Transport & Energy System Integration: “alternative” fuels

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Overview

- Transportation fuels: “clean” options
- System interactions
- Trends
- Other means of transport

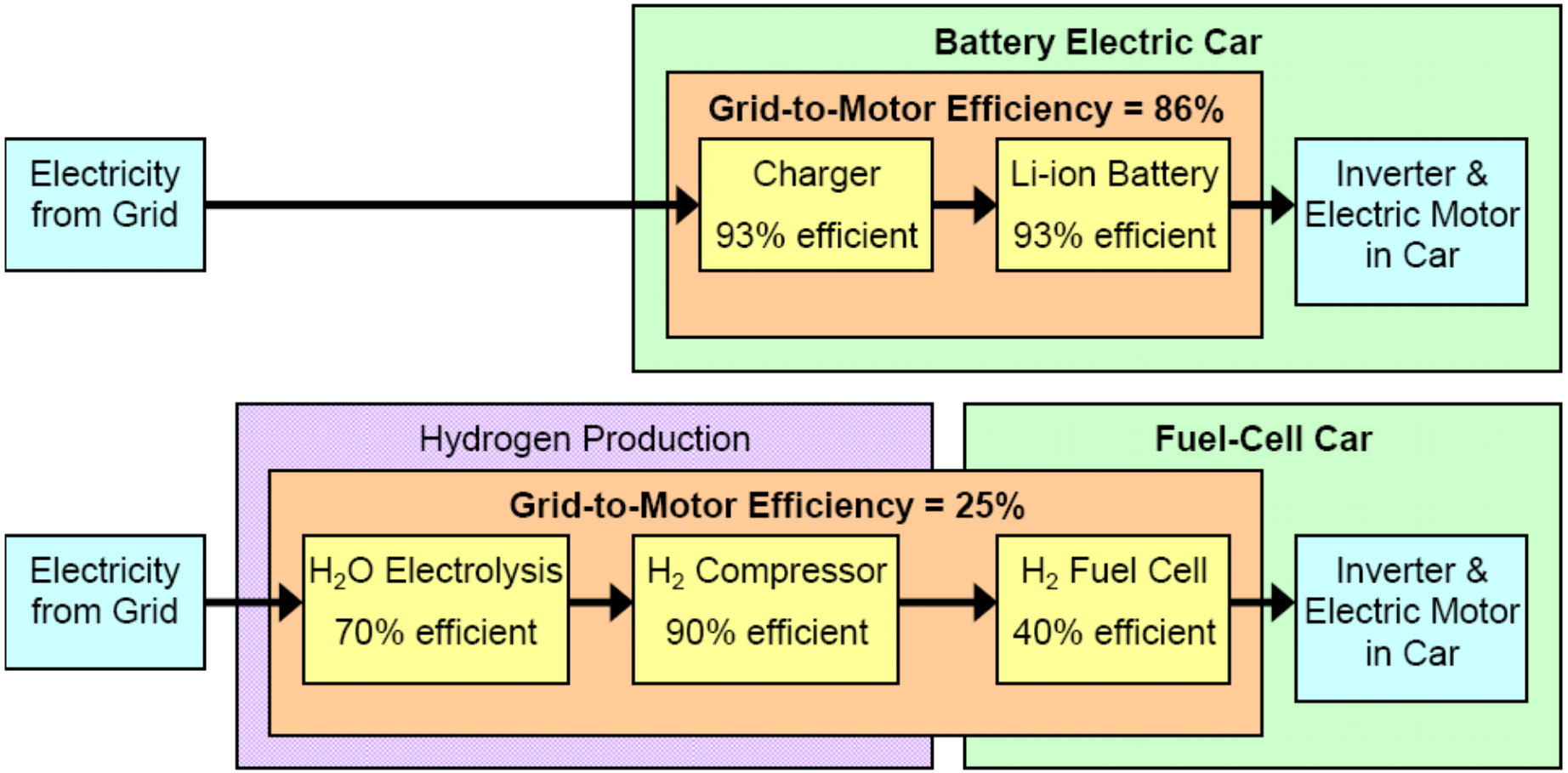
How to define “clean”?

- First concerns were environmental (e.g. contribution to smog) or health-related (e.g. lead)
- Due to climate change actions, focus shifted (entirely) to decarbonisation
  - Consequence: some fuel options hit their limits, leading to fraud
- Currently, there is renewed attention for health-related pollution, e.g. particles and NOx
- Indirect issues: noise
- Broader considerations: LCA of the vehicle option, security of supply

Hydrogen

- Concept: electric series hybrid car, with on-board generation using fuels cell
- Pro
  - Exhaust = water
  - Hydrogen can be a (cheap?) byproduct
  - High storage density
- Con
  - Bad efficiency well-to-wheel for clean production route
  - Safety
  - Hardly any infrastructure
  - Slow response of fuel cell (still need battery)

