Modelling transition towards sustainable transportation sector

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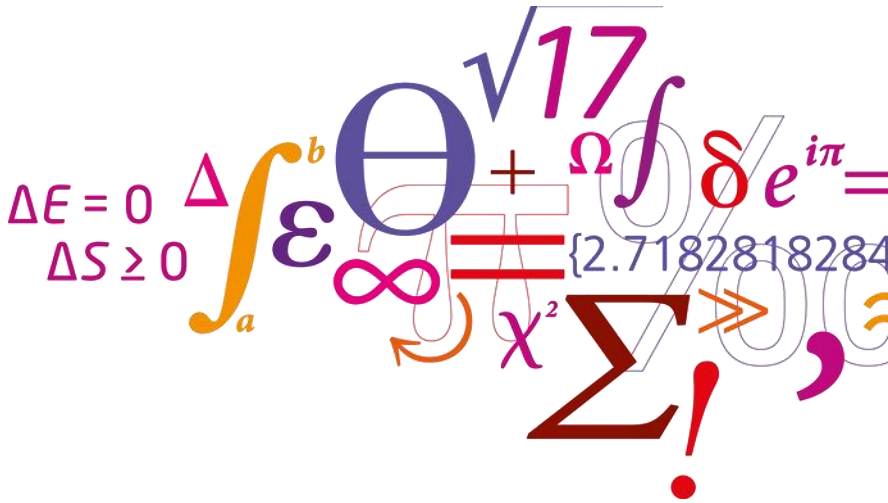

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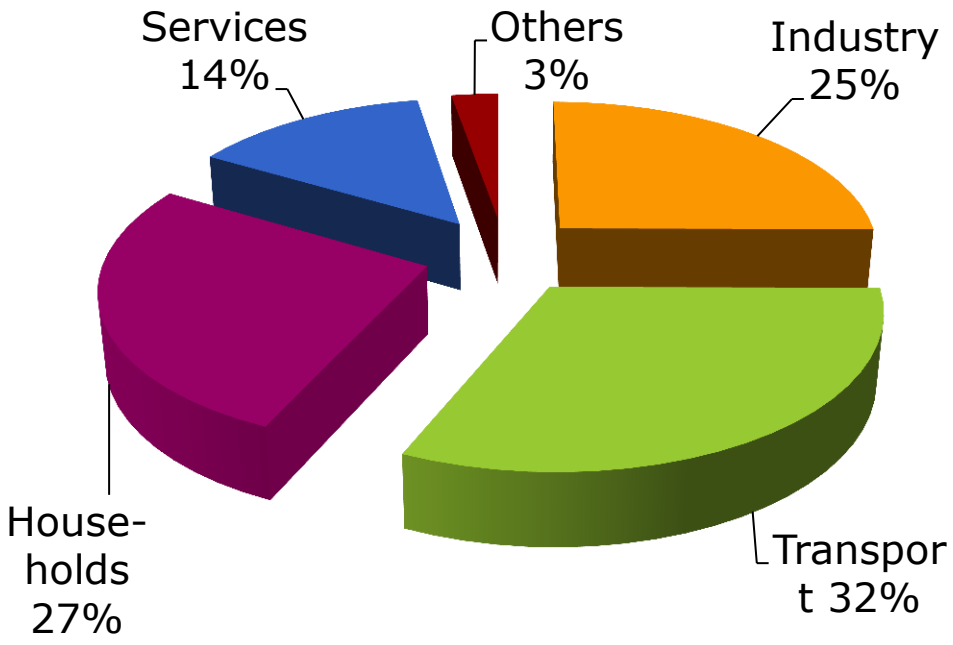
Department of Energy Conversion and Storage

Outline

- Background: energy consumption in the EU per sectors
- Methods
  - Scenario development
- Results
  - Qualitative assessment of the alternatives
  - Infrastructure and economic barriers for the alternatives
- Discussion of results
- Conclusions

