Improving representation of electric end-use technologies in global scenarios

Taishi Sugiyama*, Masa Sugiyama** and Takeo Imanaka
CRIEPI
* sugiyama@criepi.denken.or.jp, ** s-masa@criepi.denken.or.jp

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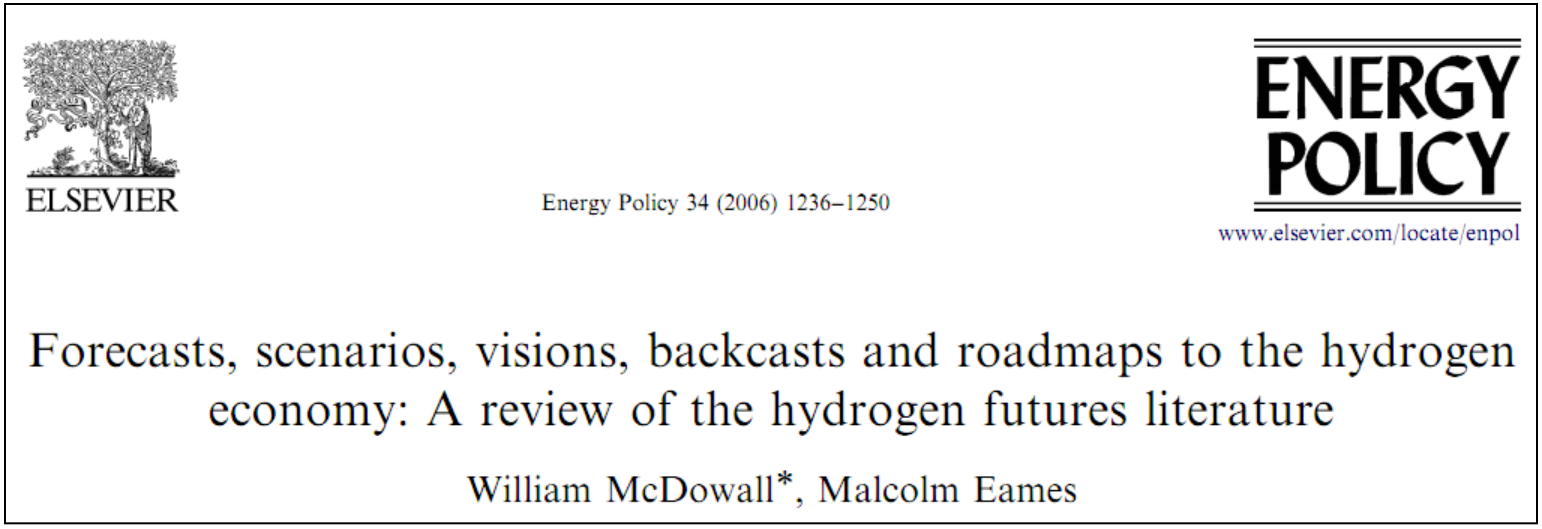
1. Role of electricity

Many studies on hydrogen and bioenergy. What about electricity?



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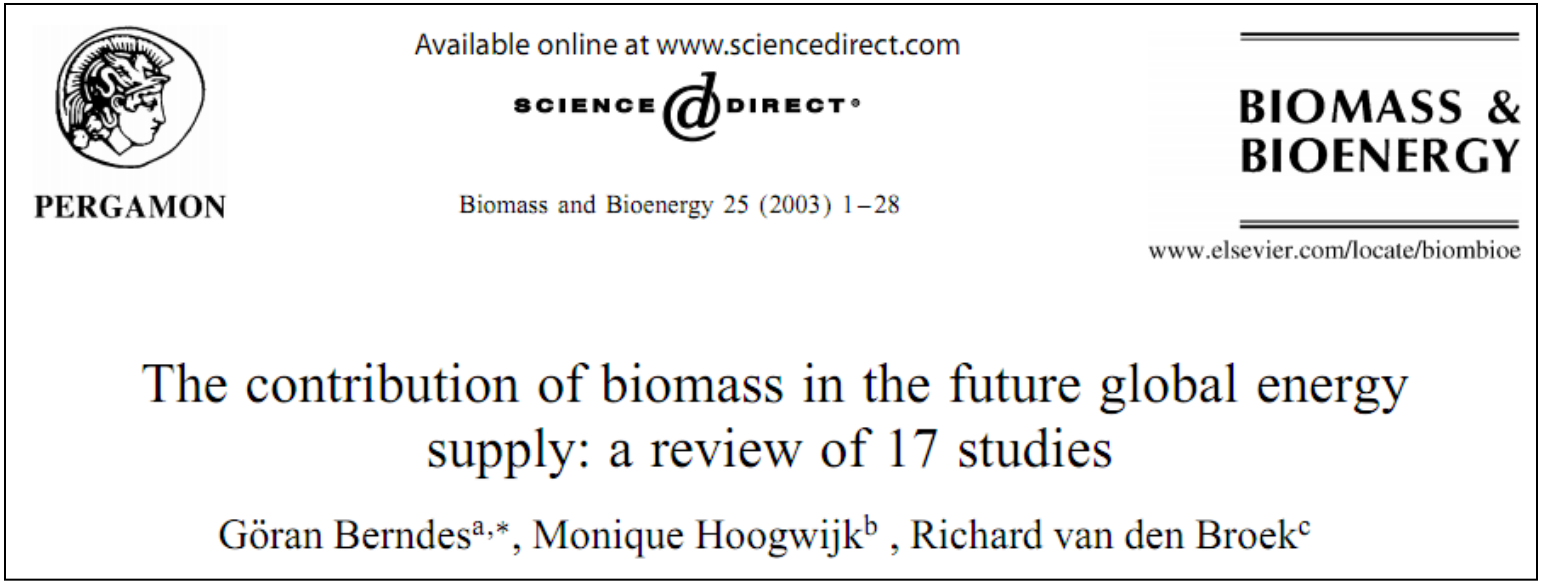

