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Comparison of Total Lifecycle Emission of hybrid Aircraft with Different Propulsion System

Introduction
1. **Preliminary considerations**
2. **Total impact calculation**
3. **Results**

Conclusions

MOBILITY

Introduction

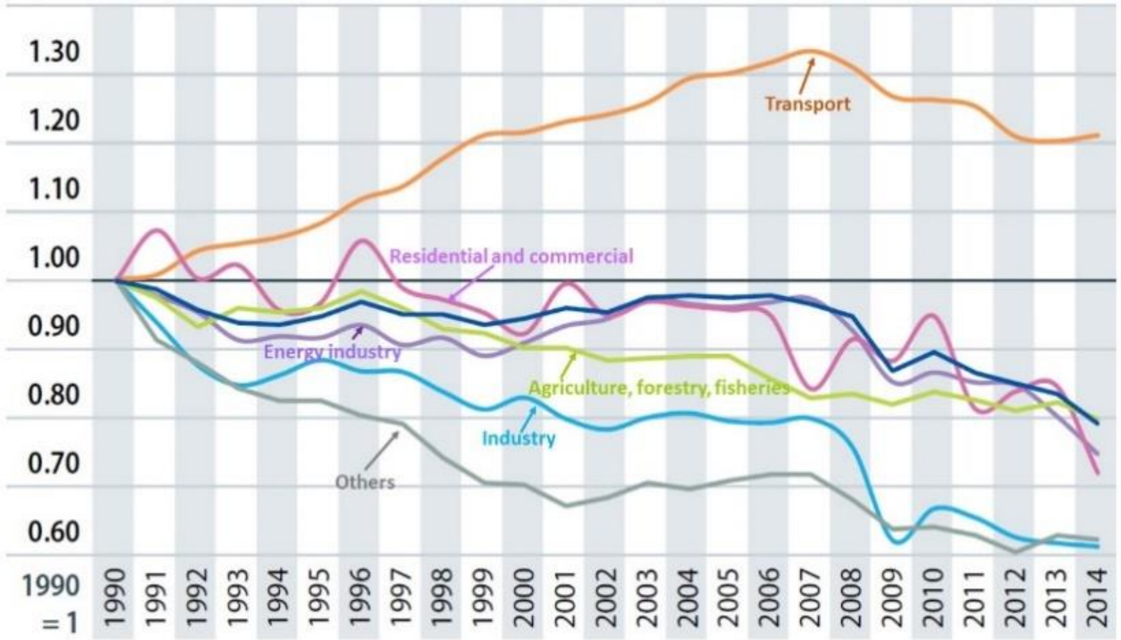
- Transport plays deterministic role in economy and society developments
- European goal