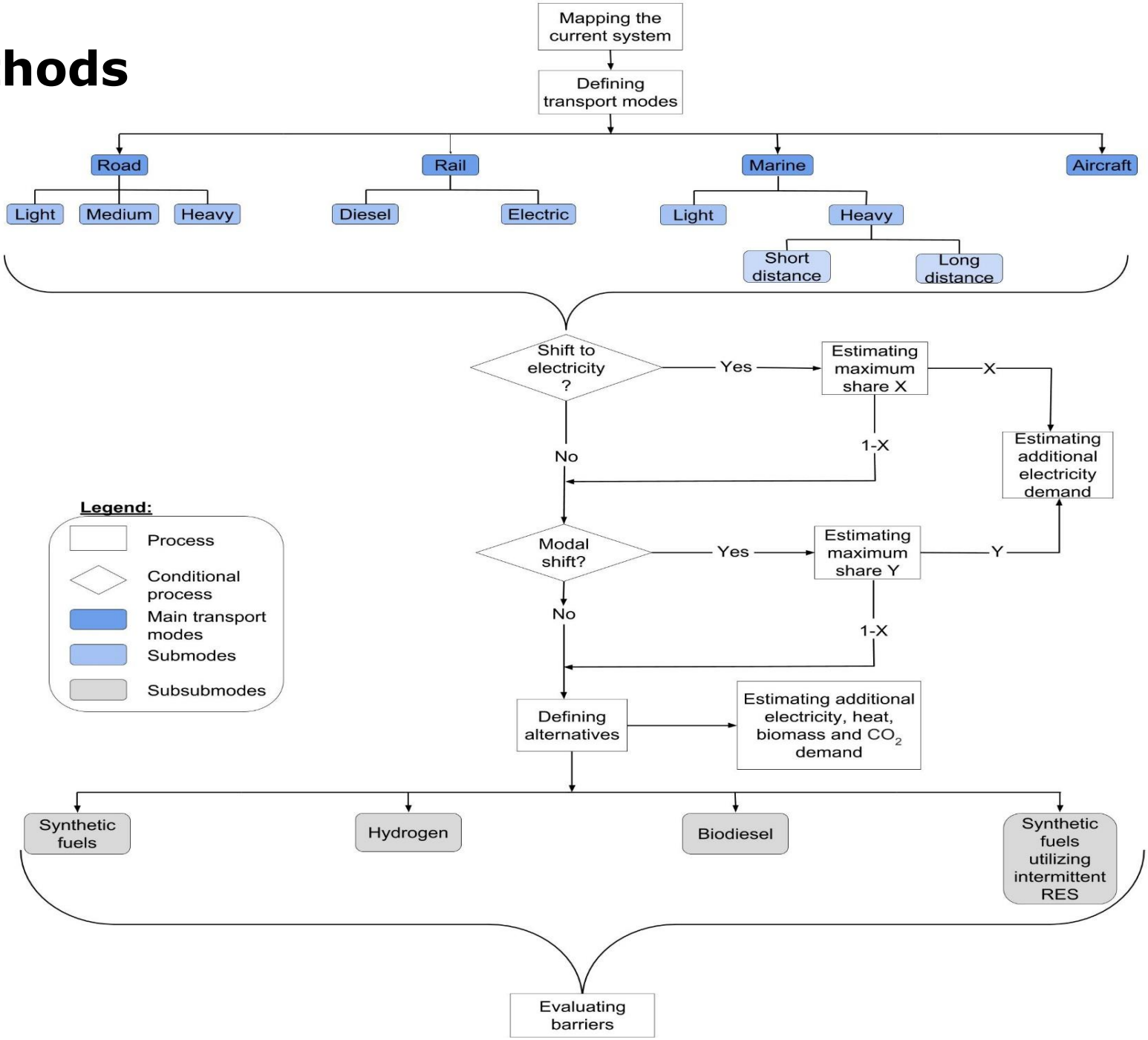
Final energy consumption per sectors

- The European Union
- 2013



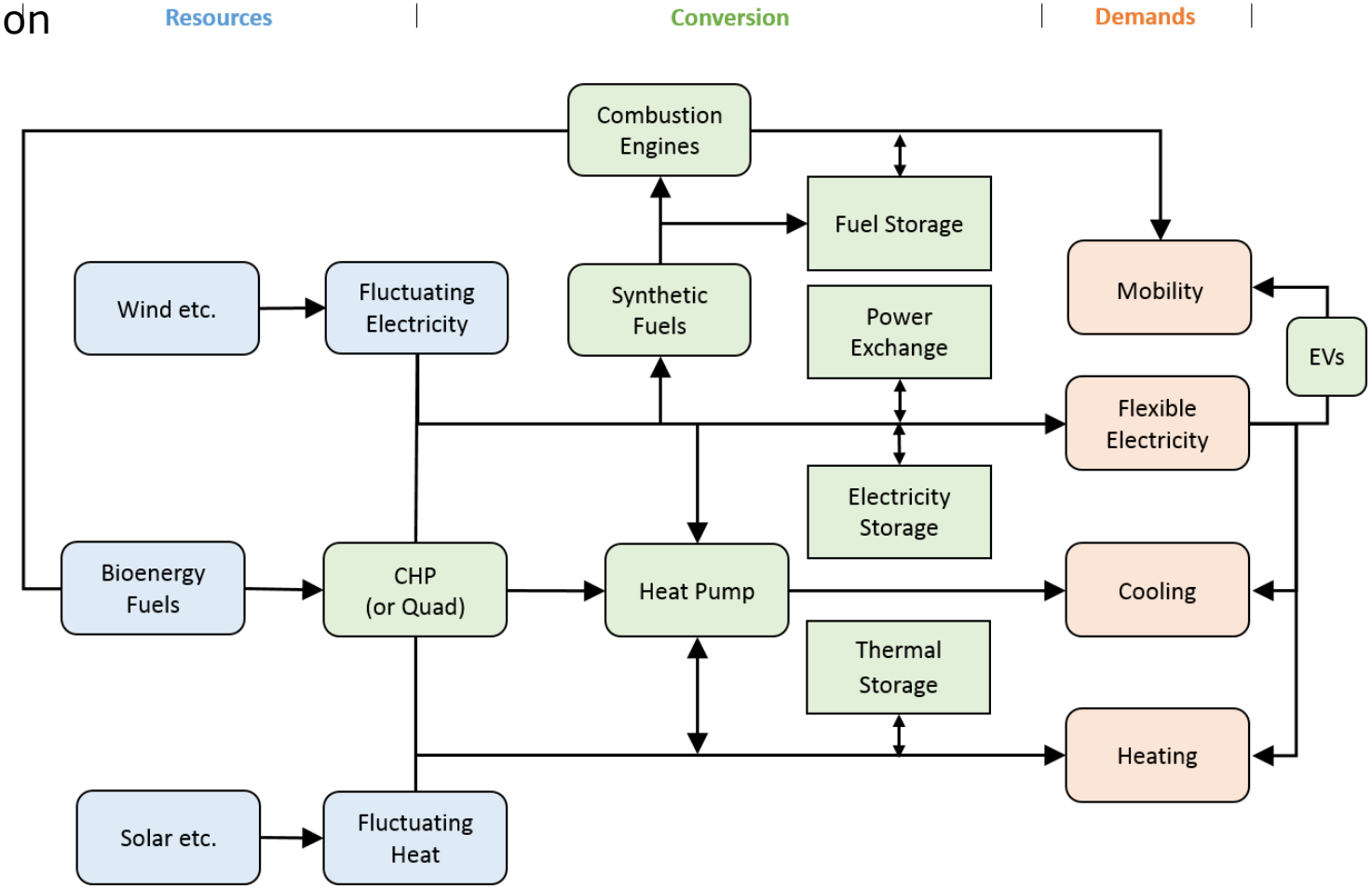
Source:European Environment Agency

Methods


Mapping the current system
Defining transport modes
Road
Light
Medium
Heavy
Rail
Diesel
Electric
Marine
Light
Heavy
Short distance
Long distance
Aircraft
Shift to electricity ?
Yes
Estimating maximum share X
X
1-X
No
Estimating additional electricity demand
Modal shift?
Yes
Estimating maximum share Y
Y
No
1-X
Defining alternatives
Estimating additional electricity, heat, biomass and CO_2 demand
Synthetic fuels
Hydrogen
Biodiesel
Synthetic fuels utilizing intermittent RES
Evaluating barriers
Legend:
Process
Conditional process
Main transport modes
Submodes
Subsubmodes

Methods (II) - EnergyPLAN

- Used for modelling of more than ten 100% RES (EU, national and regional)
- Deterministic simulation model
- Input/output model
- Hourly resolution



