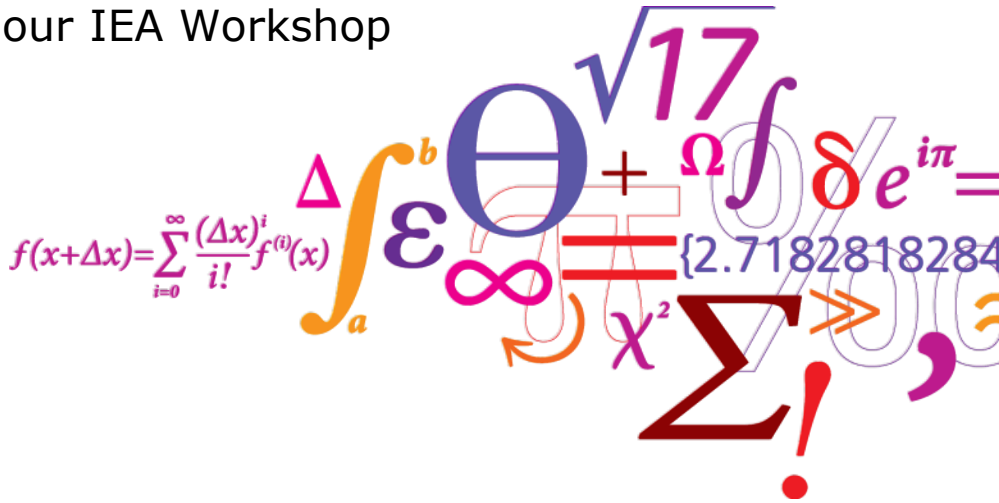
Improvements in the representation of behaviour in integrated energy and transport system models

Venturini G., Tattini J., Mulholland E., O'Gallachoir B.

Transport, Energy Efficiency & Behaviour IEA Workshop
Paris, 10-11th May 2015



Jacopo Tattini
PhD student
Energy System Analysis group
DTU Management
jactat@dtu.dk

DTU Management Engineering
Department of Management Engineering

Agenda

- Background
- Purpose of the review
- Integration of energy and transport models
- Behavioural features in transport
- Conclusions

Background

- (Schafer, 2012) identifies the **lack of behaviour representation in energy models.**

- New technologies have to be accepted by consumers: necessary to include in energy models **real household preferences** capturing purchase decisions and use of transport technologies.

- New research interest: to **realistically represent consumer choice** in energy models by including attributes related to the level of service and sociological aspects.

Purpose

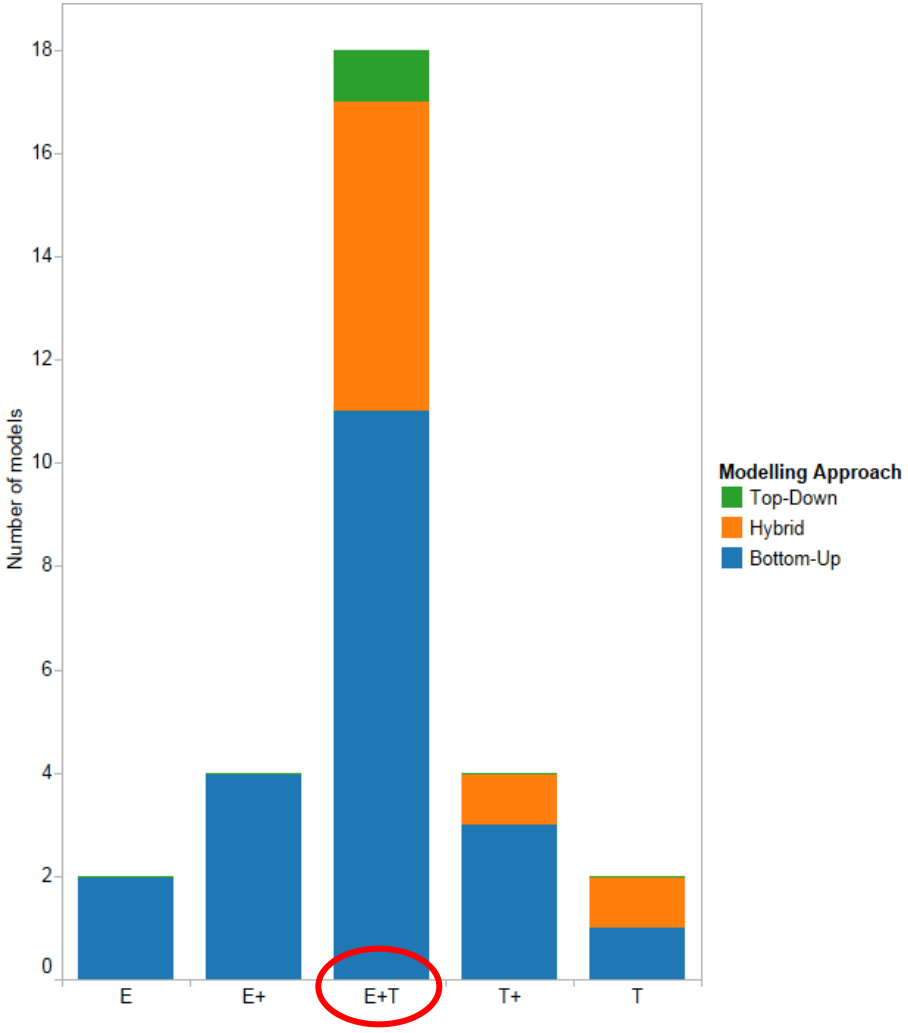
- Integrated Energy and Transport system models:
    - Analyse the **interactions** between the two systems to evaluate potentially unexplored climate change mitigation options
    - Study of the **effects** that a sector-specific policy may have on the rest of the system
- Behaviour in transport:
    - Evaluate **modelling approaches** for transport behaviour