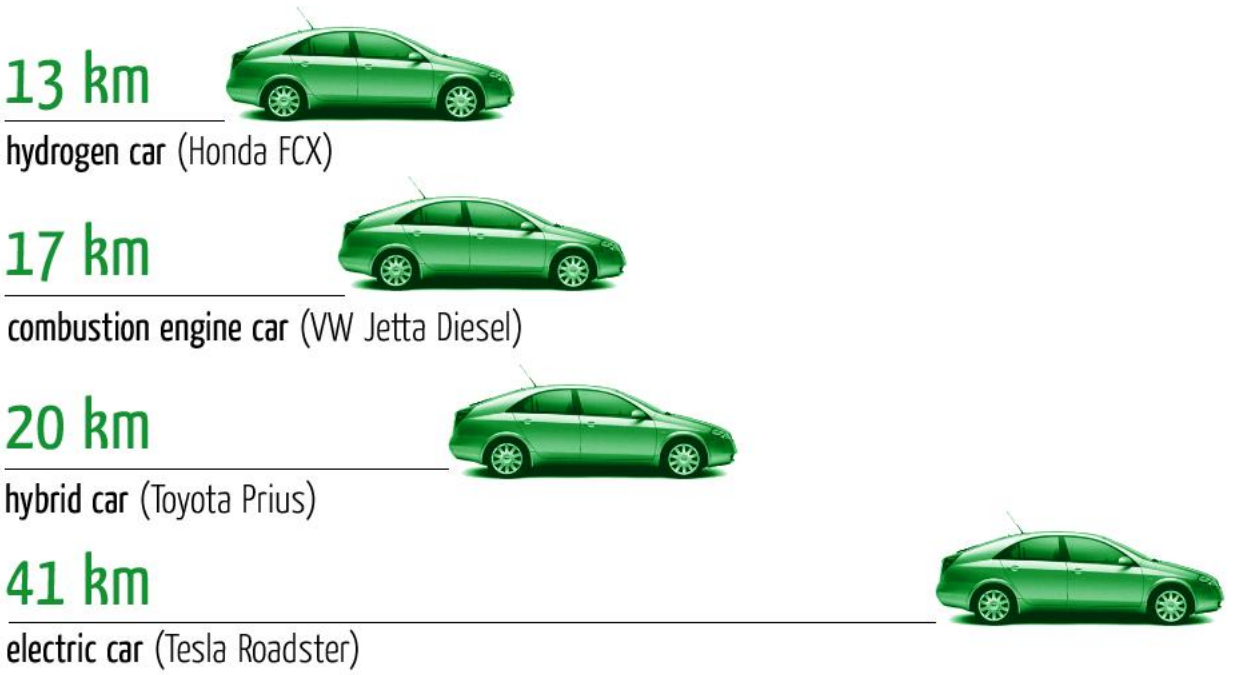
BEV vs. Fuel cell car



Well to wheel

How far can you drive with 10 kilowatthours of energy?

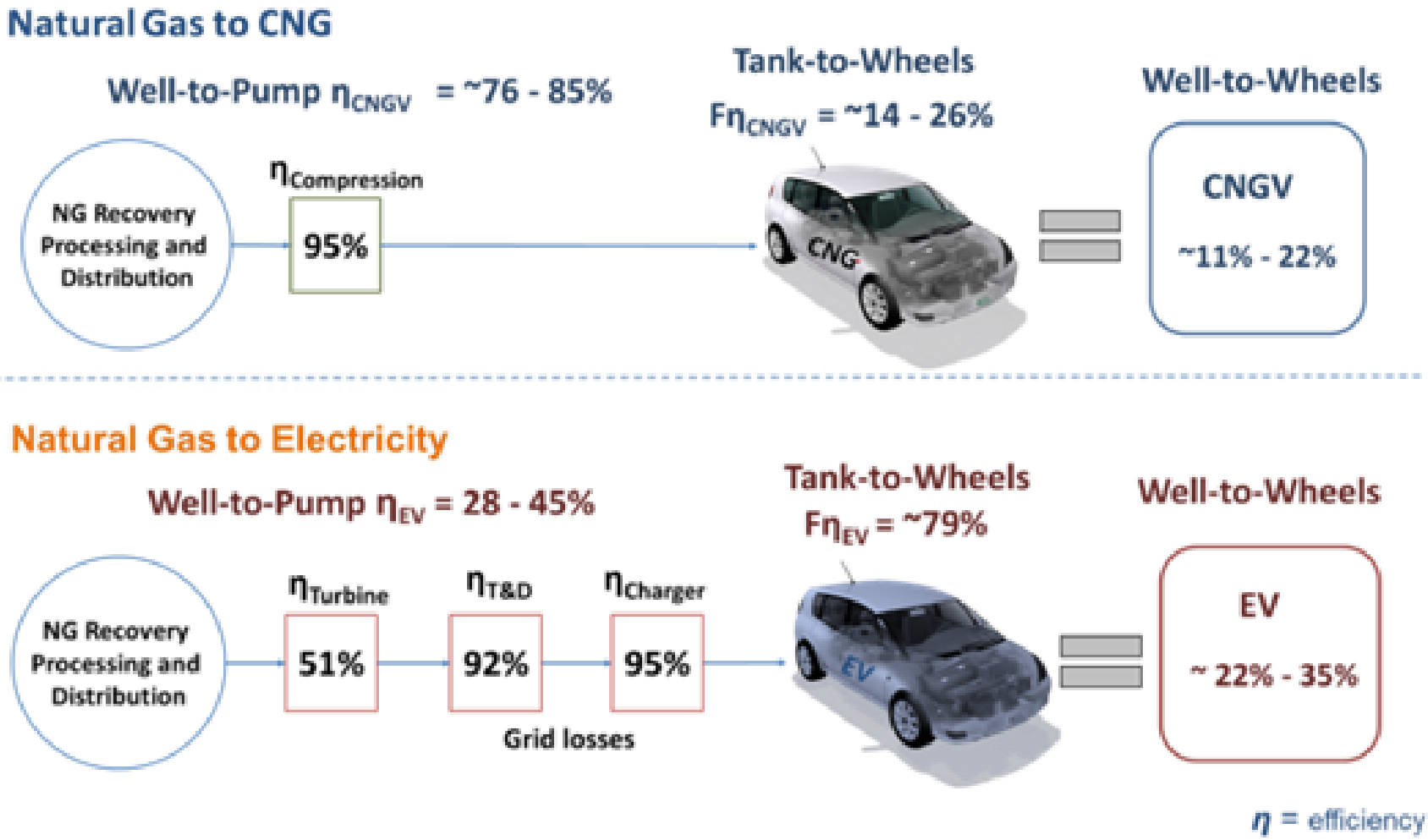
losses from energy production and delivery included (well-to-wheel)



