Transport and Power System Scenarios for Northern Europe in 2030

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Transport and power system scenarios for Denmark in 2030

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Overview

- Purpose
- Balmorel and Transport – the model
- Cases
- Results

Purpose

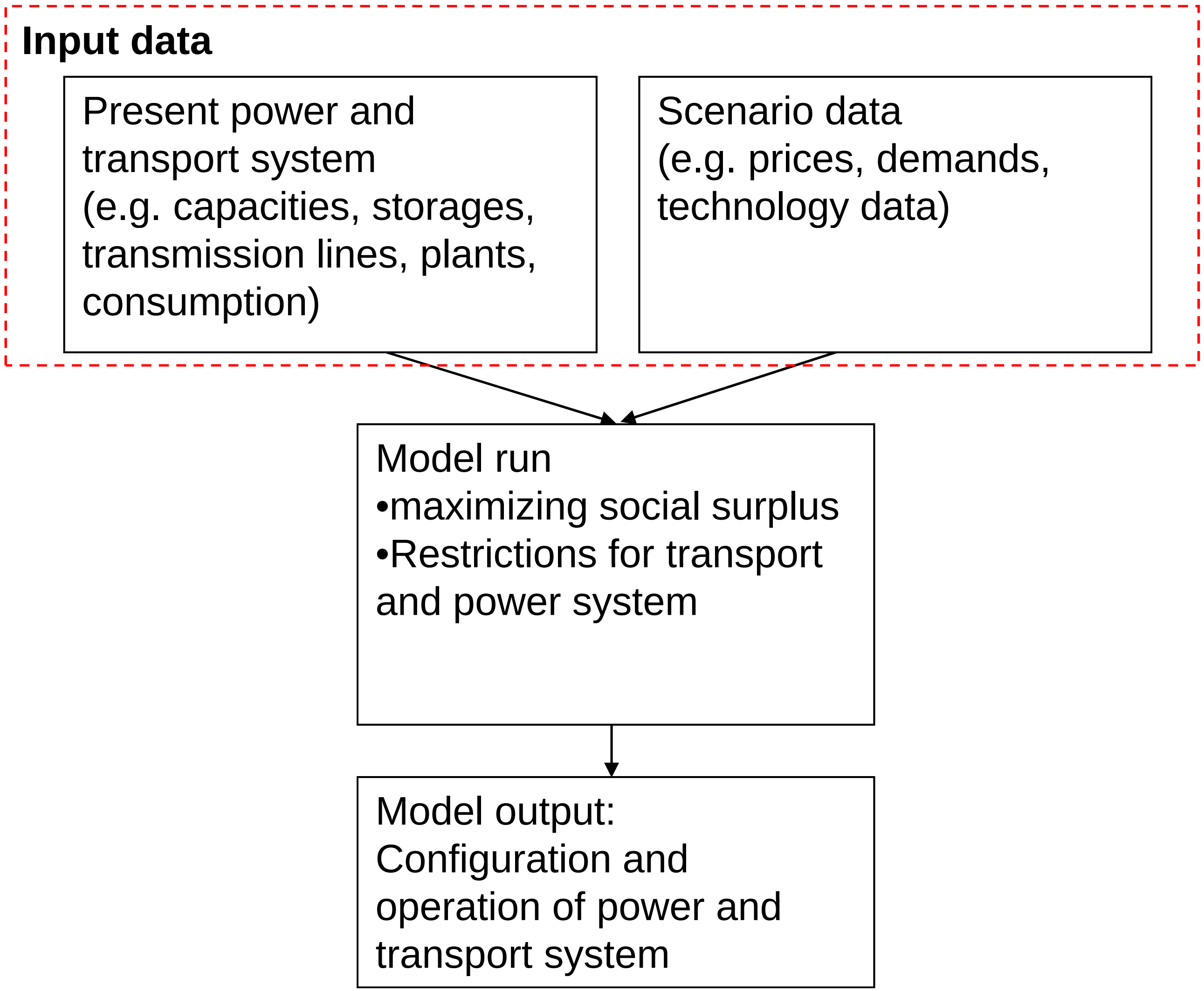
Adding transport to a power system model (Balmorel) enables analysis of:

- consequences of possibility of using electric power in transport sector
- consequences of adding vehicle-to-grid technologies
- competition between different vehicle technologies

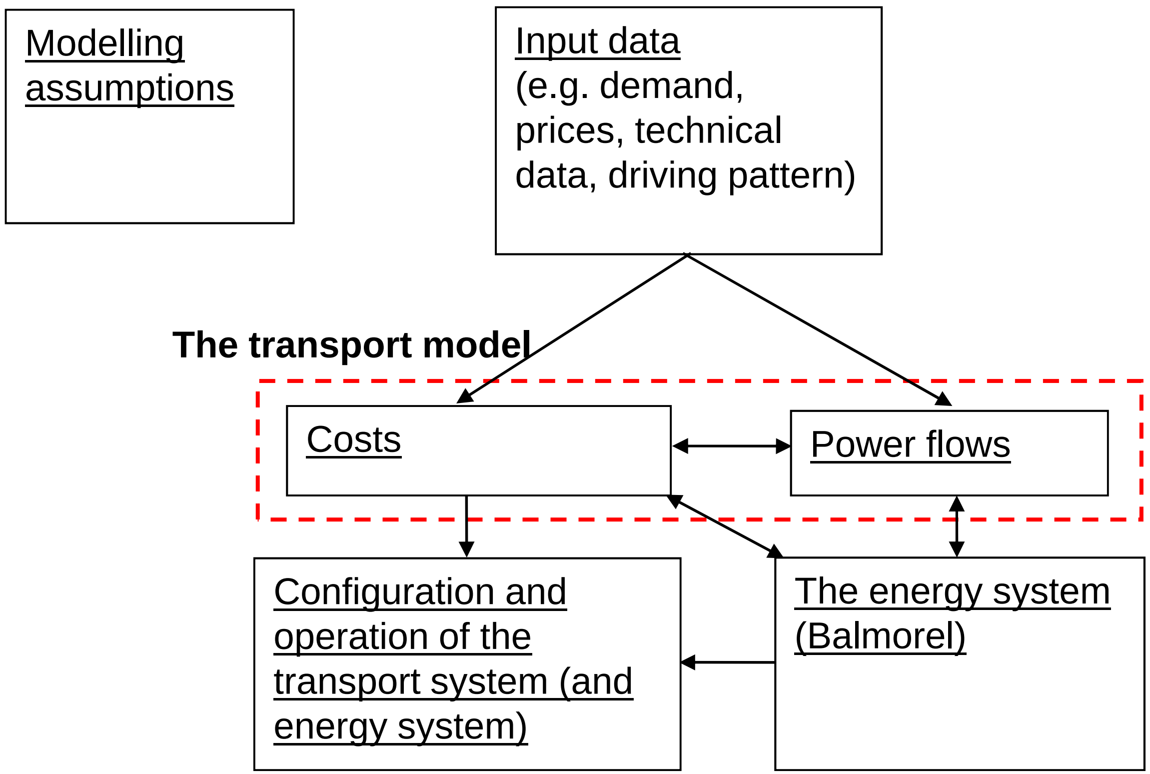
Balmorel (www.balmorel.com)

- Developed by Hans Ravn, RAM-løse edb
- Further development and usage: Risø DTU, EA Energianalyse, Cowi, Energinet.dk
- Investment model: calculates optimal future configurations of power systems
- Time resolution: from hourly to more aggregated time steps
- Deterministic assuming perfect foresight
- Power plants, CHP plants, boilers, heat pumps, electricity and heat storages, transmission lines
- Lately:
  - hydrogen storage, production (electrolysis, steam reforming), consumption
  - plug-in electric vehicles