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Göran Berndes[a,*], Monique Hoogwijk[b], Richard van den Broek[c]

Role of electricity in global warming mitigation

- SUPPLY SIDE: carbon-free electricity: nuclear, CCS, renewables

- **DEMAND SIDE: efficient end-use technologies**
  - Heat pumps: hot water / space heating / industrial heating
  - Electric vehicles

Improving the representation of electricity end-use in global scenarios

- Old scenarios
  - Few considered end-use technologies in sufficient detail
    - simple thermal-based substitution at end use:

      - 1Ws of electricity = 1J of fossil fuel
    - No or limited substitution from fossil fuel to electricity

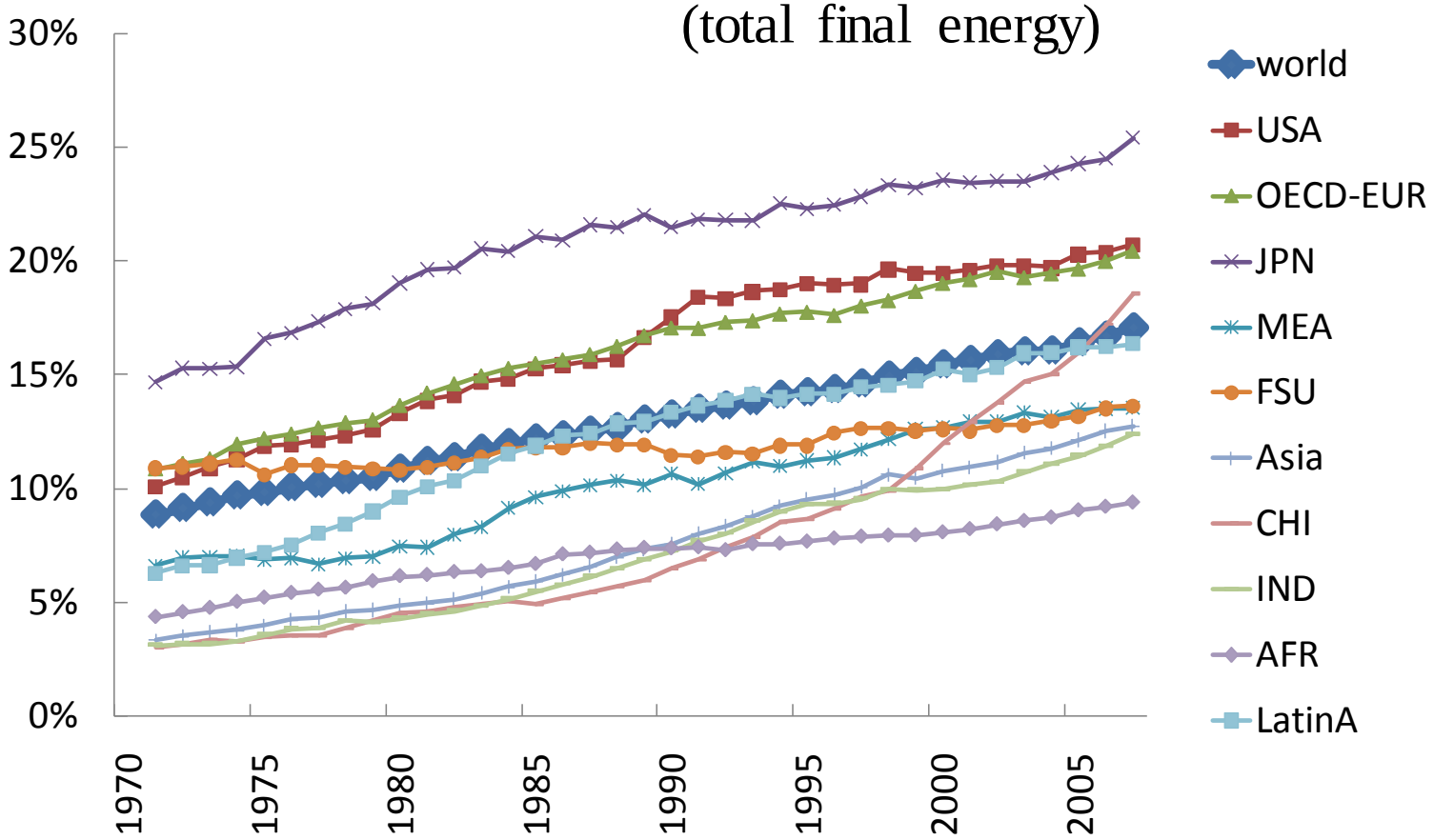
      - No substitution to electricity (e.g. heat pumps) in Linear Programming Models