Compressed Natural Gas (CNG)

- Concept: highly pressurized methane in reciprocating engine
- Pro
  - Clean burning: exhaust without PM, low NOx
  - Easily available
  - Interesting for heavy traffic, buses
- Con
  - Still CO2 emissions
  - Well-to-wheel performance

Natural gas for transport

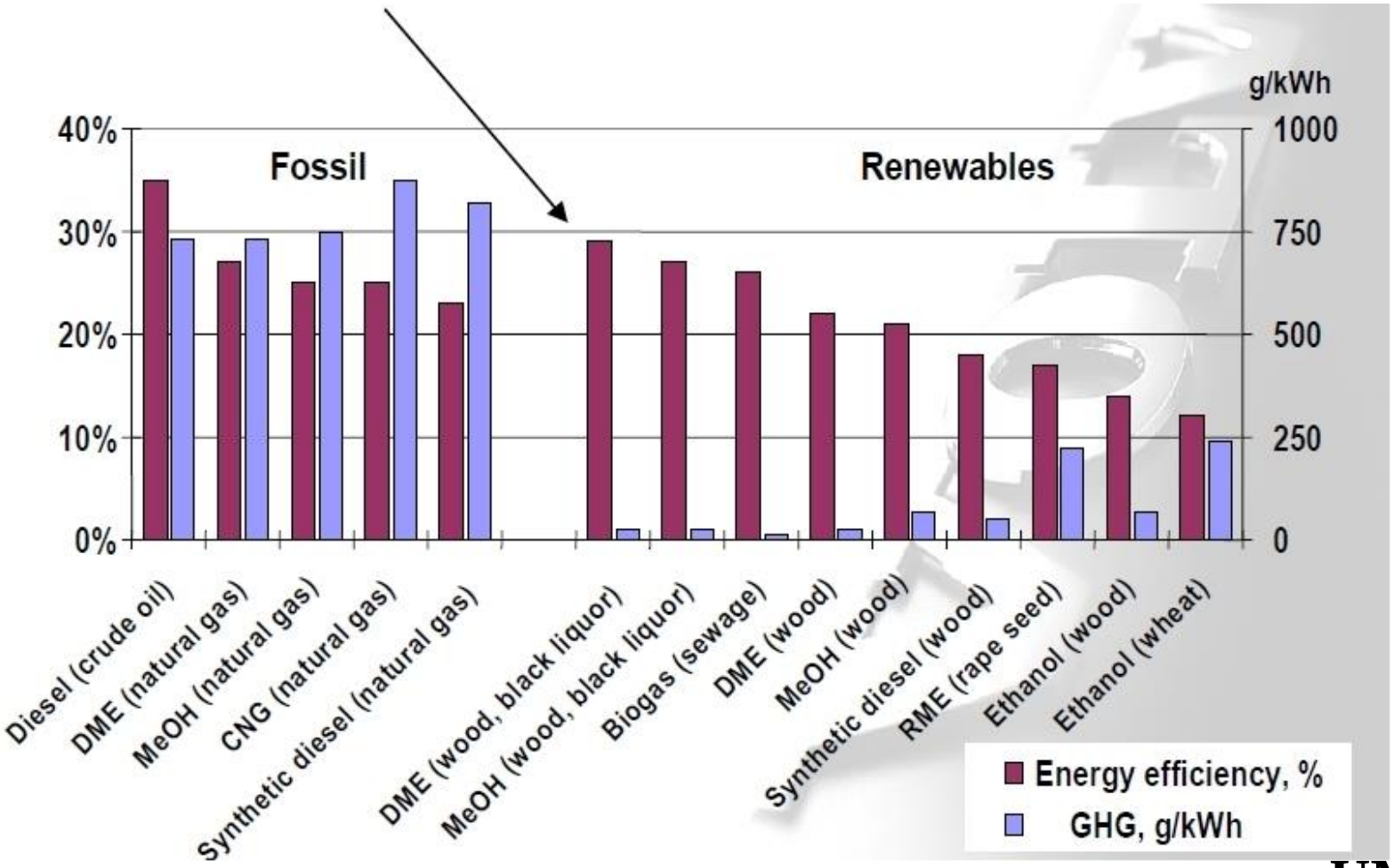


ORNL

Liquid fuels: biofuel

- Concept: replace (partially) fossil fuels with almost identical bio-based fuels (e.g bio-diesel)
- Pro
  - Limited adaptations to engine
  - Same distribution infra
  - May include waste as a resource
- Con
  - On-going debate on interaction with food chain
  - On-going debate on total chain efficiency/CO2 production
  - (e.g. fertilizers, processing)
  - Not solving local pollution