Sketch of the Balmorel model including transport

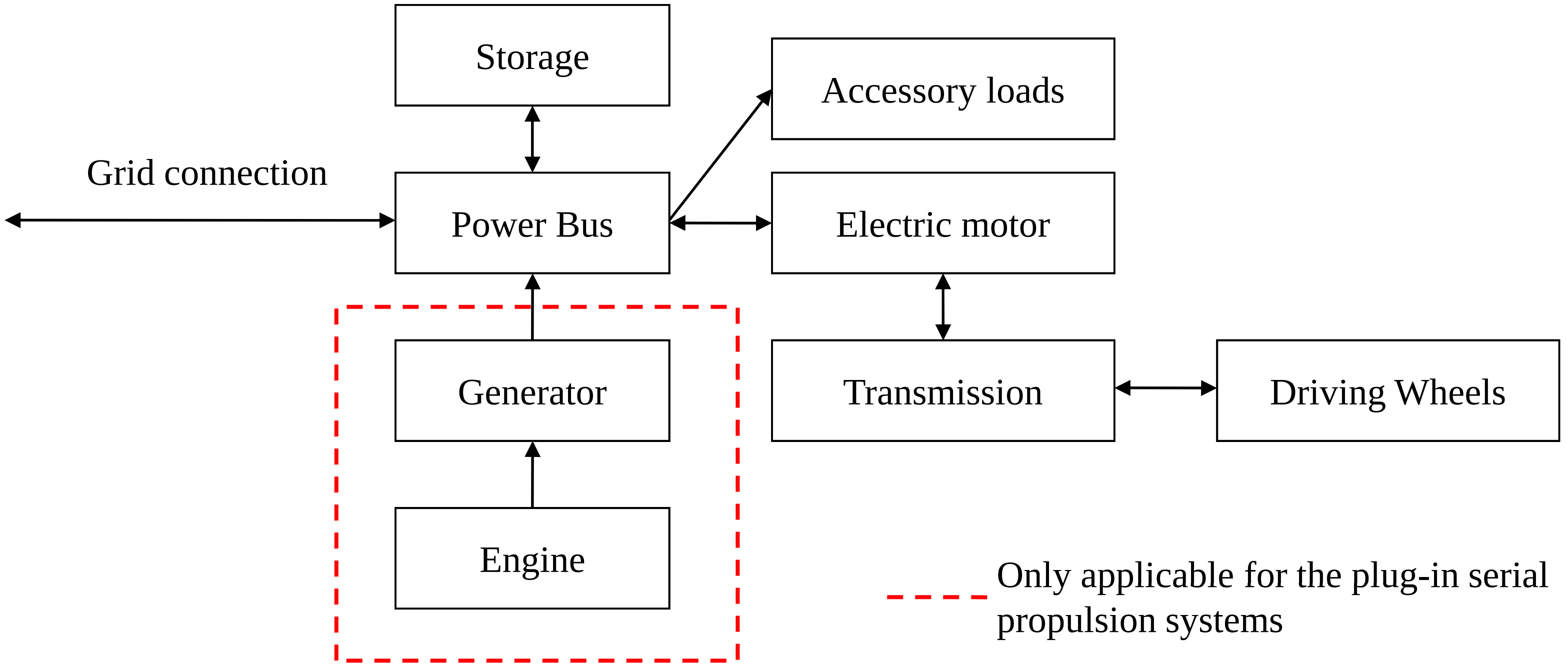


Transport add-on in Balmorel



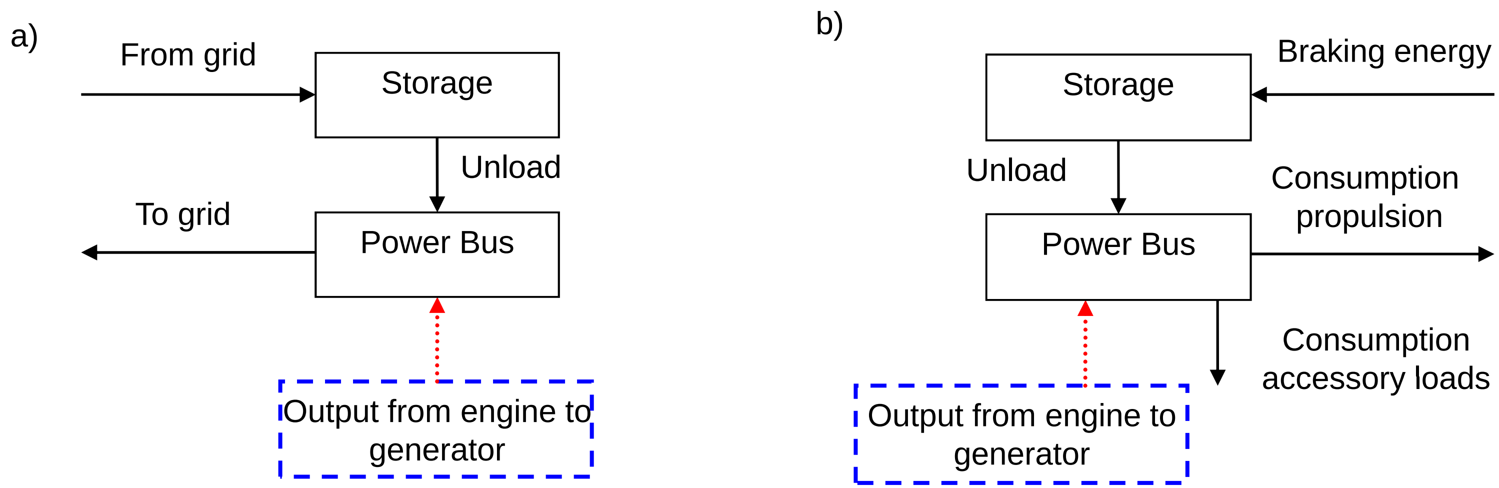
Power flow

Propulsion system configuration of electric drive vehicles



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)
  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
- Loading and unloading depending on vehicles plugged in (cannot exceed max storage level)
- Average driving patterns (forcing specific patterns for use of diesel)
- All vehicles leave grid with predefined storage level
- 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

DTU

RISØ

Case description

- Denmark without transmission possibilities to neighbouring countries
- 1.2 GW transmission capacity between Western and Eastern Denmark
- 26 selected weeks with hourly resolution (26 X 168 time steps)
- Year 2030
- Oil prices $100/barrel
- CO_2 prices 40€/ton
- Road transport
- Including ICE, BEV, PHEV for persons transport

Case description

Demand input data year 2030

	Denmark East	Denmark West	Total demand
Electricity demand (TWh/yr)	15	23	38
District heat demand (TWh/yr)	16	19	35
Transport demand (b. persons km/yr)	32	42	74