      - Limited substitution by “fixed share and elasticity” in energy-economic models
    - Limited consideration of benefits of electrification (clean, safe and convenient)
- New scenarios
  - Full considered end-use technologies in sufficient detail
    - HP and EVs have efficiencies > 1
    - Switch to electricity fully represented

Electrification: historical perspective

- "Electrification" could mean "access to electricity on the grid," but we here mean "electricity usage at the energy service demand."

$$\text{Electrific ation rate} = \frac{(\text{electricit y})}{(\text{total final energy})}$$

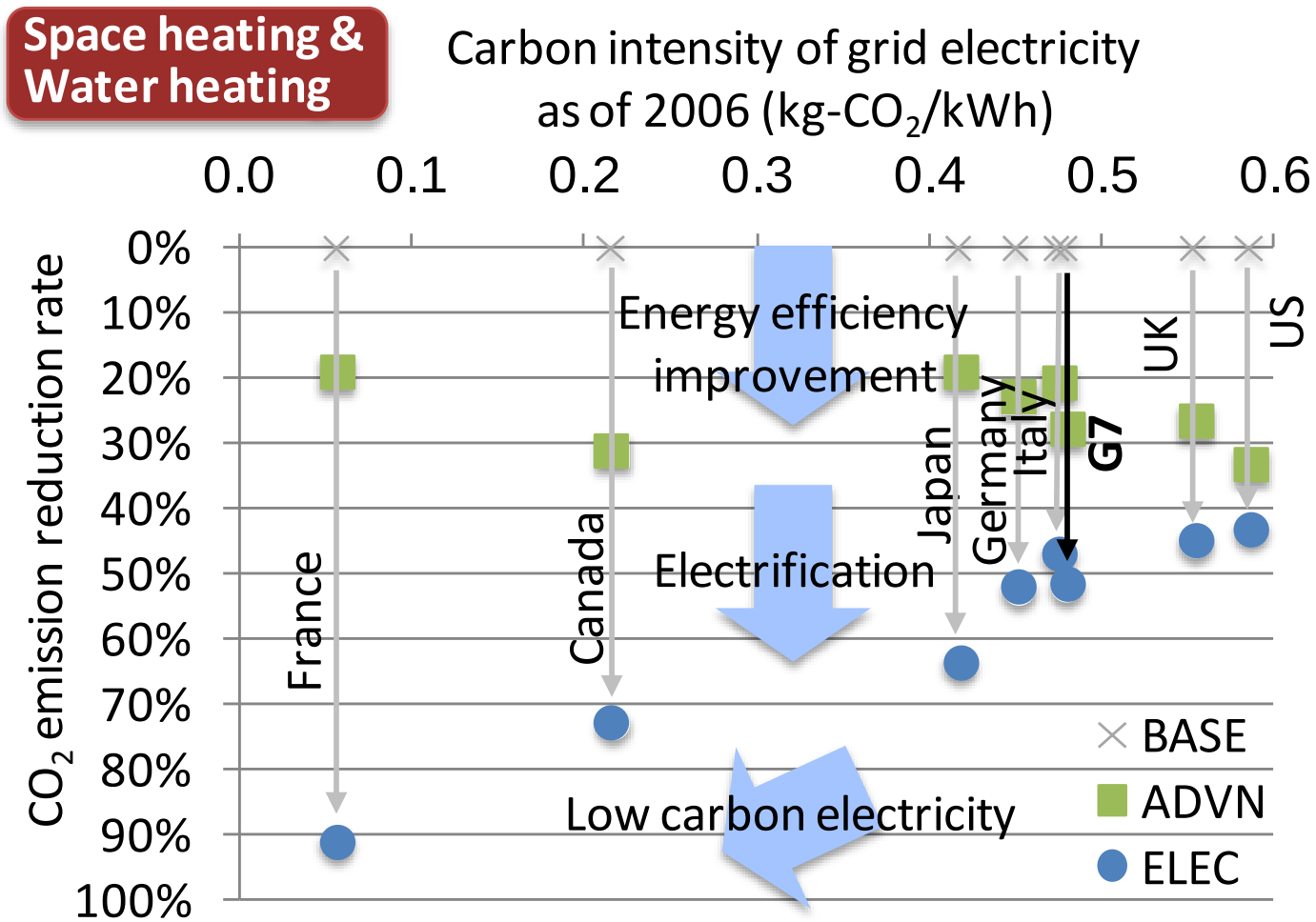


IEA Energy Balance

World electrification rate to increase under mitigation scenarios

Study	Year	Electrification rate	
Actual (EDMC 2010)	1990	14.9%	Final energy basis
	2007	19.1%	
Manne &Richels (1990)	2050	36% (BAU) 52% (20% CO2 cut)	Primary energy basis
Sugiyama, T. (2000)	2050	19%（BAU） 44%（500ppm）	Final energy basis
Edmonds et al. (2006)	2050	27%（BAU） 28%(WRE650) 29%(WRE550) 43%(WRE450)	Final energy basis
IEA (2010) Energy technology perspectives	2050	25%(baseline) 32%(BLUE)	Final energy basis