Biofuels vs. fossil fuels



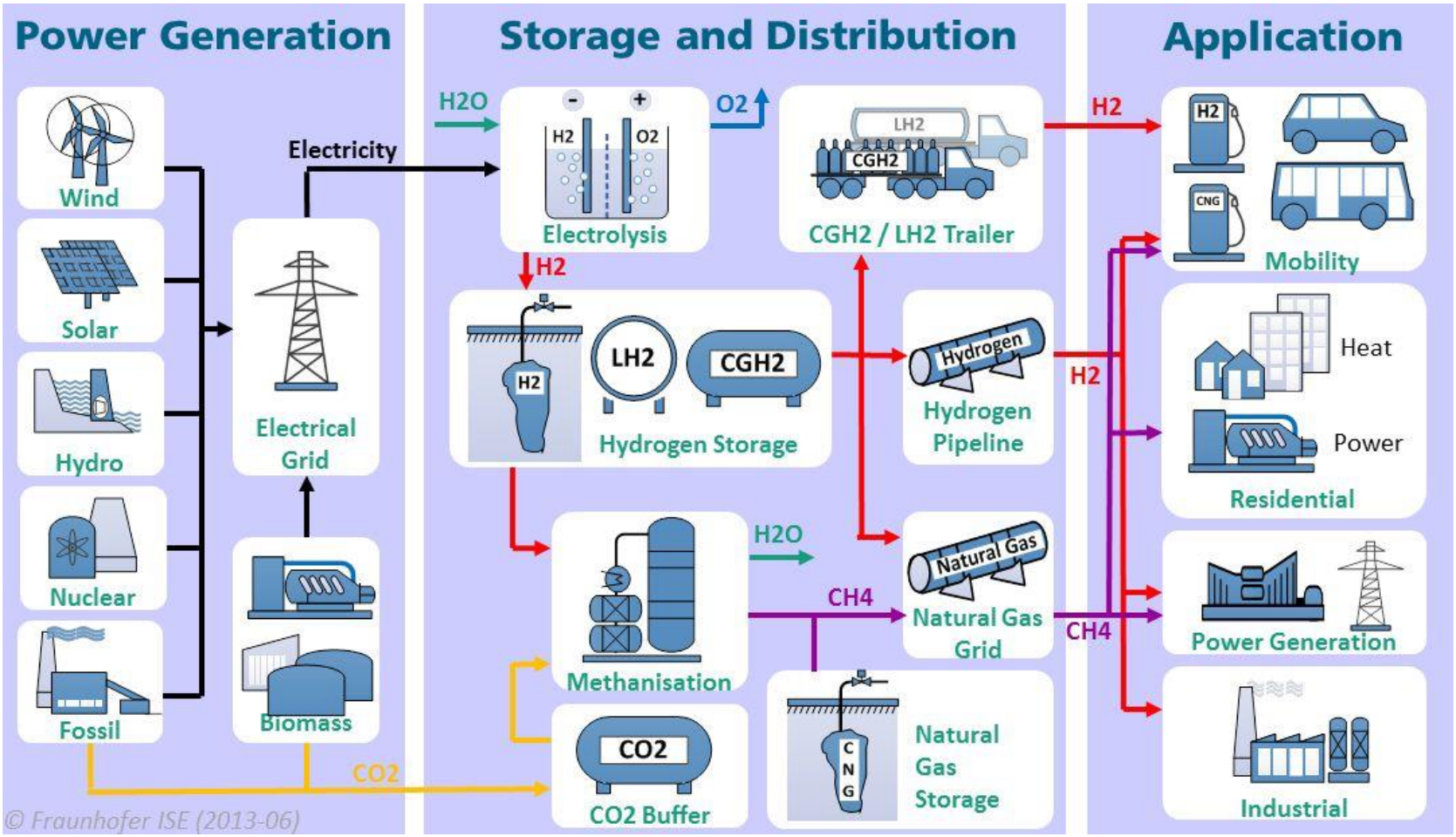
UMN

Power to gas, source for synthetic fuels

- Alternatively, use (excess) [renewable] electricity to generate (and store) Hydrogen, or process further to liquid fuel
- Complicated process with many in/out: linkage with other end-uses
- New?