  drastic reduction

  in CO_2 emission
- Only emission

  origins from trans-

  port is increasing



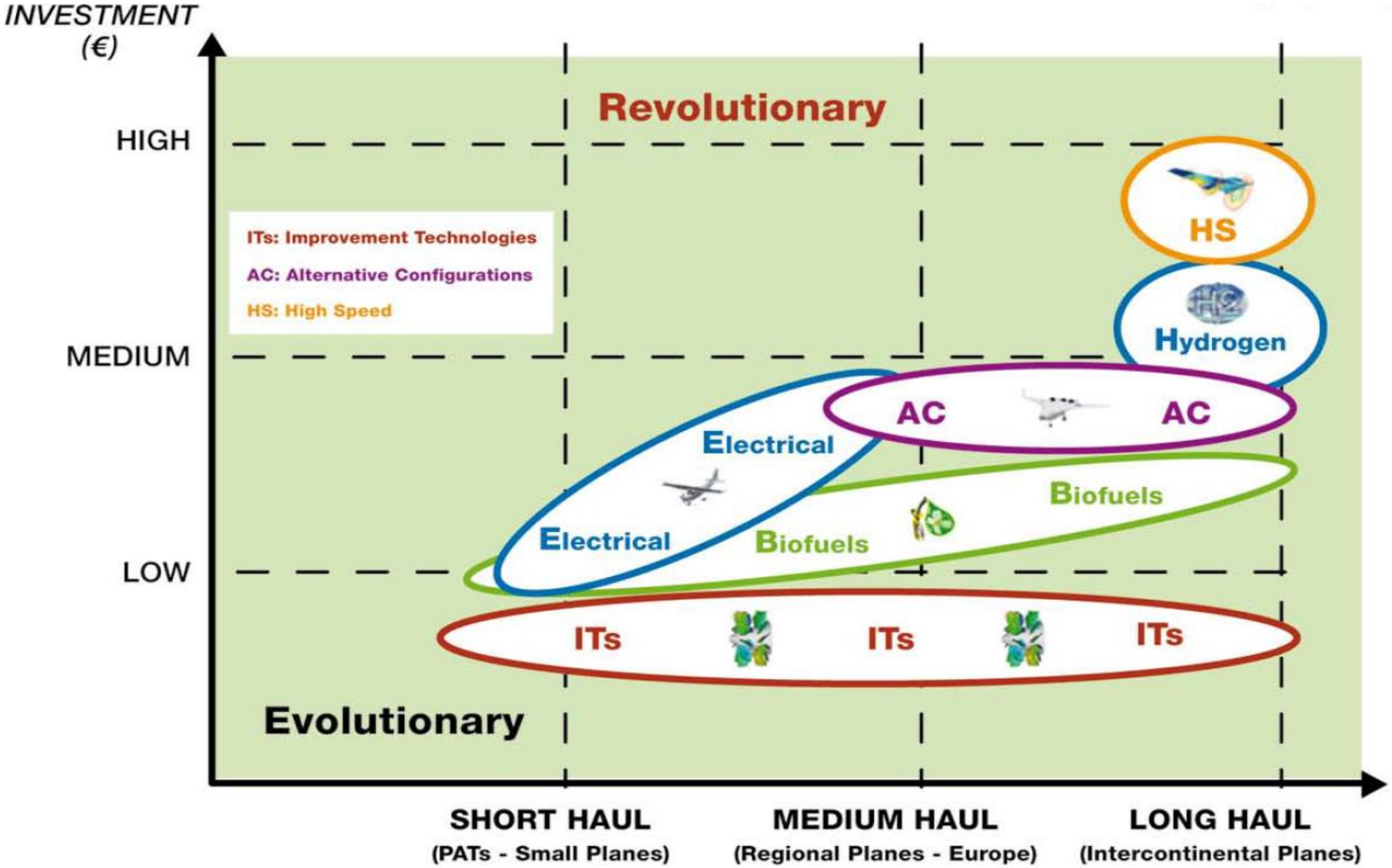
- Possible solution e-mobility
- Objective of this lecture: total impact evaluation for

  e-mobility with respect to hybrid aircraft

Introduction cont'd. 1.