G7 CO2 reduction potential (Nishio and Hoshino 2010): heat pumps



Technologies are improving

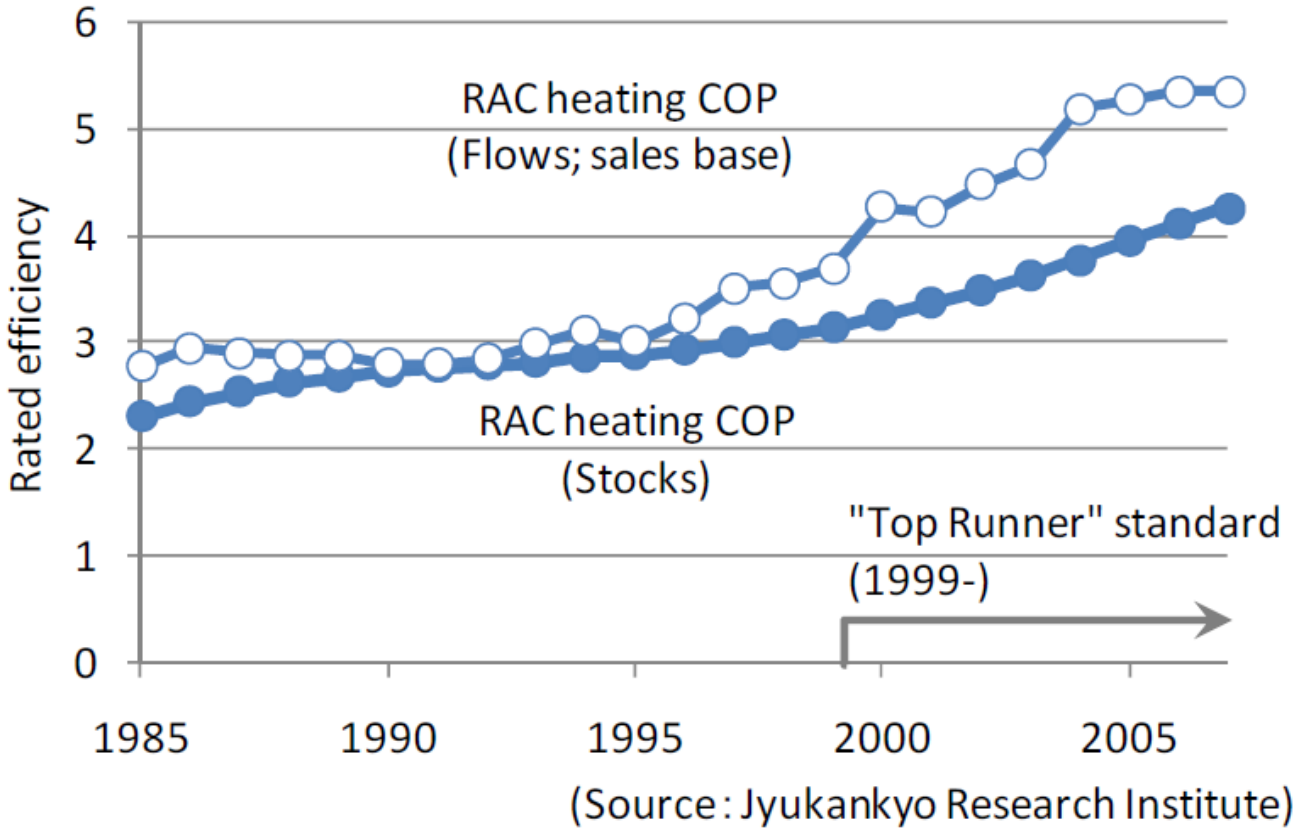
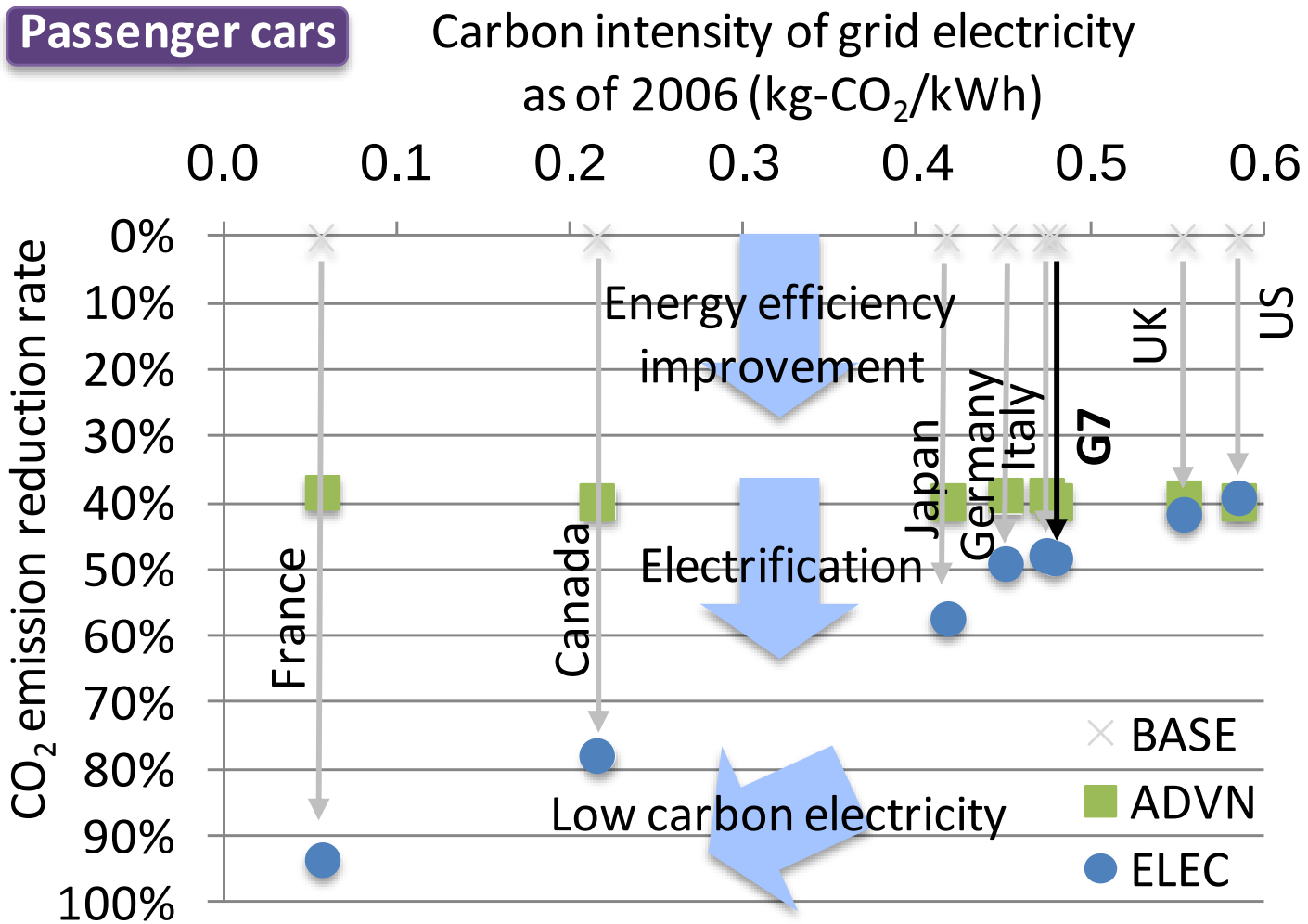


