Road Transport and Power System Scenarios for Northern Europe in 2030

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Road Transport and Power System Scenarios for Northern Europe in 2030

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Purpose

- Adding transport to a power system model (Balmorel) enables analysis of:
- consequences of possibility of using electric power in transport sector
- consequences of adding vehicle-to-grid technologies
- competition between different vehicle technologies

Balmorel (www.balmorel.com)

- Investment model: calculates optimal future configurations of power systems
- Power plants, CHP plants, boilers, heat pumps, electricity and heat storages, transmission lines
- Lately:
 - hydrogen storage, production (electrolysis, steam reforming), consumption

Sketch of the Balmorel model including transport

Power flow

- Power flow model of electric drive vehicles

.....Applicable for PHEVs propulsion systems

- - - Replaced with output from fuel cell for FCEVs

a) vehicles plugged in

b) vehicles not plugged in

Model formulation

- Objective function: investments in vehicles
- Vehicle restrictions: balancing of on board storage (plugged in)
balancing of the power bus (plugged in)
transport supply and demand must meet
minimum and maximum capacities
- Electricity balance equation: power to grid - power from grid

Assumptions

- Communication system in place
- Vehicles are aggregated in vehicle groups
- Average driving patterns (forcing specific patterns for use of diesel)
- All vehicles leave grid with full storage
- Energy consumption of accessory loads and propulsion power proportional to vehicle kilometre driven
- PHEVs and FCEVs are assumed to use the electric motor until storage is depleted

Case description

- Denmark, Finland, Germany, Norway and Sweden with transmission possibilities among these countries
- 7 selected weeks with hourly resolution (7 X 168 time steps)
- Year 2030
- Oil prices \$120/barrel (base), \$90 (low), \$130 (high)
- Constant fossil fuel price elasticities to oil
- CO₂ prices 40€/ton (base), 10€/ton (low), 50€/ton (high)
- Including ICE, BEV, PHEV for persons transport

Case description

Vehicle technology investment options

Type of vehicle	Annualised inv costs (€)	O & M costs (€/year)	Electric storage cap. (kWh)
ICE	1,065	1,168	0.8
BEV	1,513	1,101	50
PHEV	1,484	1,168	10
FCEV	1,893	1,101	10

Medium and high wind targets (MW)

Wind target	Denmark	Sweden	Norway	Finland	Germany
Medium	7,291	10,000	5,980	3,200	54,244
High	8,020	17,000	11,970	6,000	63,587

Case description

- Investment options in power system:
 - Onshore wind
 - Offshore wind
 - CHP plant biomass
 - Open cycle gas turbine
 - Heat storage
 - Solid oxide electrolysis
 - Heat pump
 - Electric boiler
 - Combined cycle natural gas
 - Hydrogen storage, cavern

Results

- Vehicles investments:
 - ICEs in low oil scenarios
 - PHEVs in all other scenarios

Charging of EVs distributed on hours during the day

Denmark: Yearly electricity production on fuel type

Germany: Yearly electricity production on fuel type

Conclusions

- PHEVs are very competitive across many scenarios compared to ICEs and BEVs
- Co-optimisation of vehicle and power system investments yields interesting results
- More work needed on requirement to leave the grid with full batteries
- Sustainability of EVs depend on development in surrounding power system:
 - EVs drive on wind power in DK and on coal and lignite in D
 - BUT: CO2 emission market might handle that issue