What level of integration of transport and energy systems is required for adequatly represent transport related behaviour?

Integration of energy and transport models

Sectoral energy models studying an energy-related aspect of a specific system	Energy system models where transport sector is represented at **aggregated** level	Highly **integrated energy and transport models**, with transport sector at **disaggregated** level	Transport system models linked to an energy model, allowing studying systems interactions	**Sectoral transport models** studying a transport-related aspect of a specific system

Integration of energy and transport models

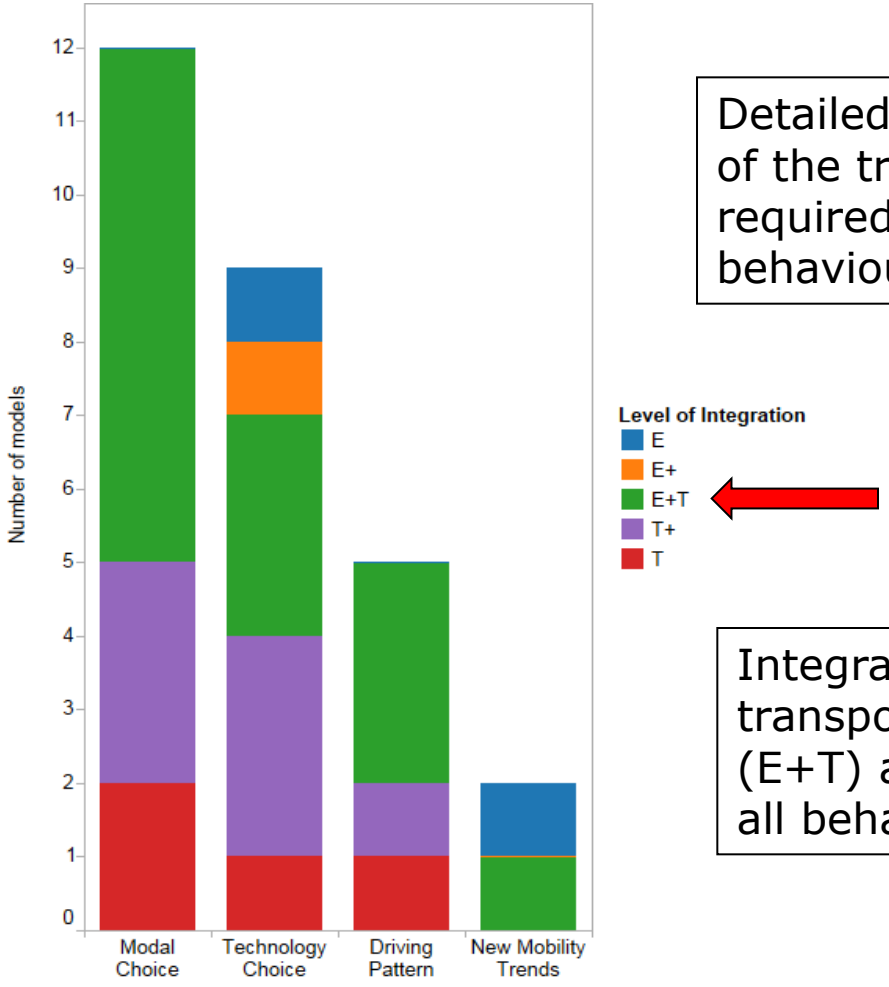


Behavioural features in transport

Remarkable features incorporated in energy and transport models in order to represent transport behaviour:

- **Technology and vehicle choice**: endogenous technology choice among a set, on the basis of cost and non-cost parameters
- **Modal choice**: endogenous modal share calculation
- **Driving pattern**: speed profile, geographical travel distribution
- **New mobility trends**: car sharing, car pooling

Transport related behavioural features



Detailed representation of the transport sector required to introduce behavioural features.