Figure 3: Efficiency of space heating by RACs

Nishio and
Iwafune (2009)

G7 CO2 reduction potential (Nishio and Hoshino 2010): electric vehicles



Increasing interest in end-use electric technologies

- Sample of studies
  - Global: IEA Energy Technology Perspectives (2008, 2010)
  - EU: Eurelectric (2007, 2010)
  - US: EPRI (2009)
  - UK: MacKay (2009)
  - Japan: Nishio and Nagano (2008), Nagata (2009)

2. ES model

Electricity Society Model (ES model)

- Objectives
  - To explore the role of electric technologies in global warming mitigation scenarios

- Electricity Society Model (ES model)
  - Based on Fujii (1992), updated from Taishi Sugiyama (2000)
  - Related models: DNE21+ developed by RITE

- Structure
  - Explicitly treats demand-side technological choice between electric and non-electric technologies
  - Minimizes global, total energy system cost at each time step, including distribution and retail costs
  - Linear programming

End-use electricity

- 13 regions

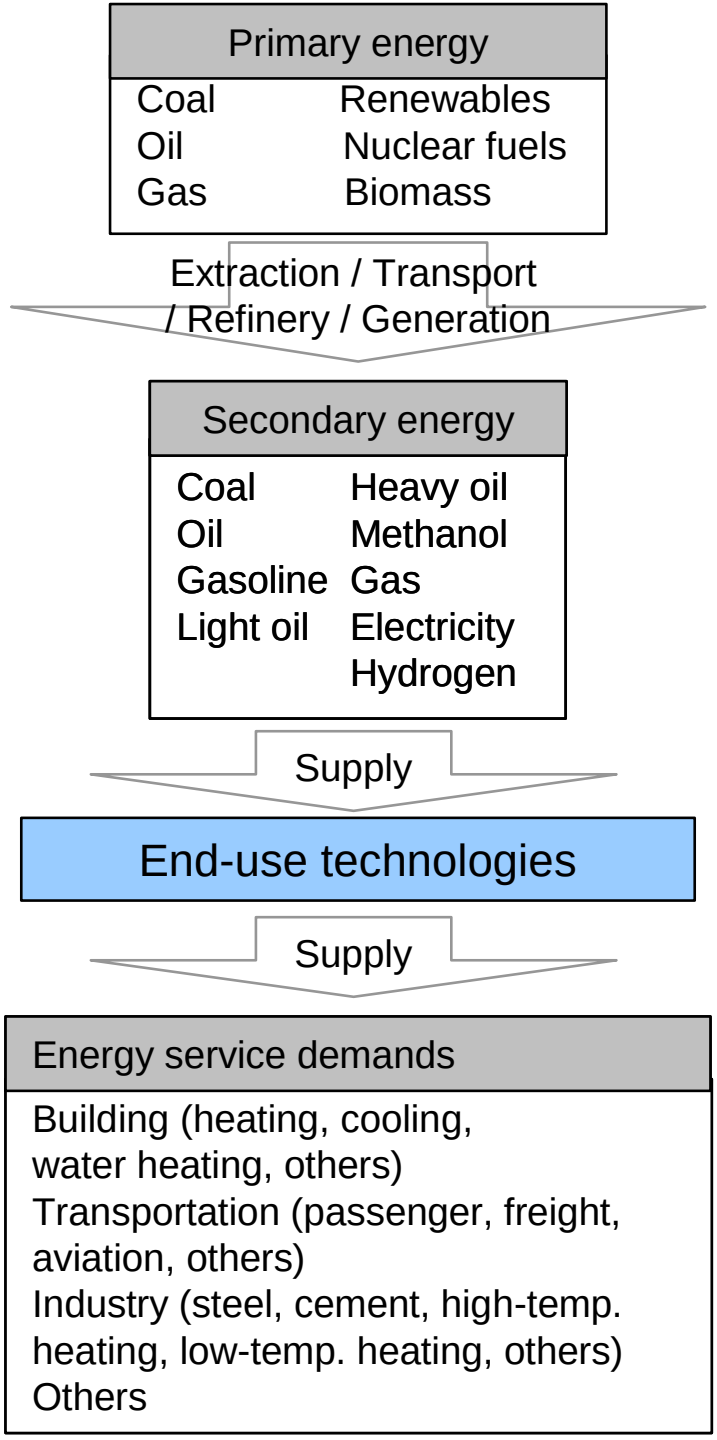
United States	Canada	EU
Australia+New Zealand	Japan	Russia
Eastern Europe	China	Central & South America
Middle East	Africa	India
Asia		

