Powertrain Technologies and Energy Carriers for Future Transport - a sectoral portfolio approach

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Outline

- Climate change mitigation: challenge of high priority
- Decarbonizing transport as strategic goal
- Expected developments worldwide and in Switzerland
- Powertrain technologies – comparison of operational CO₂ emissions
- Energy carriers portfolio for different transport sectors
- Consequences for sector coupling → investments in new infrastructure and “clean-up of the electricity system first” absolutely necessary
Mobility future worldwide / I

Key findings from IEA – ETP 2017

- Globally total final energy consumption (Reference Technology Scenario) grows from 113 exajoules (EJ) in 2015 to 165 EJ in 2060
- In 2060 most of the demand (36%) comes from road freight vehicles followed by passengers LDV (28%)
- Decarbonizing transport requires the combination of measures that alter the nature and the structure of transport demand, efficiency and transitions towards low-carbon fuels
- Reducing GHG emissions from transport requires incremental vehicle improvements (including engines), especially in the short to medium term
- Electrification is crucial for short-distance vehicles and the rail sectors, and needs to go hand in hand with decarbonizing the electricity sector
Mobility future worldwide / II

Key findings from IEA – ETP 2017

Transport sector transition - Trucks drive global oil demand

Trucks were responsible for nearly 40% of the growth in global oil demand since 2000; they are the fastest growing source of oil demand, in particular for diesel.
Mobility future worldwide / III

Key findings from IEA – ETP 2017

A modern truck sector is still a long haul away

**CO₂ emissions growth in the Reference Scenario, 2015-2050**

- **Coal use**
  - Power sector
  - Industry sector

- **Trucks**

Nearly 40 countries have fuel efficiency standards for cars; Only Canada, China, Japan and the United States have standards for trucks

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CO₂-Emissions across sectors in Switzerland

- Mobility (incl. International aviation)
- Households
- Industry
- Services

source: BAFU 2017
The Swiss mobility system

Past CO2 trends and future transport demand

- Road-based transport (passenger cars)
- International air traffic
- Road-based freight transport
- Freight transport (tkm)
- Passenger transport (pkm)

Source: BAFU 2017
Decarbonizing the Swiss Energy System

Decarbonization time horizon: CO2 Budget

- IPCC 2°C (66%) global carbon budget in 2010: 1000 Gt CO2
- “per-capita” distribution = 1.14 Gt CO2 for Switzerland
- With linear decrease and considering international transport (shipping & air traffic), the budget will be reached by mid 2055
- The transport sector has the same time horizon

Switzerland

Budget 2010: 1.14 Gt CO2
Decoupled representation of mobility sector

Simplified tool to address a complex system

\[
\begin{align*}
\text{CO}_2 & = \text{POP} \cdot \frac{\text{GDP}}{\text{POP}} \cdot \frac{\text{pkm}}{\text{GDP}} \cdot \frac{\text{vvm}}{\text{pkm}} \\
\text{NO}_x & \text{ ppm} \end{align*}
\]

\[
\begin{align*}
\text{demand for services} & \quad \text{supply of services} \\
\text{exogenous} & \quad \text{behaviour} \\
\text{fleet} & \quad \text{operation} \\
\text{investment} & \\
\end{align*}
\]

→ «easy» tool to communicate (decouples system, shows snapshot perspective)
→ past evolution and future perspectives can be illustrated
→ helps to align research topics (shows point of action)
→ be aware of coupling (rebound) effects
Overall vision, ambitions and approach

Vehicle & powertrain technology potentials - motorized individual transport

**Operational emissions in Mt CO₂ per year**

- **Conventional technologies**
  - Optimization
  - Hybridization
  - Natural gas

- **Battery electric**
- **Fuel cells**

**EU export electricity mix CO₂ emissions** = estimate based on data from 2014

source: Messmer & Frischknecht 2016

- **Optimization** = aerodynamics, rolling resistance, light weighting, motor efficiency
- **CCGT** = combined cycle gas turbine plant
- **+** = CH consumer electricity mix
- **EU export electricity mix**
Why still consider fuel cell electric vehicles (FCEVs)?

Undisputedly,
- electricity demand of FCEVs is much higher than for BEVs
- additional infrastructure for H2 generation and distribution is expensive

But,
- larger driving range for same weight
- H2 production important option for storing excess electricity
- shorter recharging times and less charging stations

Example: no. of refueling stations required to refuel the equivalent of 40’000 km in 1 hour:

source: Felix Büchi, PSI
Life cycle assessment of transport technologies

Emissions in Mt CO2 eq. per year

- **upstream processes abroad**
- **upstream processes Switzerland**
- **operational**

ICEV = internal combustion engine vehicle
BEV = battery electric vehicle
FCEV = fuel cell electric vehicle
SMR = steam methane reforming
HYD = electrolysis using Swiss hydropower
BEV charging = based on average generation mix

source: Hirschberg et al. 2016
International air travel departing from Switzerland

Direct emissions in Mt CO₂ per year

- passenger cars
- international air travel

Ratio in %

- international air travel
- passenger cars

source: BAFU 2017
The long-term challenge

Long-range, heavy-duty global transport modes

<table>
<thead>
<tr>
<th>Mode / sector</th>
<th>2010 share of transport GHG emissions</th>
<th>Growth 2010-2015</th>
<th>Projected increase 2030 (compared to 2010)</th>
<th>Projected share 2030 (if all other transport sector emissions stay constant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger air travel</td>
<td>10.6%</td>
<td>37.5% (pkm)</td>
<td>3.57 x</td>
<td>27%</td>
</tr>
<tr>
<td>Maritime freight</td>
<td>9.3%</td>
<td>23.1% (tkm)</td>
<td>2.3 x</td>
<td>16%</td>
</tr>
</tbody>
</table>

→ Direct electrification not possible in these two sectors → renewable chemical energy carriers (H₂, CₓHᵧ) will be a MUST

source: IPCC 2014
Long-term vision

Market shares of different energy carriers and powertrain technologies that support the decarbonization of transport → qualitative

- H2: fuel cells
- Battery electric vehicles
- Synthetic (“electric”) hydrocarbons: combustion engines
SCCER Mobility strategy

Embedded in a holistic energy transition vision (exergy based)

Therefore, we need: investments in integrated infrastructures
Infrastructure challenges – lifetime of assets

- Passenger cars ≈ 15 years
- Trucks & busses ≈ 10-20 years
- Ships & airplanes ≈ 20-30 years
- Electricity generation & power plants ≈ 20-50 years

→ Required investments will be huge → asset/infrastructure transformation process must be well coordinated both on country level and worldwide
Conclusions & outlook

- Decarbonization of the transport sector is an absolute necessity, but also a huge challenge (in Switzerland and worldwide)
- Innovation on both the demand and supply side must be pursued in parallel
- Technology will be crucial – evolutionary and disruptive paths must be well orchestrated for optimal CO₂ reduction trajectories
- BUT, keep an eye on renewable chemical energy carriers for long-range, heavy-duty transport
- Socio-economic policy must be designed in line with these targets
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