Three scenarios

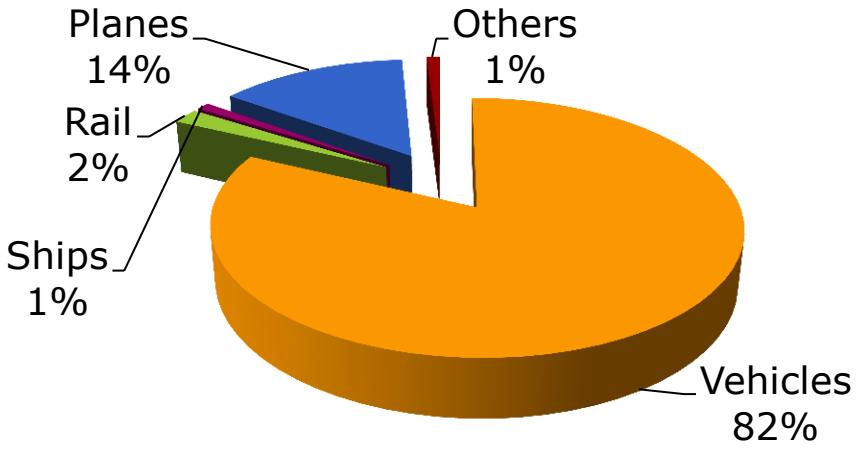
Scenario I	Replacement by biofuels
Scenario II	Replacement by synthetic diesel, methanol and biokerosene
Scenario III	Replacement by synthetic fuels only

Process	Efficiency
2nd gen. bioethanol fermentation	41%
2nd gen. biodiesel BTL	39%
2nd gen. biokerosene BTL	39%
Syngas synthesis methanol	67.3%
FT biodiesel&kerosene	51%
SOEC co-electrolysis	65%
SOEC assumed energy input distribution	
Heat	25%
Electricity	75%
CO_2 demand for SOEC	[t/GJ output]
CO_2	0.105

Fuel	LHV [GJ/ton]
Methanol	19.9
Kerosene	44
Bio-diesel	37.8
Bio-ethanol	29.7
Gasoline	44.4
Diesel	43.4
Biokerosene	44

Results – mapping the current energy needs

- Energy end-use of different transportation modes in the EU:



Transport mode	Transport sub-mode	Share
Road	Light	59%
	Medium	23%
	Heavy	18%
Rail	Electric	80%
	Diesel	20%
Marine	No sub mode	
Aircraft	No sub mode	

Results – possibilities of direct electrification of transport sector

Measures:
Shift of 87% of passenger cars fuel demand to electricity
Shift of 70% of medium-heavy vehicles fuel demand to electricity
Shift of 90% of heavy vehicles fuel demand to electricity (modal shift to electric rail transport)
Shift of all the remaining diesel railway transportation to electricity
Shift of 20% of light ships and 10% of heavy ships fuel demand to electricity
Modal shift 12.2% of aircraft sector demand to electric rail transport

Results of scenarios – resources needed

	Scenario I	Scenario II	Scenario III
Biomass demand [TWh]	3069.00	1279	0
Electricity demand [TWh]	0.00	1646	2775
Heat demand [TWh]	0.00	549	925
CO_2 demand [Mton]	0.00	539	909