- Periods: 2000-2100 (10-year time interval)

- Forms of energy (end-use)

coal	heavy fuel oil	light fuel oil
gasoline	gas	electricity (inc. biomass)
hydrogen		

- GDP/population — IPCC SRES
- Fossil fuel resources — Rogner (1997)



Sample of end-use technologies

Space heating	Water heating	Passenger vehicles
Air conditioner (Heat pump)	***Heat pump***	Conventional
Electric stove	Electric heater	Hybrid
Gas	Gas	***Plug-in Hybrid***
Light fuel oil	Light fuel oil	***Electric***
Coal	Coal	Fuel cell
Gas CGS	Gas CGS	
Etc	Etc	

Technology choice and implicit discount rate

- Consumers apply high discount rates when making decisions
- We define “Implicit discount rate” as the discount rate observed in the market
- In ES model, the implicit discount rate for buildings and vehicle sectors starts at 30% in 2010 - and assumed to decline to 10% in 2050 by policies

Sanstad et al. (2006, *Managing Greenhouse Gas Emissions in California*)

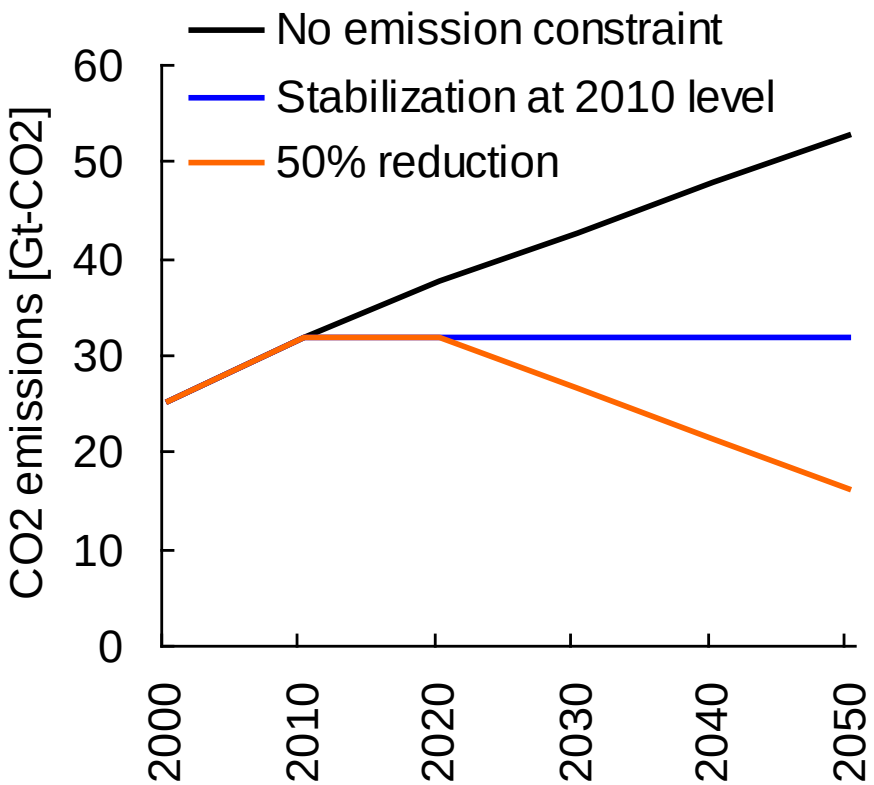
Average Implicit Discount Rates in Energy-Efficiency Investments