Audi

P2X


Power Generation
Storage and Distribution
Application
Wind
Solar
Hydro
Nuclear
Fossil
Biomass
Electrical Grid
Electricity
H2O
O2
Electrolysis
H2
CGH2 / LH2 Trailer
LH2
CGH2
Hydrogen Storage
Hydrogen Pipeline
Methanisation
CO2
CO2 Buffer
Natural Gas Grid
Natural Gas Storage
CH4
Mobility
Heat
Power
Residential
Power Generation
Industrial
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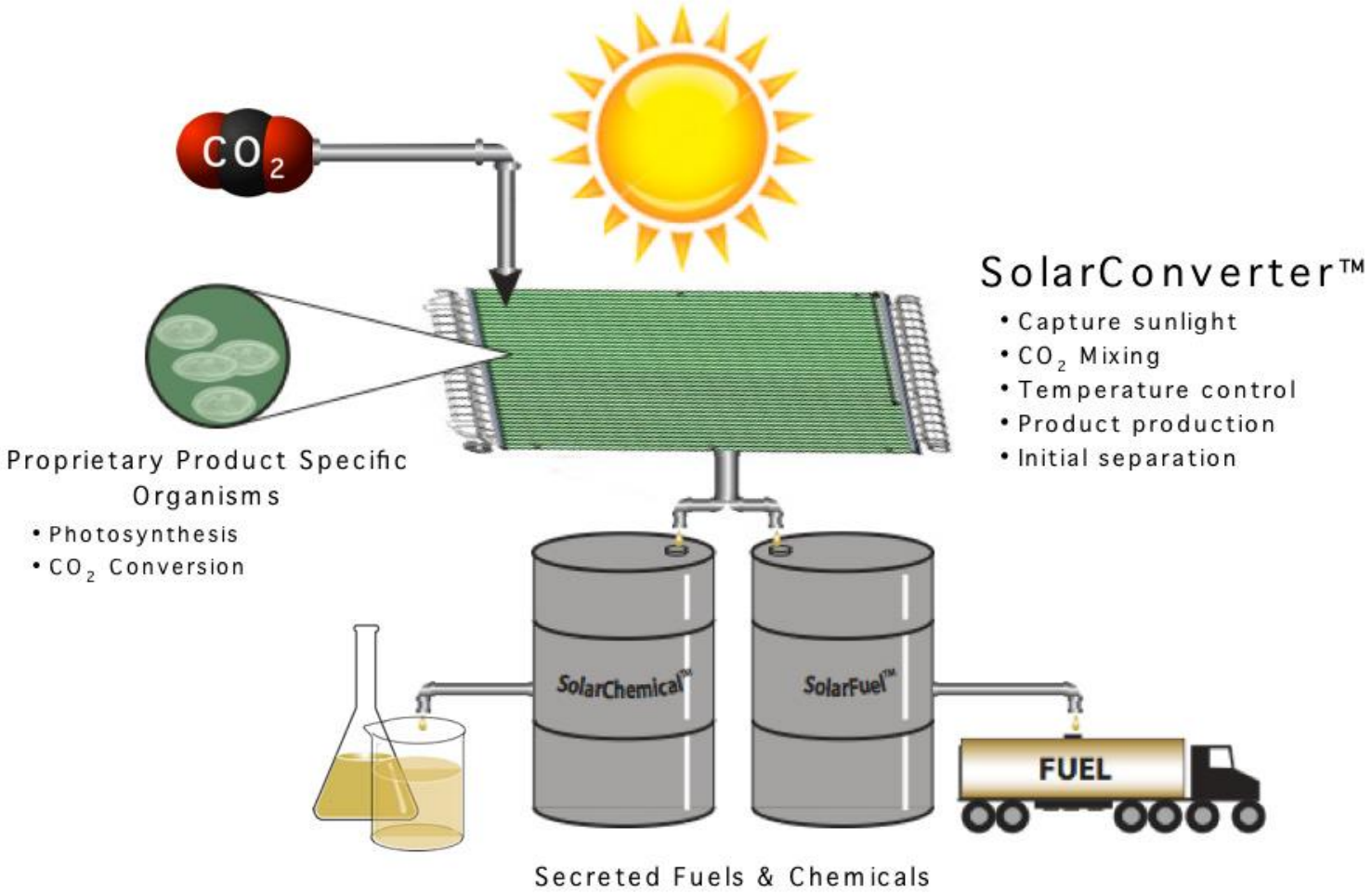
Liquid fuels: solar fuels

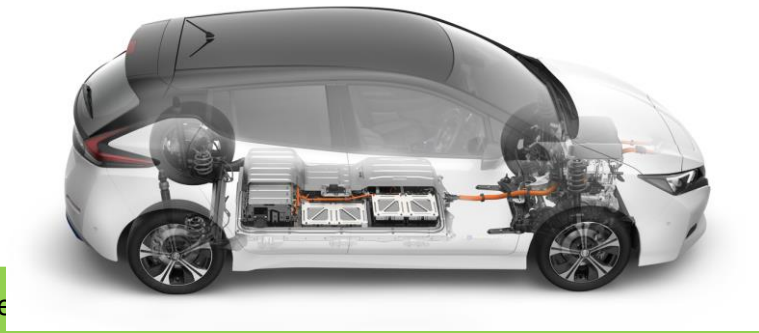
- Concept: solar energy driven direct chemical production of fuel (no PV involved)
- Pro
  - reuse infra fro hydrogen, gas
- Con
  - Low TRL,
  - Reliability, stability of process
  - Unclear well-to-wheel performance: able to compete against solar-electric option?