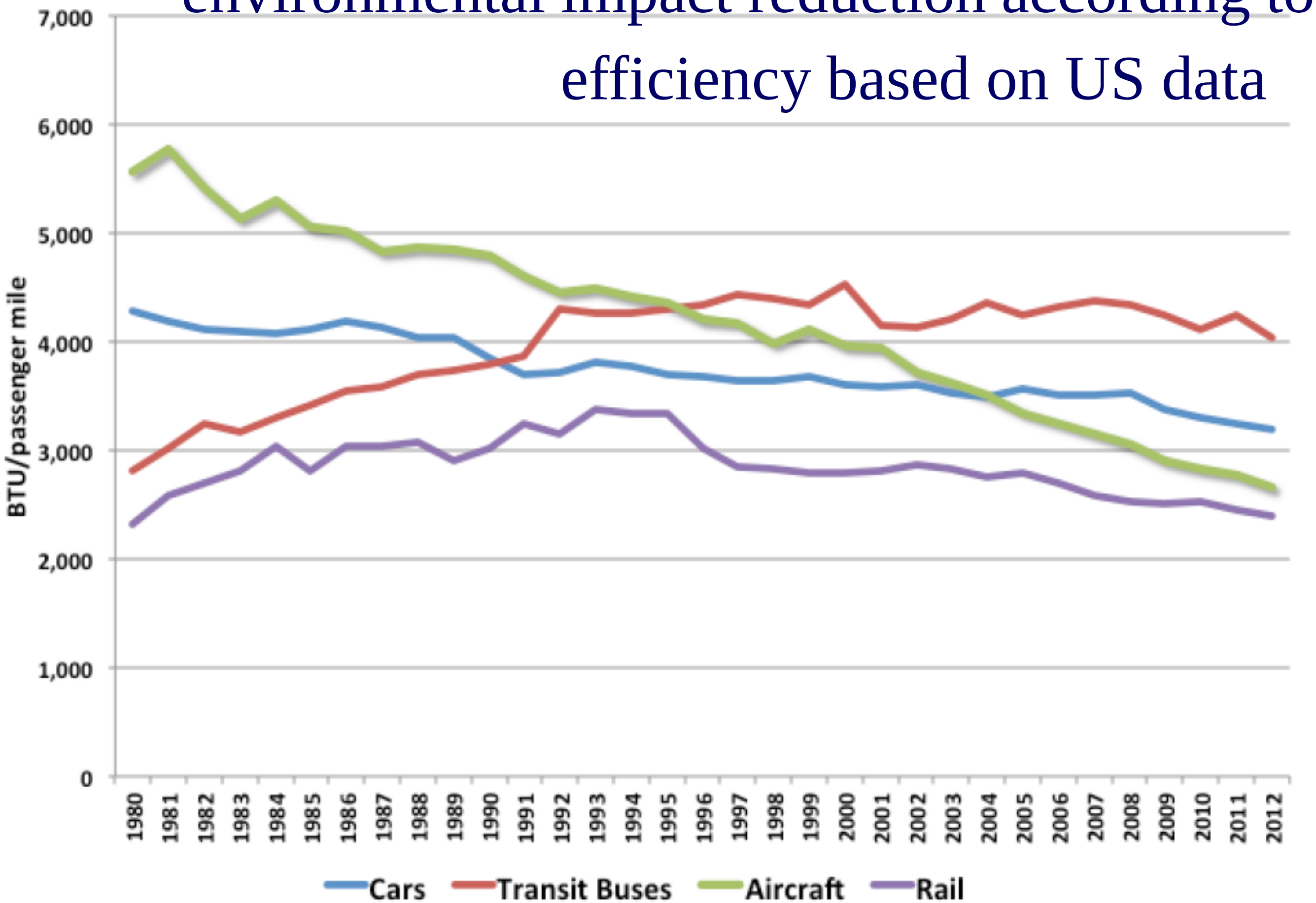
➢ Flight path 2050 defines the overall goal as "……….without negative effects on the environment."

It seems, the small/personal aircraft might be equipped by full electric propulsion system, only.