Integrated energy and transport models (E+T) able to include all behavioural aspects.

Behavioural features representation

Behavioural feature	Modelling methodology	Reference
Technology choice	Discrete choice models	Horne et al., 2005 Kloess & Müller, 2011 Brand et al., 2012 Girod et al., 2012 E3MLab, 2014
	Discomfort costs	McCollum et al., 2013 Bunch et al., 2015
	Virtual technologies	Kanala et al., 2013
	Constant elasticities of substitution	Karplus et al., 2013

- Non-monetary costs included

Technology choice - Discrete choice models

Calculate the probability of an individual's choice among a finite set of alternatives, based on RUM principle.

$$Share_{r,v,t} = \frac{e^{(\lambda \times Cost_{r,v,t})}}{\sum_i e^{(\lambda \times Cost_{r,v,t})}}$$

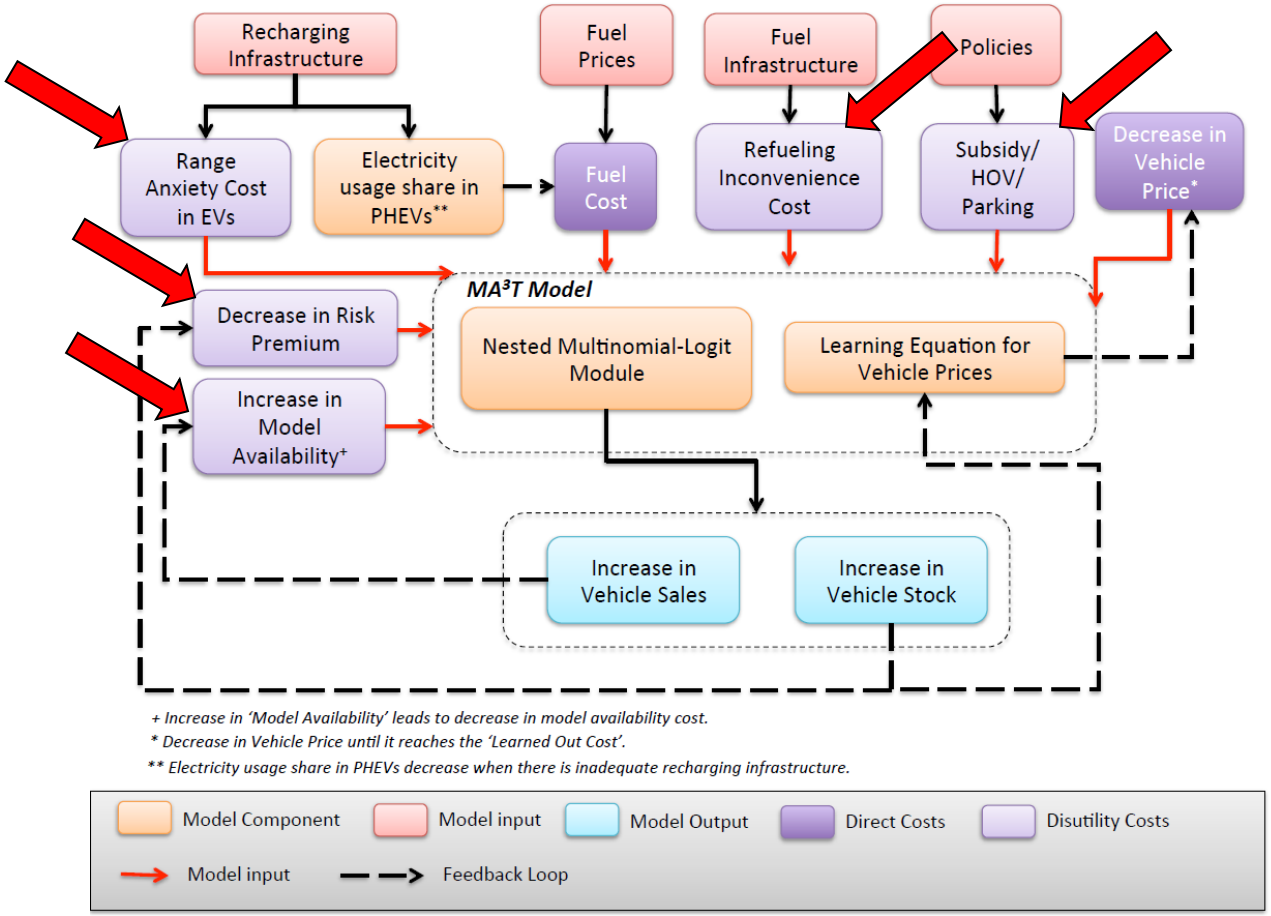
$$Cost_{r,v,t} = \frac{AddTechCosts_{v,t} + EnergyCosts_{r,v,t} + NonEnergyCosts_{r,t}}{load_{r,t}}$$