Solar fuel


CO_2
SolarConverter™
• Capture sunlight
• CO_2 Mixing
• Temperature control
• Product production
• Initial separation
Proprietary Product Specific Organisms
• Photosynthesis
• CO_2 Conversion
SolarChemical™
SolarFuel™
FUEL
Secreted Fuels & Chemicals

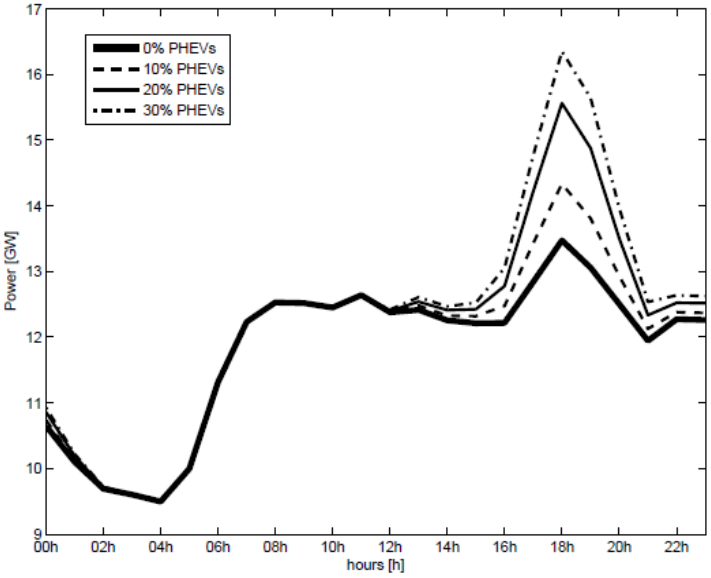
Electricity (in batteries)

- Pro
  - Performance
  - Well-to-wheel
  - Pollution control
  - Mass production in sight
  - Reliable, safe
  - No noise
- Con
  - Where to charge?
  - Weight(?)
  - Range Anxiety(?)
  - LCA (of batteries)?



Grid impact

- EVs will impact the power system, mainly at distribution level
- Uncoordinated charging will increase peak power demand
- Potential for coordinated charging
  - Shifting charging to off-peak moments
  - Flexibility within the mobility objective
- Challenges first on the local level
  - High local penetration grade
  - Highly stochastic behavior
  - Grid constraints on the LV grid
  - Goes side by side with problems caused by PV integration