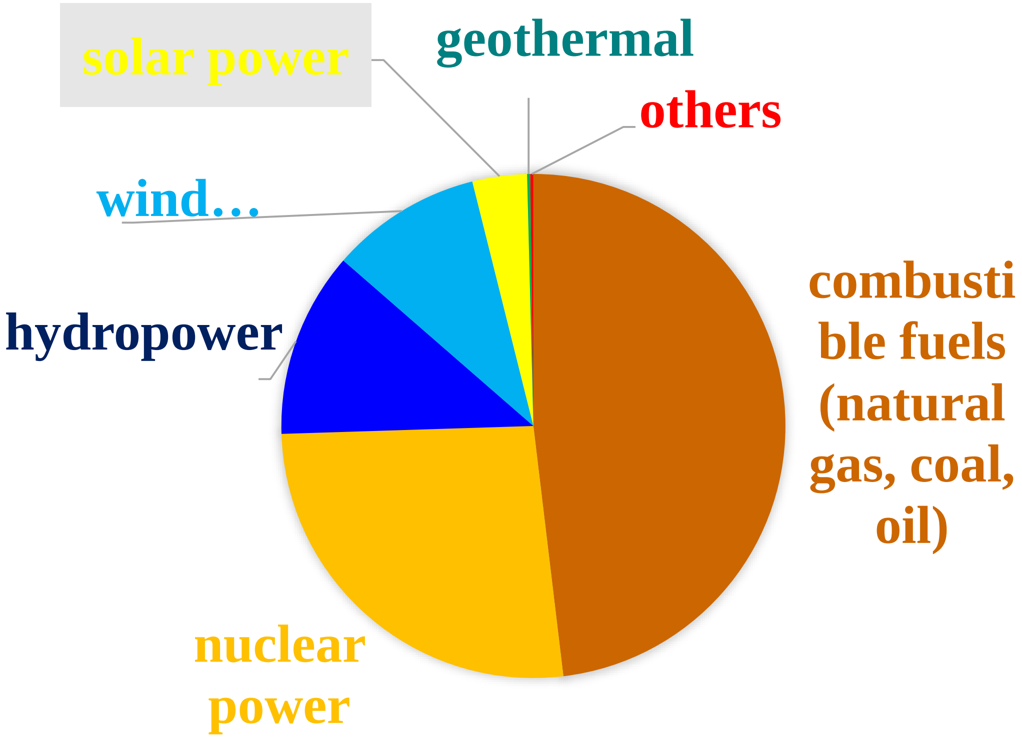
1. Preliminary considerations

- The aviation has the best results in efficiency improvements of environmental impact reduction according to Vehicle Fuel efficiency based on US data



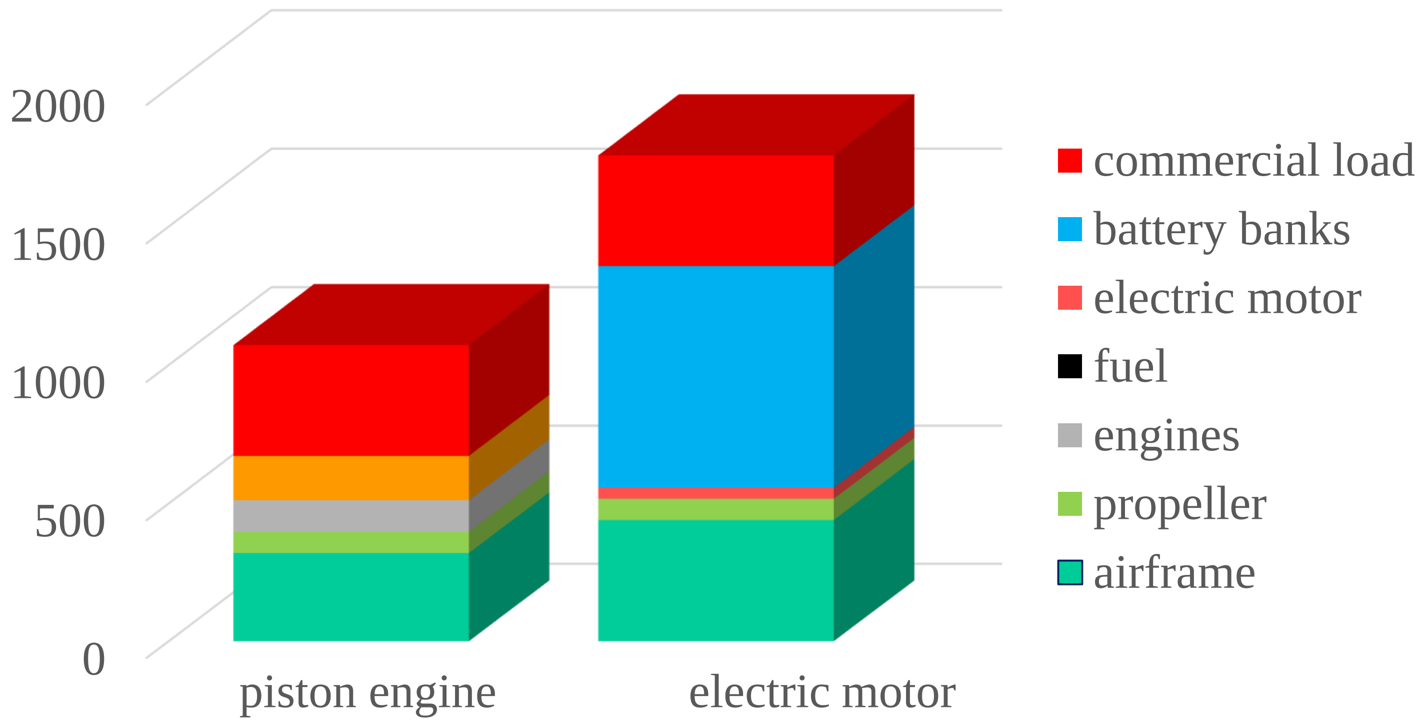
1. Preliminary considerations cont’d. 1.