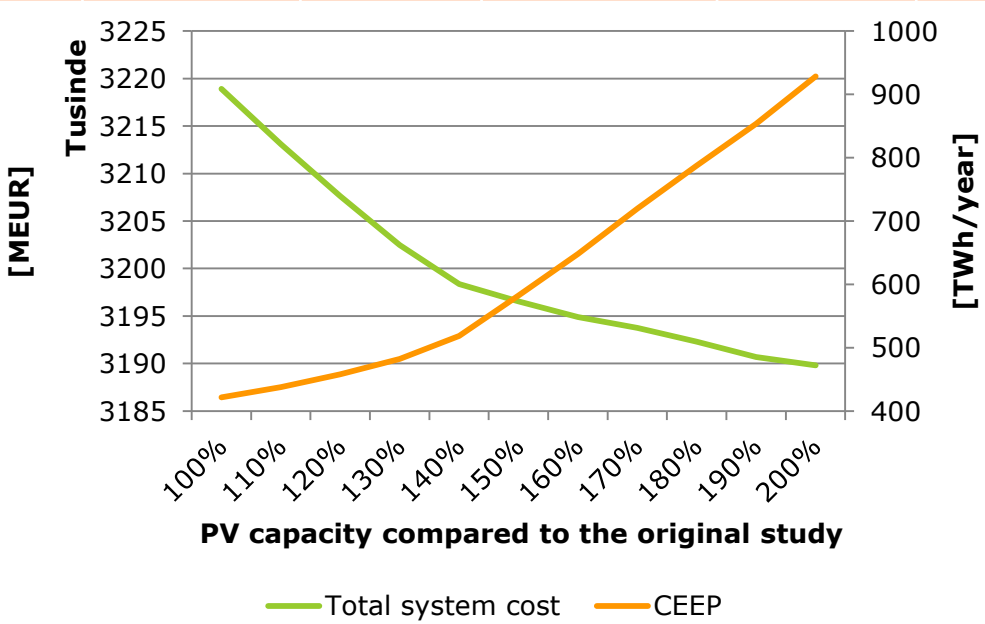
Alternatives

- Synthetic fuels
  - Methane, methanol, FT diesel
  - Still in the R&D phase
- Hydrogen
  - Large market today and growing rapidly
  - Base load production
- Biodiesel
  - 1st generation produced from sugars and vegetable oils
  - 2nd generation produced from various types of biomass
- PV for synthetic fuels
  - Still in R&D phase
  - Highly dependent on electricity price

Barriers detected

	Economic barriers				Infrastructure barriers			
	High new infrastructure costs	High production costs	Low production efficiency	Influencing food price	Need new fuelling infrastructure	Need new supply chain	High land demand/ Sustainability problem	Intermittency friendly
Hydrogen	Yes	Yes	Yes/No**	No	Yes	Yes	No	Yes*
Biodiesel	No	No	No	Yes	No	No	Yes	No
Synthetic fuels	No	Yes	Yes	No	No	No	No	Yes*
PV for synthetic fuels	No	No	Yes	No	No	No	No	Yes

PV for synthetic fuels



Discussion – How really big additional demand for resources is?

- Direct electrification of transport sector – threefold benefits (efficiency, flexibility, CO2 emissions reduction)
- 1,125 TWh of fossil fuel demand cannot be directly electrified today
  - Replacing it with biofuels – additional demand for biomass of 3,069 TWh
  - Replacing partly by biofuels and party by synthetic fuels – additional demand for biomass of 1,279 TWh
  - Current mean EU biomass potential extracted from 70 studies: 1,600 TWh, in 2050: 2,360 TWh
- Synthetic fuels – additional demand for heat and electricity of 925 TWh and 2,775 TWh
  - Electricity demand in the entire EU in 2013: 3,100 TWh
- Demand for electricity for directly electrified part of transport sector: 880 TWh

- Low well to wheel efficiencies for all the alternatives (25% for hydrogen, around 12% for synthetic fuels)

Conclusions

- ✓ All the transport means should be converted to electrified transportation modes if there is a technical possibility for it. Benefits of this transition are threefold: reduced CO_2 emissions, increased energy efficiency and integration of different energy sectors.
- ✓ It is technically possible today to shift 72.3% of the fossil fuel demand in the transportation sector to the electricity. Following this transition, increased efficiency of the electrically driven transportation means could potentially reduce the final energy demand in transportation sector for 50.6% or 2051 TWh.
- ✓ For the remaining part of the fossil fuels several alternatives exist. Due to the lower estimated well to wheel efficiency of the alternatives, a significant additional demand for resources occurs.
- ✓ If the excess capacity for synthetic fuels production would exist in the system, excess electricity for which there is no demand could be utilized at the near-zero price. With the expected technology price drop until the year 2050, the price of producing DME, a potential substitute for diesel fuel, was estimated to be 38 €/GJ of fuel, which would be cost-competitive with the current end user fuel prices.
- ✓ Significant costs of building completely new infrastructure, as well as lower efficiency compared to the electric vehicles, could be too large burden for the wide scale development of the hydrogen driven transportation system.
- ✓ Potential of alternatives such as drones used for delivery, car sharing and similar concepts, increased usage of bicycles and public transportation, induction charging and others should all be seriously taken into consideration and planning of the future transportation sector if additional energy savings are to be achieved.

Thank you for your attention!