Challenges of modelling transport sector in cross-sectoral energy planning models

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Energy planning model

Bottom-up LP/MIP partial equilibrium optimization model for energy planning

\[\text{minimizes total discounted cost}\]

Energy planning modelling software:
- TIMES/MARKAL
- MESSAGE
- Balmorel
Why should you incorporate the transport sector?

• The most GHG emitting sector in US[1] and 2nd in EU[2]
• EU objective to reduce emissions by 90% till 2050[3]
• Zero carbon emission transport fuels: electricity, hydrogen, biofuels
• EV fleet expansion increases electricity demand and affects the shape of the demand curve
• The effectiveness of transport sector decarbonization depends on the electricity generation energy mix.
• Flexible electric vehicle charging to balance RES
• Hydrogen production through electrolysis
Challenge 1. How to model vehicles in a system designed to model an energy system

**Parameters:**
- Efficiency
- Variable costs
- Fixed costs
- Investment costs
- ...
Challenge 1. How to model vehicles in a system designed to model an energy system

\[ \eta_{\text{fuel}} = \frac{100 \cdot \text{OR}}{\text{FC}} \left[ \frac{\text{Pkm}}{\text{kg}} \right] \]

- \( \eta_{\text{fuel}} \) – efficiency
- \( \text{OR} \) – occupancy rate
- \( \text{FC} \) – fuel consumption kg/100km

**Parameters:**
- Efficiency
- Variable costs
- Fixed costs
- Investment costs
- ...

Fuel

Input

Vehicle

Output

1 \( \rightarrow \) Pkm

(Person kilometers)

2 \( \rightarrow \)
Challenge 1. How to model vehicles in a system designed to model an energy system
Challenge 1. How to model vehicles in system designed to model energy system

* Investments costs and fuel prices were assumed to be constant
Challenge 2. Public transport

Input:
- Diesel bus
- Diesel cars
- Petrol cars

Output:
- Diesel bus
- Diesel cars
- Petrol cars

Pkm (Person kilometers)
Challenge 2. Public transport

Public transport is much more cost-efficient compared to private transport!
Incorporating travel behaviour and travel time into TIMES energy system models

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\[ TCR = \frac{\eta_{fuel}}{\bar{v}} \left[ \frac{h}{x \ km} \right] \]

\( \bar{v} \) – average speed \( \left[ \frac{km}{h} \right] \)

TCR = \( \frac{18.57 \ Pkm/kg}{1 \ kg} \)

0.58 h/18.57 km

32 km/h

Petrol cars

Diesel cars

Diesel bus

18.57 Pkm/kg

1 kg
Challenge 2. Public transport

Transportation Research Part A: Policy and Practice
Volume 34, Issue 3, April 2000, Pages 171-205

The future mobility of the world population

Andreas Schafer, David G Victor

Travel time budget for motorized travel [h/cap/d]:

\[ ttb_{mot} = a + \frac{b}{(TV - c)^d} \]

\[ a = -\frac{b}{(-c)^d} \]

\[ b = \frac{1.1}{\left(\frac{1}{(240000 - c)^d}\right) - \left(\frac{1}{(-c)^d}\right)} \]

\[ c = -176083 \quad d = 20 \]
Challenge 2. Public transport

- Diesel buses
- Electric cars
- Petrol cars
- Diesel cars
Challenge 3. Increasing the detail

- Distinguishing short and long distance travel
- Additional vehicle types
- Distinguishing vehicles by build year
Challenge 3. Increasing the detail

Vehicle parameters that depend on its build year/age:

• Purchase cost
• O&M cost
• Fuel economy
• Cost of EV inconvenience
Problem: unrealistic car age distribution
Vehicle age constraints
Vehicle age constraints

\[
\sum_{f} PKT_{y,f,a,d} = \alpha_{y,a,d} \cdot \sum_{f,a} PKT_{y,f,a,d}
\]

\[
\sum_{a} \alpha_{y,a,d} = 1
\]

- \(y\) – vehicle type
- \(f\) – fuel type
- \(a\) – vehicle age group
- \(d\) – travel mode (short or long distance travel)

\(\alpha_{y,a,d}\) - the share of age group \(a\) in age distribution of the vehicle type \(y\).
Challenge 3. Improving detail

The graph illustrates the CO2 emissions and MPkm for different types of vehicles over time. The x-axis represents years from 2018 to 2050, and the y-axis represents MPkm and kt CO2. The graph compares the performance of vehicles such as diesel cars, petrol cars, electric cars, diesel city buses, CNG city buses, trolleybuses, diesel Intercity buses, and electric Intercity buses for both short and long distance travel. The data shows a reduction in CO2 emissions and an increase in MPkm over the years, particularly for electric vehicles.
Challenge 4. Electric vehicles

\[ \eta_{EV} = \frac{C_{\text{vehicle}}}{P_{\text{charger}}} \]

\[ C_{\text{vehicle}} = \frac{365 \cdot 24 \cdot OR \cdot \bar{v} \cdot OT}{10^6} \]

\[ \text{consa} = - \frac{1000}{r \cdot 365 \cdot 24 \cdot OR} \]

- \( \bar{v} \) – EV efficiency km/kWh
- \( r \) – operation time
- \( OR \) – operation rate

Diagram:
- charger standby
- short distance travel
- long distance travel
- hour in a day
- charging availability
- energy consumption
- electric vehicle
- battery
- electricity
- dummy TT

Challenge 5. Incorporating transport model into power system model
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Further improvements

• Vehicle classes (e.g. A-B, C-D, E-F, J)
• Constraints on market penetration
• Consumer groups by income (untested)
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