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

Scenarios

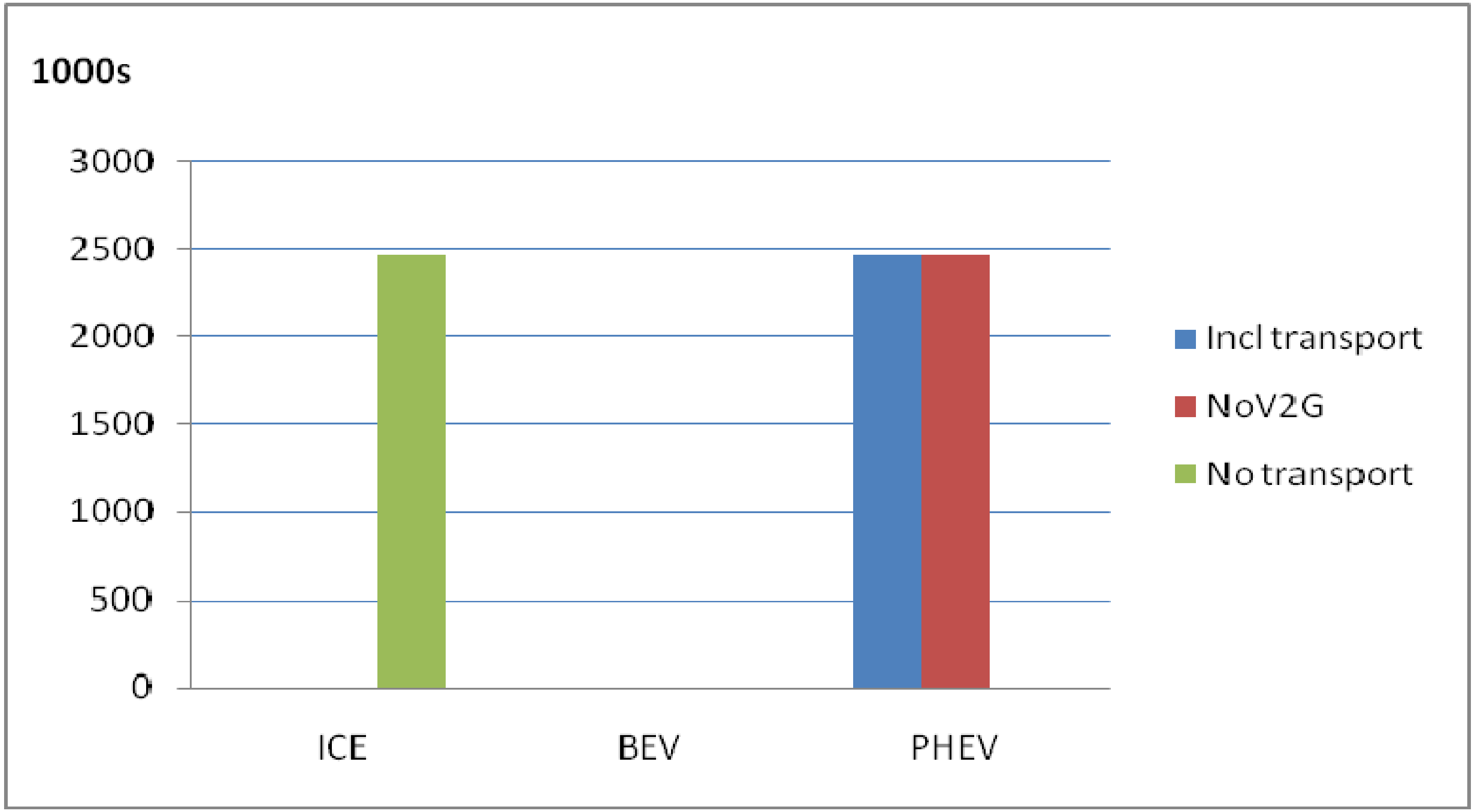
- No usage of electricity in road transport
- Integrated power and transport system with V2G facilities
- Integrated power and transport system without V2G facilities

Case description

Type of vehicle	Inv. costs (€) (yearly cost)	O & M costs (€/year)	Electric storage cap. (kWh)
ICE	1,573	1,168	0
BEV	2,520	1,101	50
PHEV	2,133	1,168	10