Discrete choice models take into account different costs:

- Investment costs
- Energy costs
- Non-energy costs: higher willingness to pay with higher income

TRAVEL - Girod et al. (2012)

Technology choice – Discomfort costs



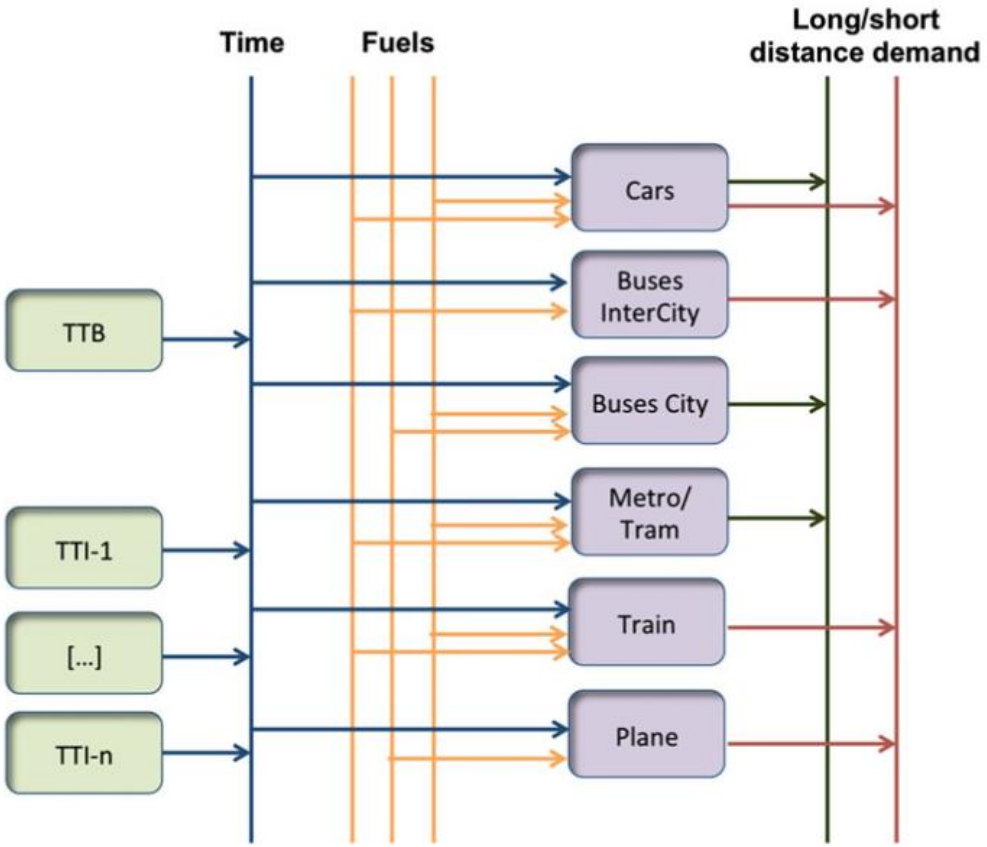
COCHIN TIMES - Bunch et al. (2015)

Behavioural features representation

Behavioural feature	Modelling methodology	Reference
Modal choice	Discrete choice models	Horne et al., 2005 Rich et al., 2010 Kyle and Kim, 2011 Girod et al., 2012
	Travel time budget constraints	Turton, 2008 Daly et al., 2014 Pye & Daly, 2015
	Constant elasticities of substitution	Pietzcker et al., 2010 Brand et al., 2012 Karplus et al., 2013 Waisman et al., 2013 E3MLab, 2014