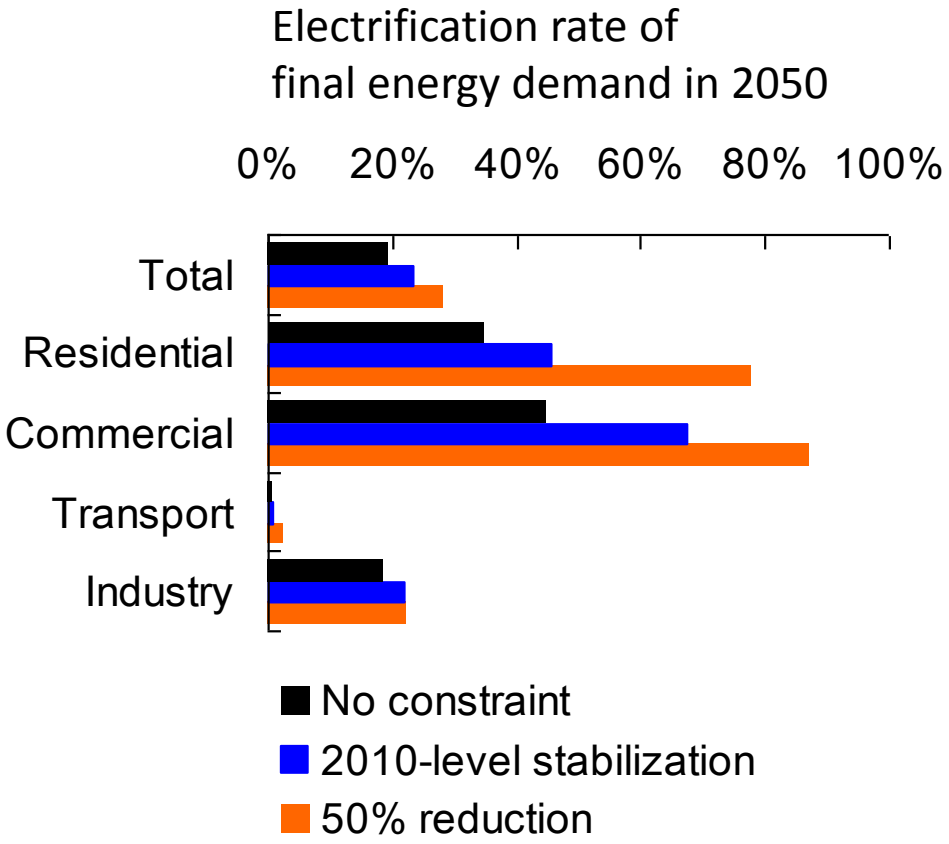
Study	*End-use*	*Average rate*
Arthur D. Little (1984)	Thermal shell measures	32%
Cole and Fuller (national survey, 1980)	Thermal shell measures	26%
Goett (1978)	Space heating system and fuel type	36%
Berkovec, Hausman and Rust (1983)	Space heating system and fuel type	25%
Hausman (1979)	Room air conditioners	29%
Cole and Fuller (1980)	Refrigerators	61-108%
Gately (1980)	Refrigerators	45-300%
Meier and Whittier (1983)	Refrigerators	34-58%
Goett (1983)	Cooking and water heating fuel type	36%
Goett and McFadden (1982)	Water heating fuel type	67%

3. Results

Results:
Electrification under 3 idealized scenarios

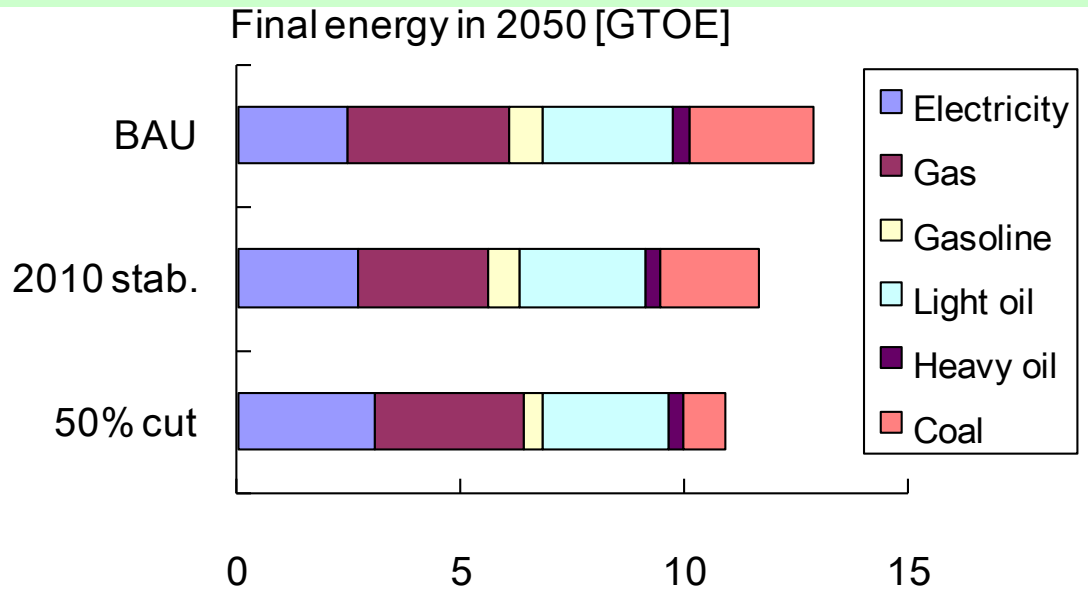
- Stringent emissions targets lead to electrification, particularly in residential and commercial sectors