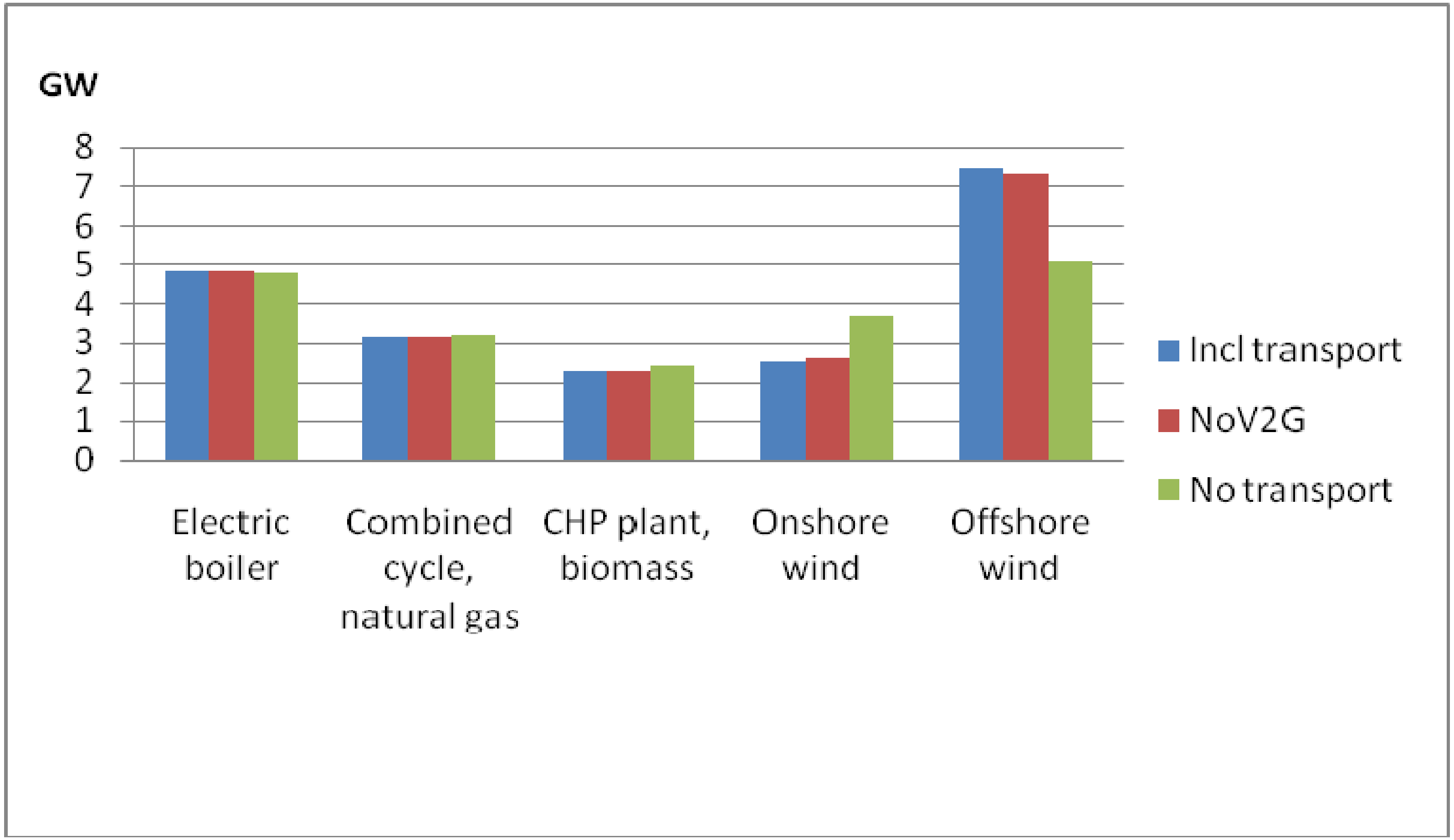
Results

Investments in vehicles 2030



Results

Investments in power plants and heat boilers 2030



Results

Total costs of running the integrated power and transport system

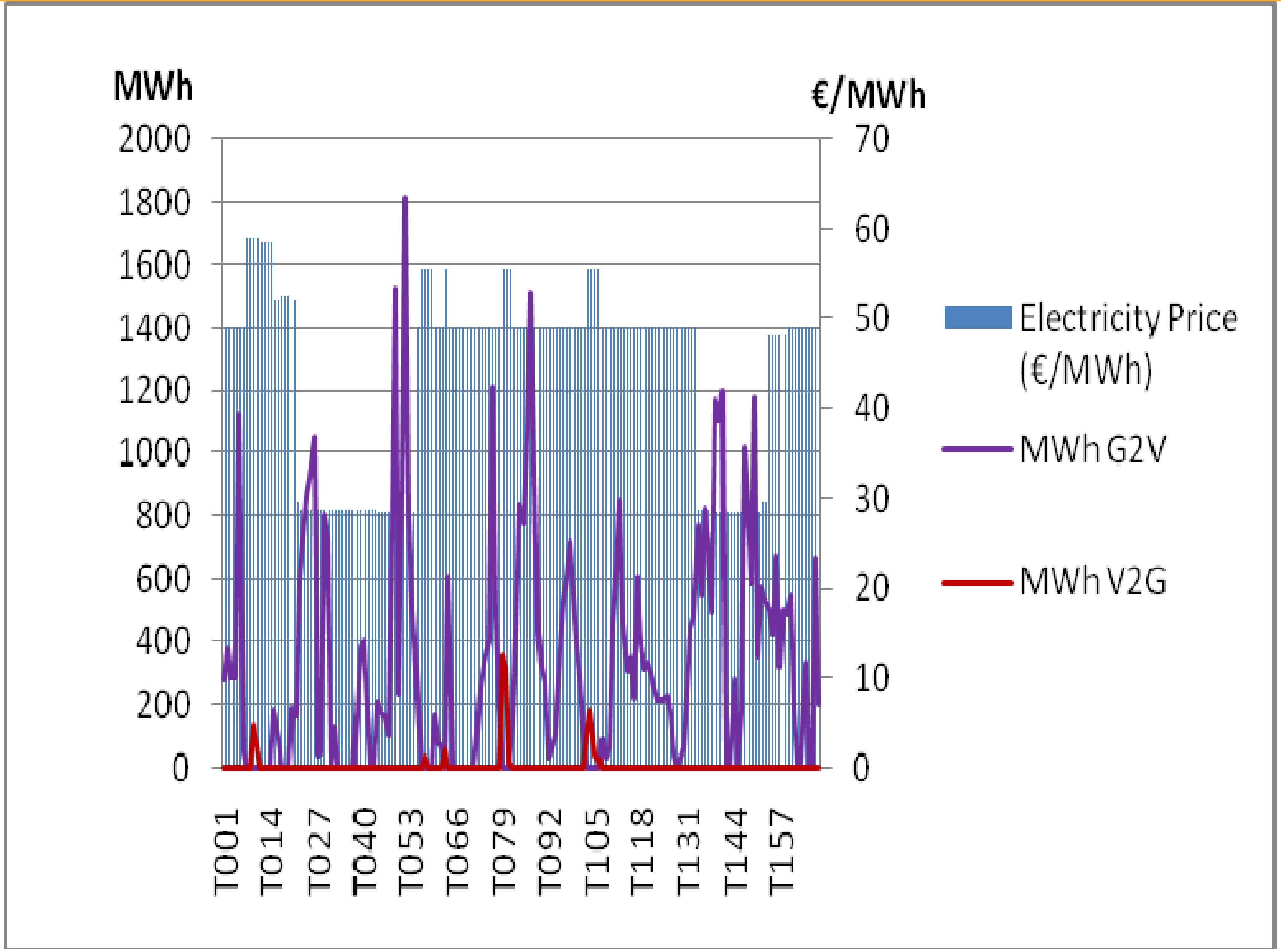
Billion	Incl. transport	No V2G	No transport
Costs	10.271	10.273	10.345

Results

Power exchange between vehicles and electricity grid

Region	From grid (GWh)	To grid (GWh)
Eastern Denmark	2,941	45
Western Denmark	3,911	82
Total	6,853	127

Week 16: Power exchange between grid and vehicles vs. electricity prices (western Denmark)



Conclusions

- Optimisation model developed for configuring and operating the integrated power and transport system.

- Using electricity for transport incorporates more wind – more than what is used by the electric drive vehicles in the transport sector

- Adding V2G facilities incorporates more wind even though the usage is small

- Electric drive vehicles will have a daily charging cycle