- Travel time is main parameter

Mode choice – TTB/TTI



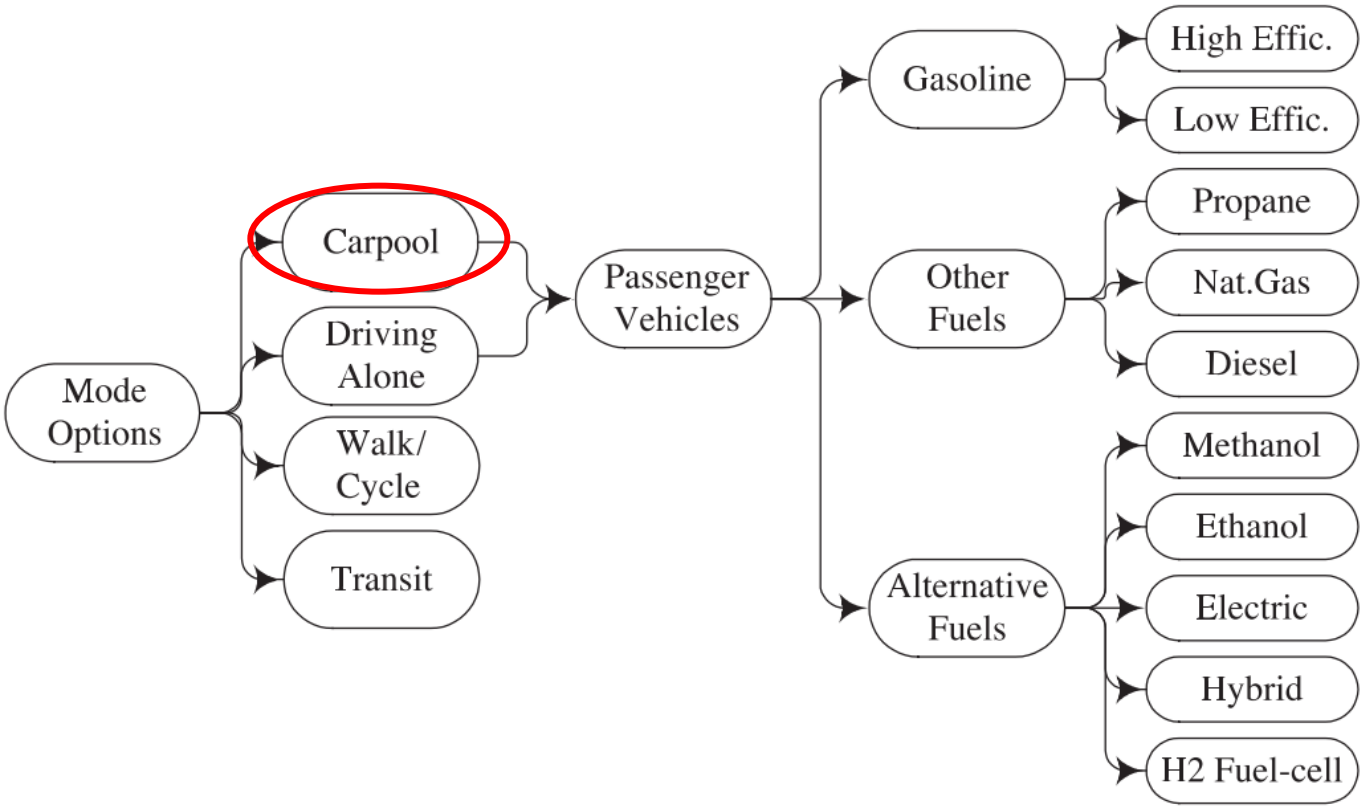
Irish TIMES - Daly et al. (2014)

Behavioural features representation

Behavioural features	Modelling methodology	Reference
Driving patterns	Cross elasticities	Kloess & Müller, 2011 Karplus et al., 2013 Waisman et al., 2013
	Driving profiles	E3MLab, 2014 Bunch et al., 2015
New mobility trends	Discrete choice models	Horne et al., 2005
	Cross elasticities	Fulton et al., 2009

- High mitigation potential for CO_2 emissions of transport sector

New mobility trends - Discrete choice models



CIMS - Horne et al. (2005)

Conclusions

- 30 **energy and transport models** have been analysed according to level of integration
- **E+T models** are able to include all behavioural aspects
- **Detailed representation** of the transport sector is required to introduce behaviour in integrated energy and transport models
- **Mode and technology choice**: efforts for including such features are already in place
- **Driving patterns**: endogenize the speed or include a more detailed spatial representation
- **New mobility trends**: endogenize the load factor

...QUESTIONS?!?!