- About half of electric energy is generated by use of combustible fuels
- Combustible fuel equal to from 400 up to 1300 tons of CO_2e / GWh depending on the type of fuel (natural gas, oil, coal) and applied technologies. These emissions about 20 – 50 times greater than the GHG emissions in cases of generating the electricity from nuclear, hydro or wind energy.



1. Preliminary considerations cont'd. 2.

- Replacing the piston engine by electric motor in moderate size 4 seater aircraft analogic to the Cessna 172N the mass take- off breakdown changes



1. Preliminary considerations cont’d. 3.

Airbus developed an electrical aircraft, E-Fan aircraft.

- two-seater,
- weighing half a ton,
- lithium-ion polymer batteries and 60kw dual electric motors, lightweight aircraft,
- CO_2 emission (about) free,
- nearly silent in flight,
- just £10 an hour to fly,
- only 90 minutes to charge in full.

Boeing and JetBlue have turned their sights to hybrid-electric planes.

- regional, up to 700 miles, hybrid-electric aircraft ready by the early 2020s,
- by 2030, this expected to jump to 1000 mile flights,
- working to build 10-50 seat planes,
- cut travel time and reduce costs for flights,
- allow for an 80 percent drop in emissions

2. Total impact calculations

- **TPI – total performance index**

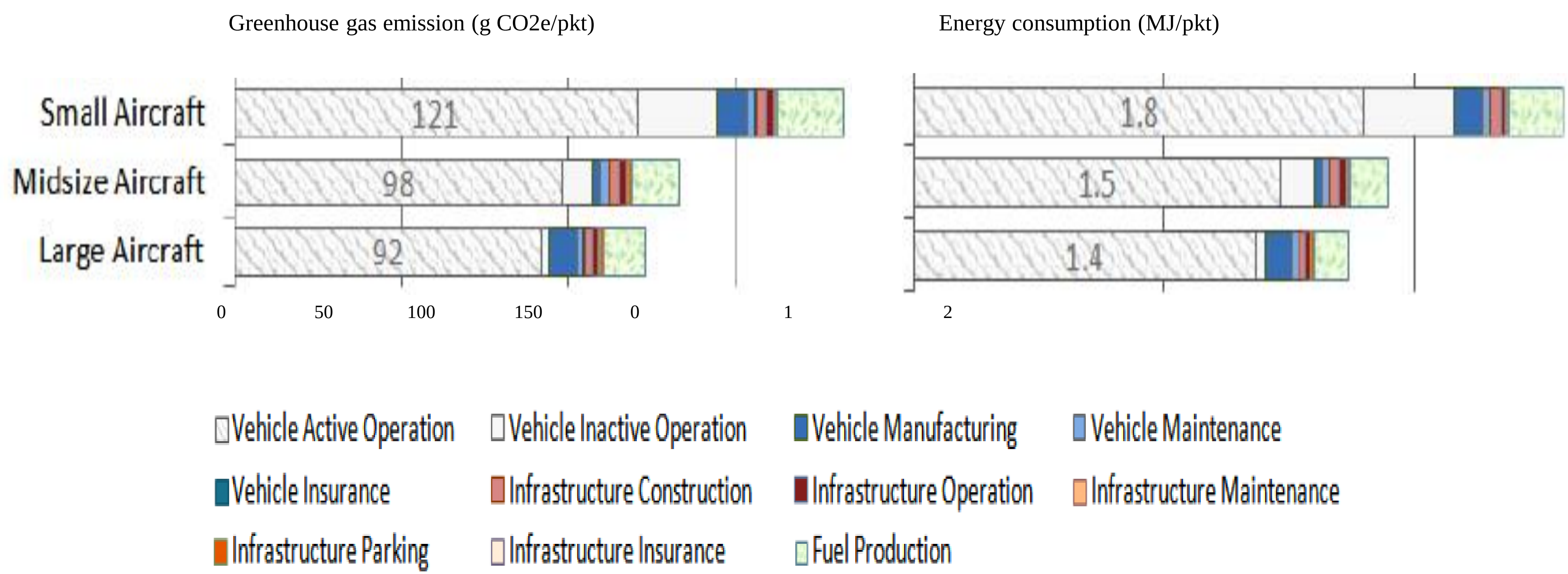
  (total life cycle cost or external costs only) related to total life cycle work done)

