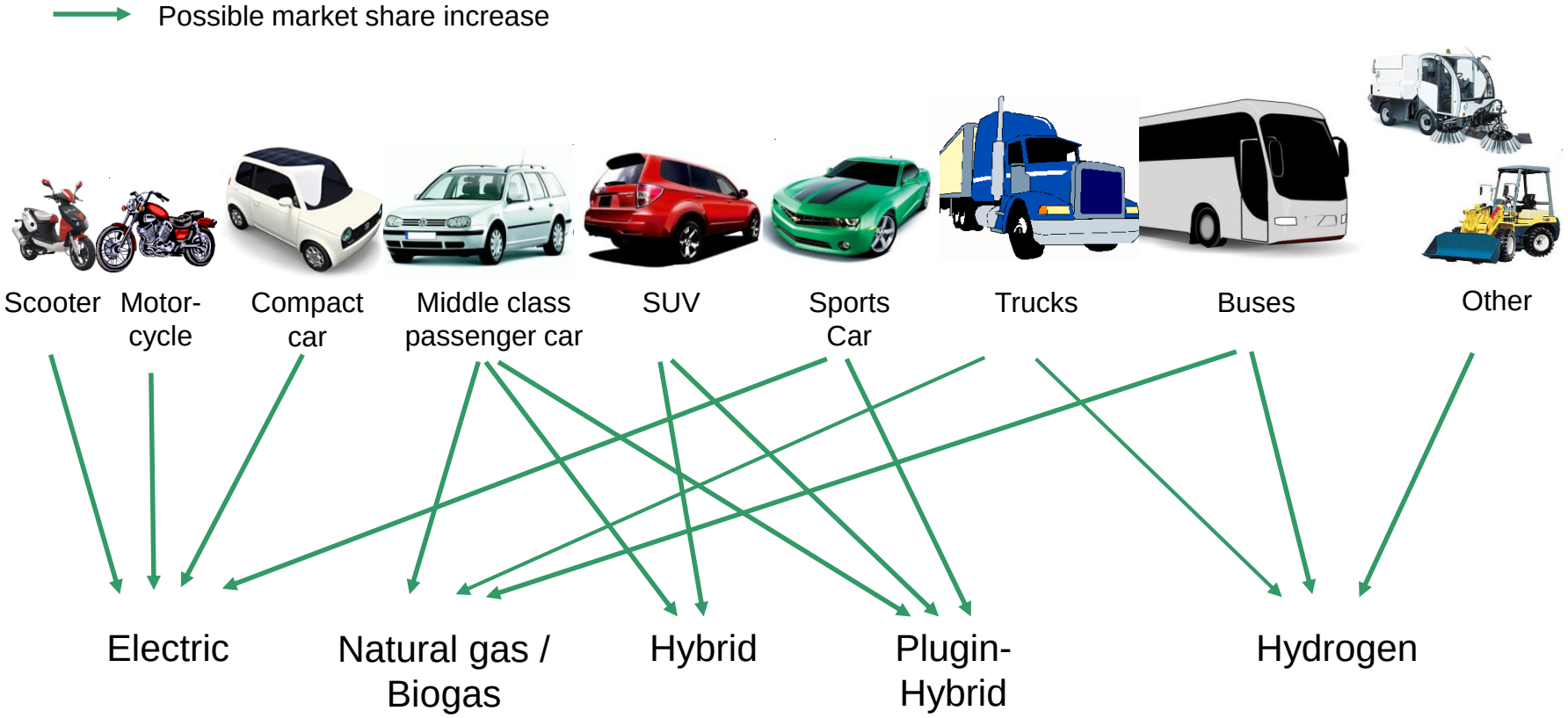
OEM start production

Turbo Engines

«real» gas engines

| until 2000 | 2000 - 2010 | since 2010 | >2020 |
|---|---|---|---|
| **Retrofits** | **1st Generation OEM-NGV's** | **2nd Generation OEM-NGV's** | **3rd Generation OEM-NGV's** |
|  |  |  |  |
| **Advantages:** All gasoline cars could be retrofitted. | **Advantages:** Big technological leap forward. | **Advantages:** Technologically equal with gasoline engines (Turbo) | **Advantages:** Use full potential |
| **Disadvantages:** Low technological level | **Disadvantages:** Only few models and old engines | **Disadvantages:** Hardly any for the end consumer | **Disadvantages:** ? |
| **Consumption:** as gasoline vehicles | **Consumption:** as old gasoline vehicles | **Consumption:** as modern gasoline vehicles | **Consumption:** as modern Diesel vehicles |
| **Range:** 150 – 250 km (Gas) | **Range:** 250 – 450 km (Gas) +250 – 600 km (Gasoline) | **Range:** 450 km (Gas) +250 – 600 km (Benzin) | **Range:** >600 km (Gas) |

# Mobility – Alternative fuels & powertrains
## Diversification




**Type of powertrain is determined by the application**



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# Summary

- Challenges

  Fluctuating production by RE → need storage (short term & seasonal)

  Need to decarbonise all sectors

  *=> Link electricity, mobility and heat sector*

  Not enough domestic renewable electricity (taking into account electricity-based mobility and heating)

- "move"

  https://www.empa.ch/web/move

  urs.cabalzar@empa.ch

- Power-to-Gas

  \+ levelize short term fluctuations
  \+ seasonal storage
  \+ $CO_2$-free or $CO_2$-neutral fuels
  \- efficiency → not important if otherwise wasted / need synthetic fuels:
  applications exist where e-mobility is not feasible (payload)
  \- economic viability → need penalties on $CO_2$ / scale effects

- Mobility

  Strict $CO_2$ limitations are important

  Important milestones reached for electric, hydrogen and methane cars

  Diversification of powertrains possible (application-oriented development)

# Questions

Thank you for your attention