Jacopo Tattini
PhD student
DTU Management
jactat@dtu.dk

Transport CO_2 emissions mitigation

Avoid: reduce the mobility demand

Shift: towards more efficient modes for both passengers and freight

Improve: the technology performances: increasing efficiency and reducing emission factors

Souce: IEA, 2012

Technology developments is only one dimension

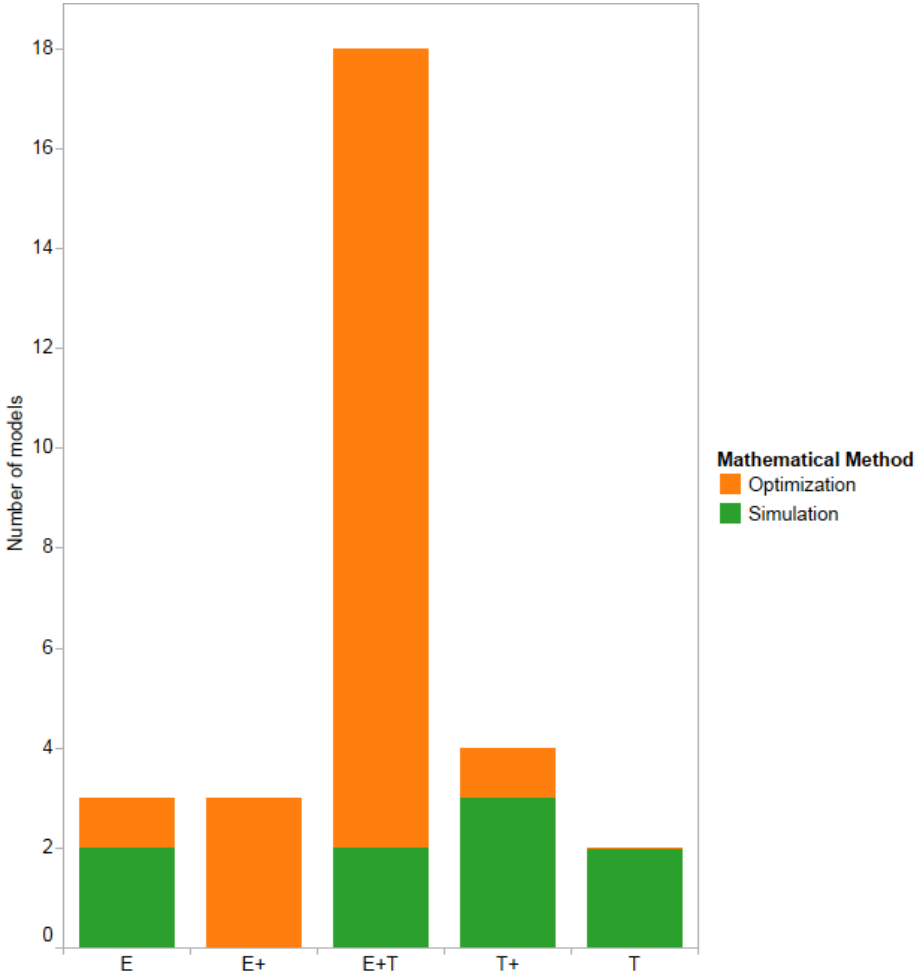
↓

Technology adoption and usage are also key factors

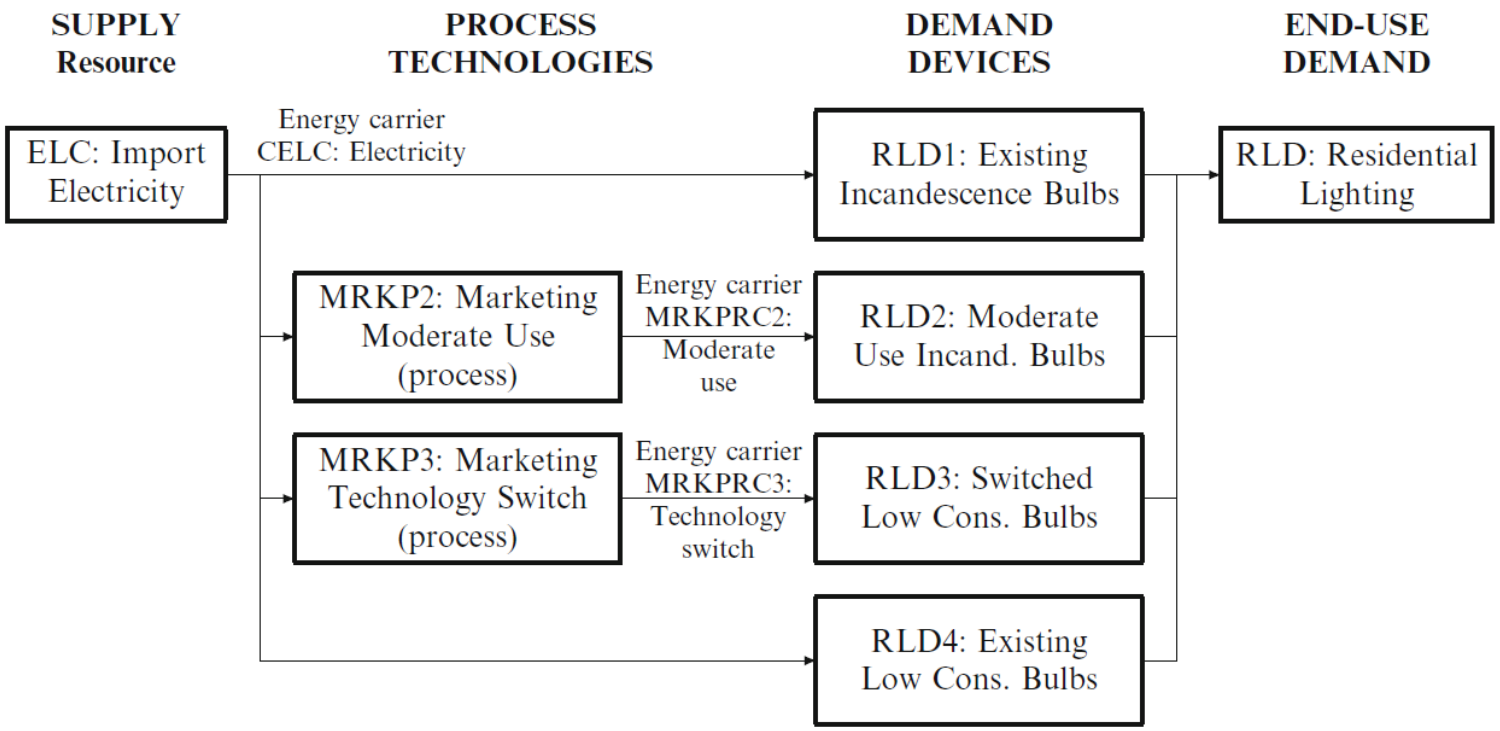
↓

Required behavioural analysis

Integration of energy and transport models



Technology choice - Virtual technologies



SocioMARKAL - Kanala et al. (2013)

Literature review

- **COCHIN TIMES:** consumer heterogeneity, technology choice (Bunch et al., 2015)
- **Irish TIMES:** value of travel time (Daly et al., 2014)
- **IMACLIM-R:** rebound effects, location decisions (Waisman et al., 2013)
- **SocioMARKAL:** technology choice, sociological surveys (Kanala et al., 2013)
- **TRAVEL:** value of travel time, soft-linking (Girod et al., 2012)
- **UKTCM:** high dissaggregation, soft-linking, transport policies (Brand et al., 2012, Anable et al., 2012)
- **GCAM:** integrated assessment tool (Kyle and Kim, 2011)
- **ReMIND-G:** integrated model, constant elasticities of substitution (Pietzcker et al., 2010)