$$TPI = \frac{TLCC}{TLCW} = \frac{TOLCC}{TLCW} + \frac{TILCC}{TLCW}$$
$$= TOPI + TIPI \quad ,$$

- **TOPI / TIPI – total operational PI / Total Impact PI**

2. Total impact calculations cont'd. 1.

- Total energy consumption (left side, in MJ/pkt) and total CO2e emission (right side, g/pkt)) of air transport



- Total impact including all the processes
- Differences might be determined by source of energy

3. Total impact calculations cont'd. 2.

- **TIPI – composed from „i" effects**

  i = safety and security; environmental impacts; system peculiarities; system support; use of resources

$$TIPI = \sum_{i=1}^{n} TIPI_i = \frac{\sum_{i=1}^{n} TILCC_i}{TLCW} \quad ,$$

- **The TIPI can be determined separately for the different group of effects**

3. Total impact calculations cont'd. 3.

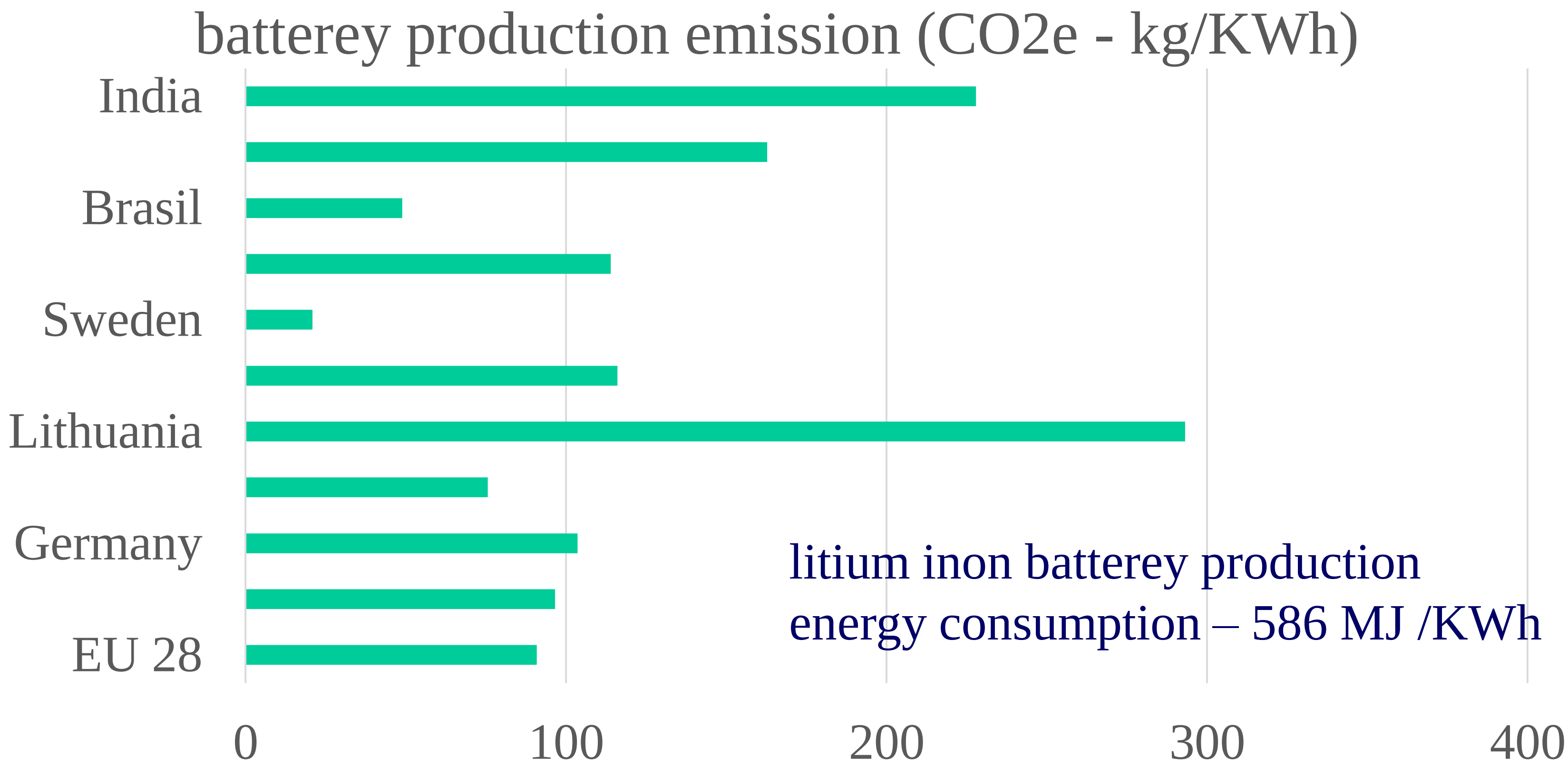
$$TIPI_i = \frac{\sum_{j=1}^{m}\sum_{k=1}^{l}\sum_{q=1}^{r} N_{j,k,q}\, p_{j,k,q}\, I_{j,k,q} \sum_{v=1}^{u} o_{j,k,q,v}\, c_{j,k,q,v}}{TLCW_i} \qquad \forall i \quad ,$$