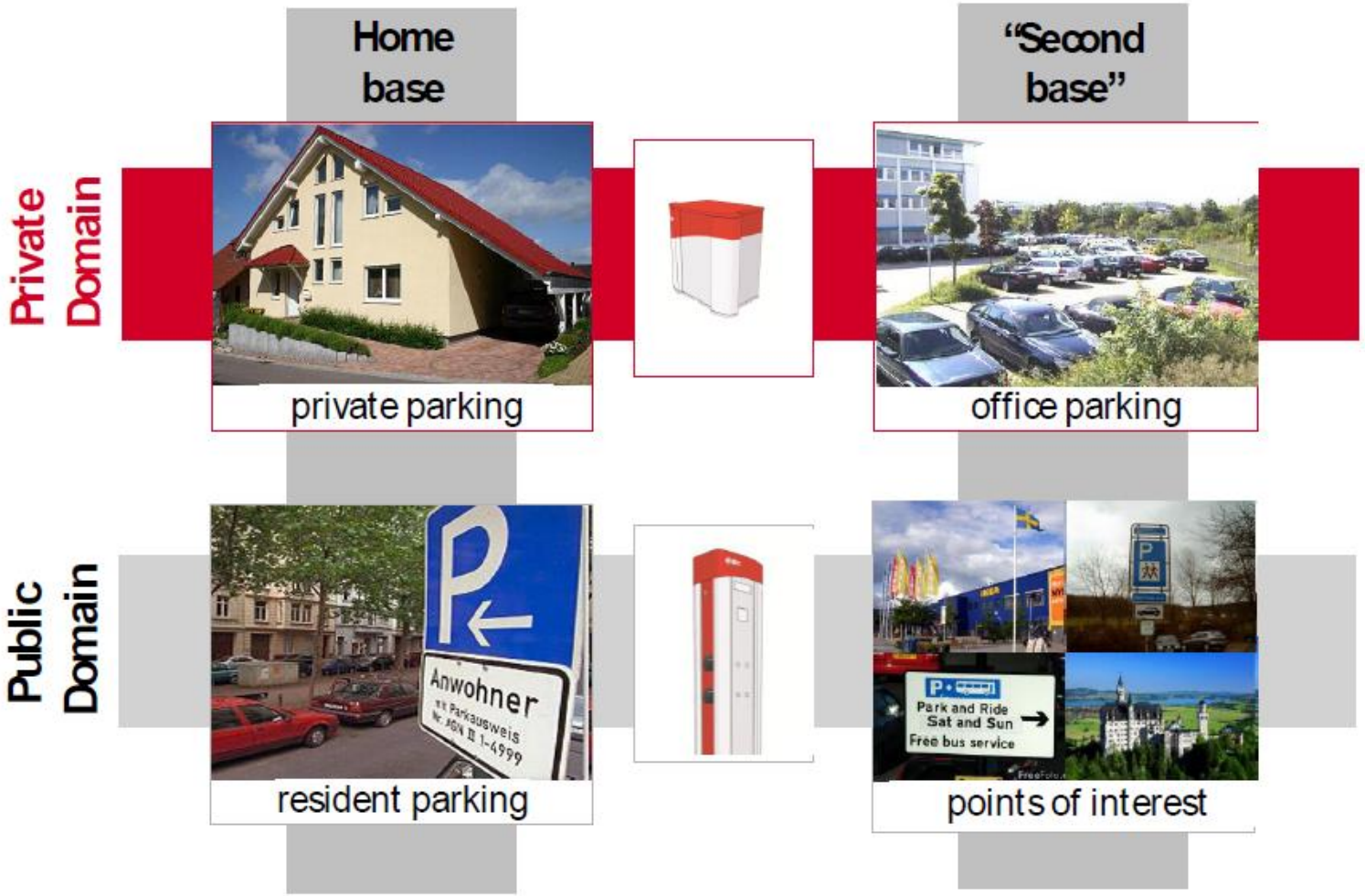


K. Clement, "Impact of Plug-in Hybrid Electric Vehicles on the Electricity system", PhD Thesis, K.U.Leuven, 2010

Electricity system interaction

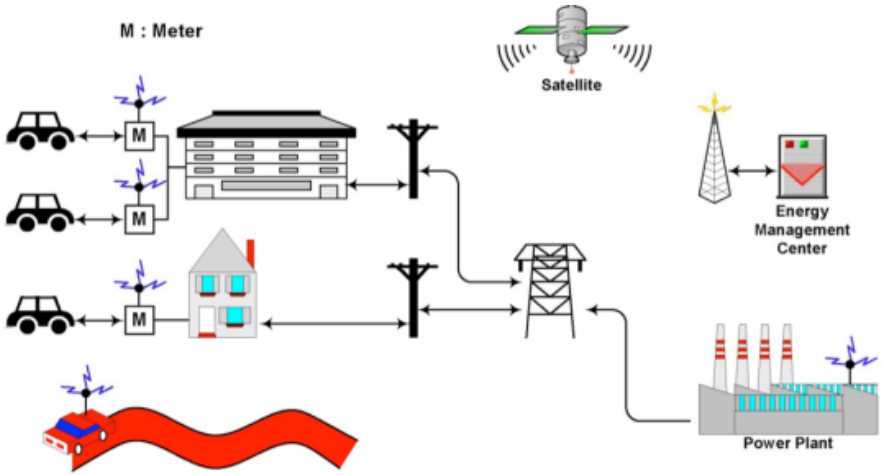
- Different fuel routes have different dynamical interaction with the electricity system
  - Battery vehicles
    - directly connected, high local impact on distribution system
    - Should be turned flexible loads, may complement PV/battery
    - High power for public transport, heavy duty
    - May offer ancillary services (reserves)
    - Vehicle-to-grid, e.g. for emergency power
  - P2X
    - Controllable: buffer on fuel side
    - Large “industrial” load
  - Market coupling: e.g. gas-electricity

Different charging types per “opportunity”



Vehicle-to-Grid (V2G)

- Vehicle-to-Grid intelligent charging
  - Adaptation of charging power
  - Injecting power into the grid
- Bidirectional power flows
- Limited storage in the grid
  - E.g. pumped storage
  - High flexibility required
  - Increasing amount of intermittend sources
  - Emergeny supply
- Potential flexibility of vehicle charging
  - Long standstill times
  - Average short daily driven distance



Human factor

- People do not want to give in on comfort (ease of charging)
- Rebound effects?
- In the end, it's the money that counts
  - Incentives needed
  - Know when to turn them back (e.g. Norway case)

Changing car ownership concept

- There is no one-solution-fits-all car for city commutes, family holidays, …
- Owning a car means having a parking spot: affordable?
- Trend towards MaaS: Mobility as a Service
  - Multimodal, shared
  - Drawing rights on alternative types (e.g. long-range car for holidays)
- Consequence: better utilization = less charging time

Self-driving car?

- Low-level self-driving (e.g. adaptive cruise control) helps improving safety, but also energy efficiency (better anticipation)
- Possible future
  - Cars go to charging stations on their own?
    - chargers at interesting spots for the grid
    - need automated charging: inductive, automated plug
  - "Batteries on demand": V2G where needed? Drivers competing against the utilities for batteries?

Other forms of transport

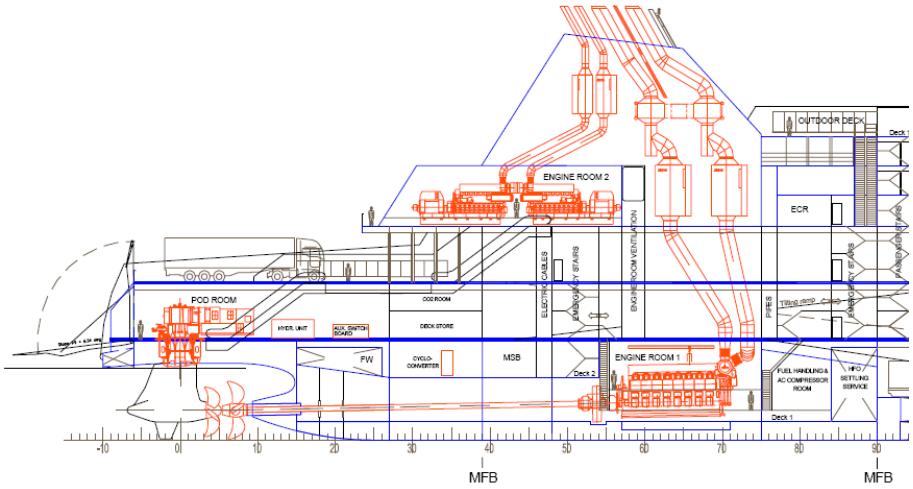
- What about?
  - Ships
  - Flying
  - Rockets
  - …