- **ECLIPSE:** disaggregated transport submodule (Turton, 2008)
- **CIMS:** simulation, vehicle and modal choice (Horne et al., 2005)
- **MIT-EPPA:** cross elasticities (Paltsev et al., 2004)

Model Name	Geographic Scope	Time Horizon	Mathematical Method	Modelling Approach	Level of Integration	Focus	Reference
Balmorel	Nordics	2005-2050	O	BU	E+	Long-term investment path with focus on renewable energy and hydrogen in the transport sector	Karlsson & Meibom, 2008
Balmorel	Nordic and Baltic countries	18 weeks in year 2030 with hourly resolution	O	BU	E+T	Creation of a road transport add-on to traditional Balmorel model, to assess integrated power and transport systems and vehicle to grid	Juul & Meibom, 2011
Car Stock	Ireland	2011-2025	S	BU	E	Modelling future private car energy demand in Ireland	Daly & Gallachoir, 2011
CIMS	Canada	2005-2035	S	H	E+T	Modelling technological changes in a more behaviourally realistic manner in order to facilitate policy analysis for a greater range of technologies	Horne et al., 2005
COCHIN-TIMES	California	2005-2050	O	BU	E+T	Demonstration of a practical approach for incorporating behavioural effects from vehicle choice models into E4 models.	Bunch et al., 2015
Daly et al., 2014	Ireland	2005-2050	O	BU	E+	Incorporating modal choice within passenger transport in a TIMES model	Daly et al., 2014