$$TLCW_i = \sum_{j=1}^{m}\sum_{k=1}^{l}\sum_{q=1}^{r} N_{j,k,q}\, W_{j,k,q}$$

where j = 1, 2, … m depicts the subgroups of impacts, while k = 1, 2, … l defines the transport means, q = 1, 2, …, r represents the types or groups of the given transport system, v = 1, 2, …, u identifies the different forms of consequences, N is the number of sub-sub-group elements contributors to the impact, like number of vehicles defined by q, p is the parameter of the given types or group of system elements causes the investigated effects, I is the impact indicator of the given system element, o the outcomes / consequences of impact defined by I or caused by the events, situations associated with the I indicator, c is the conversation coefficient for calculating the (external) cost and W is the work done during the investigated period defined by p.

3. Results

- **There is an excel table developed for TIPI calculations**
- **The coefficients were estimated or tuned from the available references (especially EU supported studies)**



3. Results – cont'd. 1.

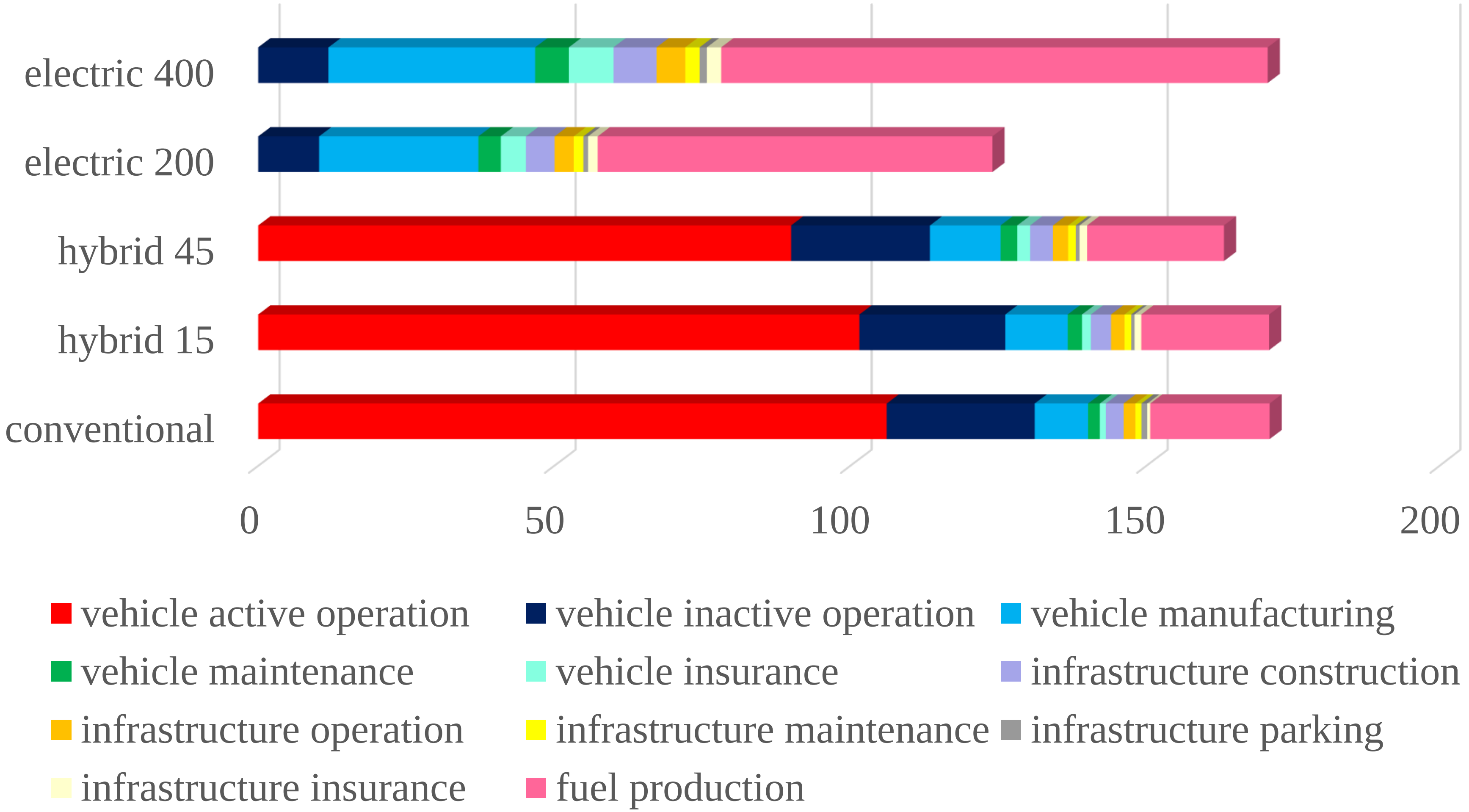
➢ Total CO_2e emission for a4 – seater aircraft – g/pkm

	conventional	hybrid 15	hybrid 45	electric 200	electric 400
airframe	320	345	380	440	510
propeller	77	77	80	87	98
engines	115	105	90	0	0
fuel	184	176	156	0	0
electric motor	0	40	42	44	50