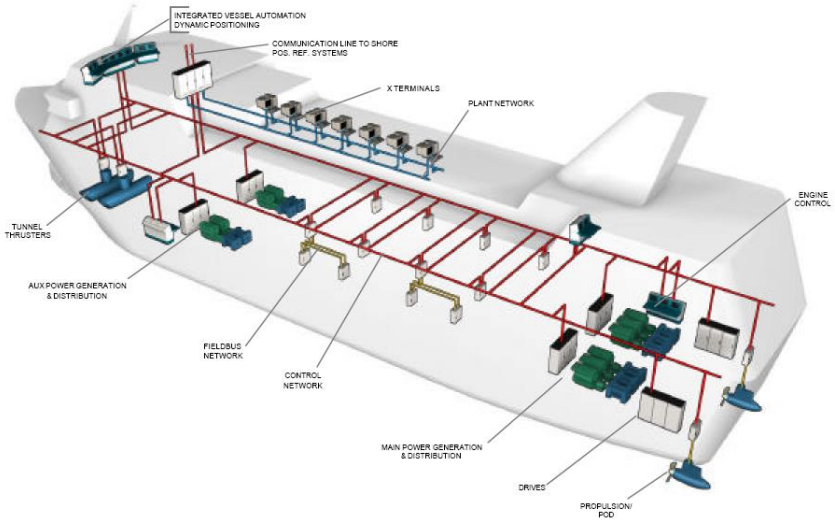
- Note: trains, trams, subway are already (mostly) electric

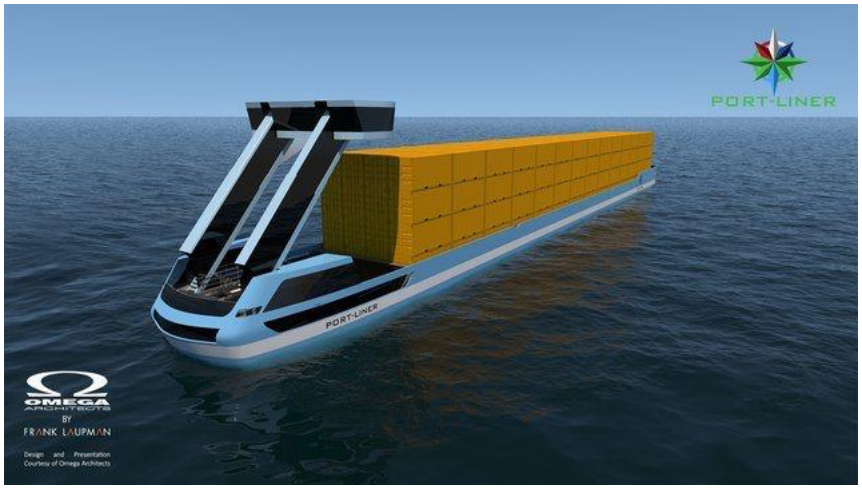
Ships

- Modern ships are hybrid
  - Electric drives for propulsion
  - full electric harbor movements
  - Go for “clean fuel”
- Full electric: ferries
- Coming: electric drone ships

Electric ships



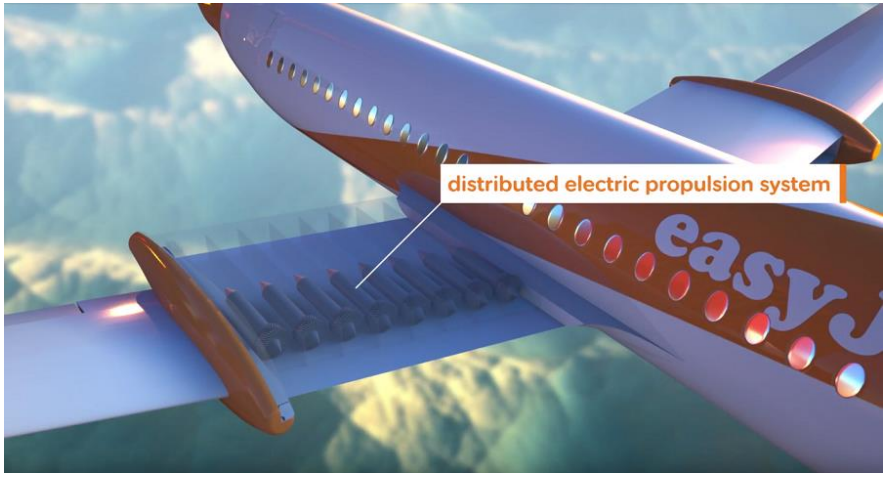




Electric flying

- Hybridisation in Dreamliner, Airbus 350, … to save weight (and fuel: save “bleed air”)
- Electric taxiing tested
- Full-electric flying possible for short range (soon)
- Drones!
- Long range & rockets: “clean” fuel?

Electric flying



Thank you!