Model Name	Geographic Scope	Time Horizon	Mathematical Method	Modelling Approach	Level of Integration	Focus	Reference
ECLIPSE	Global	2000-2100	CGE	H	E+T	Development of an **integrated** energy-economy model with a detailed transport sector representation	Turton, 2008
EnergyPLAN	Denmark	2020	S	BU	E+T	Integration of renewable energy into the transport and electricity sectors through **vehicle-to-grid technology**	Lund & Kempton, 2008
EPPA	Global	2005-2050	CGE	TD	E+T	**Disaggregation of the passenger vehicle transport** sector in a CGE model	Karplus et al., 2013
ESME	United Kingdom	2010-2050	O	BU	E+T	Representation of **endogenous mode shift** for urban passenger travel in a whole energy system model	Pye & Daly, 2015
GCAM	Global	2005-2095	IAM	H	E+T	Long-term effect of **alternative vehicles** on greenhouse gas emissions and energy demand	Kyle & Kim, 2011
GET-R	Global	2000-2130	O	BU	E+T	Analysis of **fuel and vehicle technology choice** for passenger transport under CO_2 targets	Grahn et al., 2009
Kloess & Müller, 2011	Austria	2010-2050	S	H	T+	Analysis of **policies, energy prices and technological progress** for electric vehicles uptake in the passenger car fleet	Kloess & Müller, 2011

Model Name	Geographic Scope	Time Horizon	Mathematical Method	Modelling Approach	Level of Integration	Focus	Reference
IMACLIM-R	Global	2001-2100	CGE	H	E+T	Implications of modelling **non-price determinants** of mobility	Waisman et al., 2013
LTM	Denmark	2010-2030	S	BU	T	Model for Danish passenger and freight traffic assignment	Rich et al., 2010
MESSAGE	Global	1990-2110	O	BU	E+	Analysis of the role and extent of **transport electrification** for decarbonizing the future energy system	McCollum et al., 2013
MoMo	Global	1975-2050	S	BU	E	Development of **global transport energy use** and CO_2 emissions scenarios	Fulton et al., 2009
PET36	Europe	2005-2050	O	BU	E+T	Assess the **cost-effectiveness of electric vehicles** in European countries	Seixas et al., 2015
PRIMES-TREMOVE	Europe	2005-2050	S	H	T	Used for analysis of scenario and policy in the **transport sector** for the European Member states	E3MLab, 2014
ReMIND	Global	2005-2100	O	H	E+T	Analysis of **technology and mode shif**t as different mitigation options for the transport sector	Pietzcker et al., 2010

Model Name	Geographic Scope	Time Horizon	Mathematical Method	Modelling Approach	Level of Integration	Focus	Reference
Roadmap	Global	2000-2050	S	BU	T+	Estimation of future global **transportation activity**, mode shares and corresponding well-to-wheel emissions	Facanha et al.., 2012
SATIM	South Africa	2006-2050	O	BU	E+T	Describing the TIMES model of the entire energy system in South Africa	Merven et al., 2012
SocioMARKAL	City of Nyon	2005-2025	O	BU	E	Inclusion of **consumers behaviour** measured through sociological survey as a virtual technology in an energy system model	Kanala et al., 2013
TIAM-ECN	Europe	2005-2100	O	BU	E+T	Analysis of the electricity and hydrogen shares for passenger cars under stringent climate change control	Rösler et al., 2014
TIAM-UCL	Global	2010-2100	O	BU	E+T	Explore the competitive and/or complementary relationship between hydrogen and electricity, with endogenous technological learning	Anandarajah & McDowal, 2015
TIMES California	California	2005-2050	O	BU	E+T	Assess **least-cost mitigation options** required to meet California's long-term 80% greenhouse gas emission reduction goal, by considering all the energy sectors	McCollum et al., 2012

Model Name	Geographic Scope	Time Horizon	Mathematical Method	Modelling Approach	Level of Integration	Focus	Reference
TIMES Canada	Canada	2007-2050	O	BU	E+T	Performs **policy analysis for promoting electrification** of road transport in Canada	Bahn et al., 2013
TRAVEL	Global	2010-2100	O	BU	T+	**Predict global travel demand**, modal split shifts, and changes in technology and fuel choice	Girod et al., 2012
UKTCM	United Kingdom	2010-2050	S	BU	T+	**Policy analyses** and low carbon strategy development for the transport sector	Brand et al., 2012
WITCH	Global	2005-2100	O	H	E+T	Review of the **electrification** of light duty vehicles within a model that utilizes a learning-by-researching structure.	Bosetti & Longden, 2013