battery banks	0	100	260	800	1600
commercial load	400	400	400	400	400
take-off mass	1096	1243	1408	1771	2658
wing loading (kg/m^2)	68,6	70	72	76	92
engine power (kW)	120	110	95	0	0
energy (kWh)	0	25	65	200	400
cruise speed (km/h)	226	226	226	200	200
range (km)	**1300**	**1300**	**1300**	**360**	**520**

Hybrid 15 - 15 minutes electric working time
Electric 200 – 200 kWh energy in battery

3. Results – cont'd. 2.

- Total CO_2e emission for a 4 – seater aircraft – g/pkm



Conclusions

- Possible emission reduction by e-mobility was investigated.
- A special general method had been developed for total impact calculations
- Impact might be evaluated as cost, or as impacts
- The conventional (piston engine) hybrid and full electric aircraft were evaluated.
- Nowadays, the battery energy density does not allows to develop a full electric aircraft
  - the aircraft empty mass increasing for 2 – 5 times, therefore
  - the performance (most important the range) decreases for 50 – 90 %
- The hybrid propulsion system allows to considerable reduce the emission in airport regions.

"The world is becoming electric, whether in the air, on land or at sea."

Plug me in to that future, and turn me on

~~~~~~ Anonymous ~~~~~~

Thank you for your kind attention

Support of presentation:
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