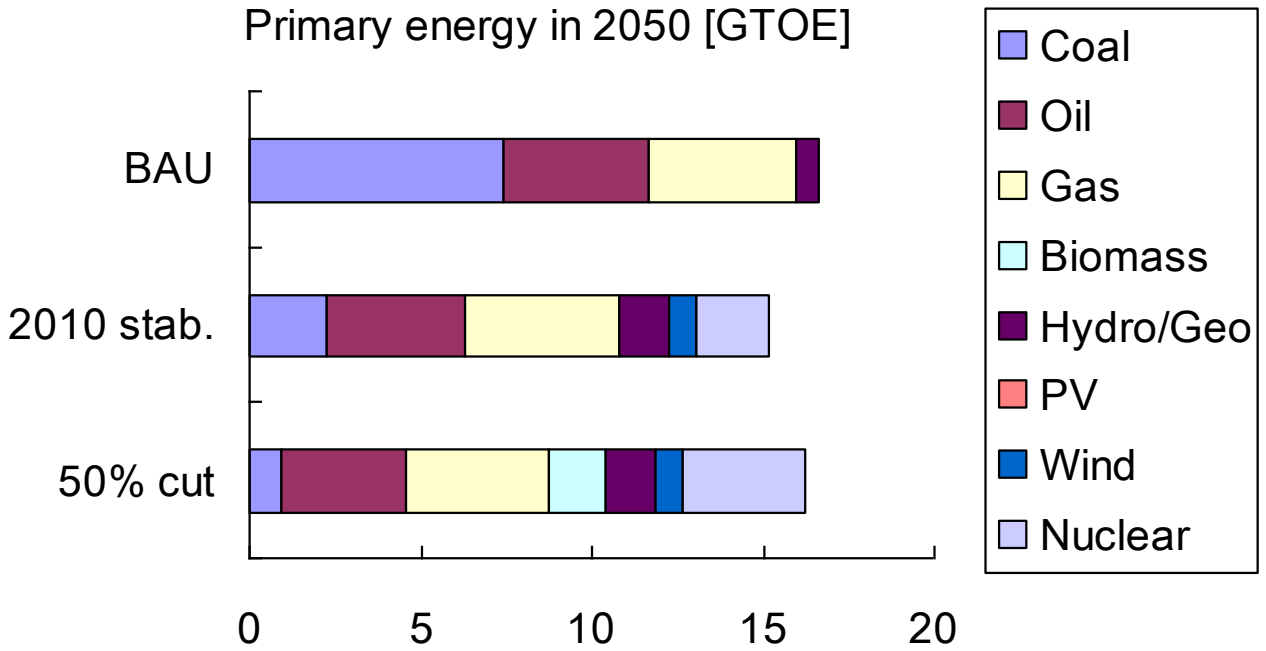


Primary energy and final energy in 2050

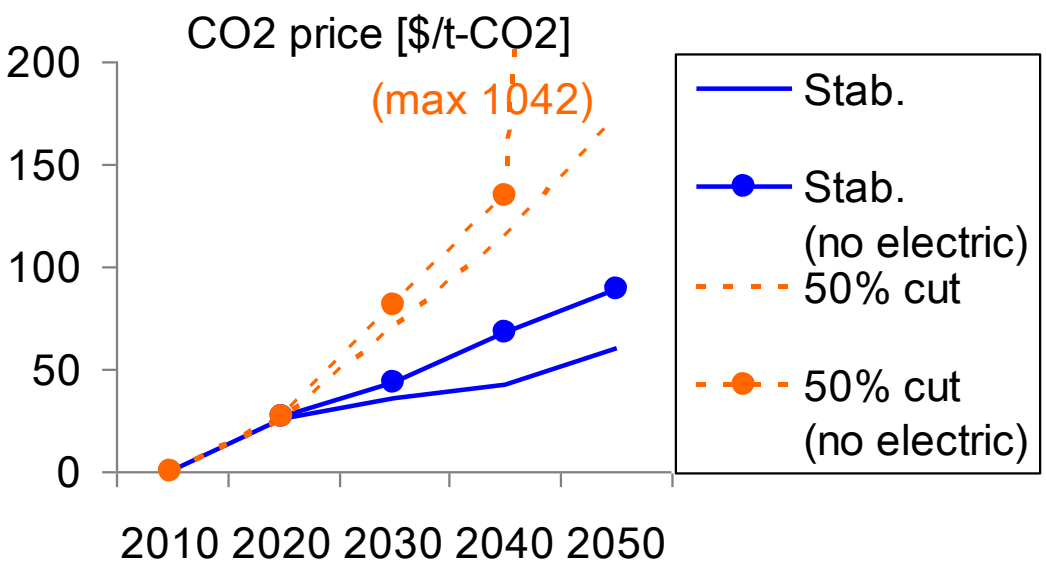
- More emission reductions lead to more electricity at the demand side



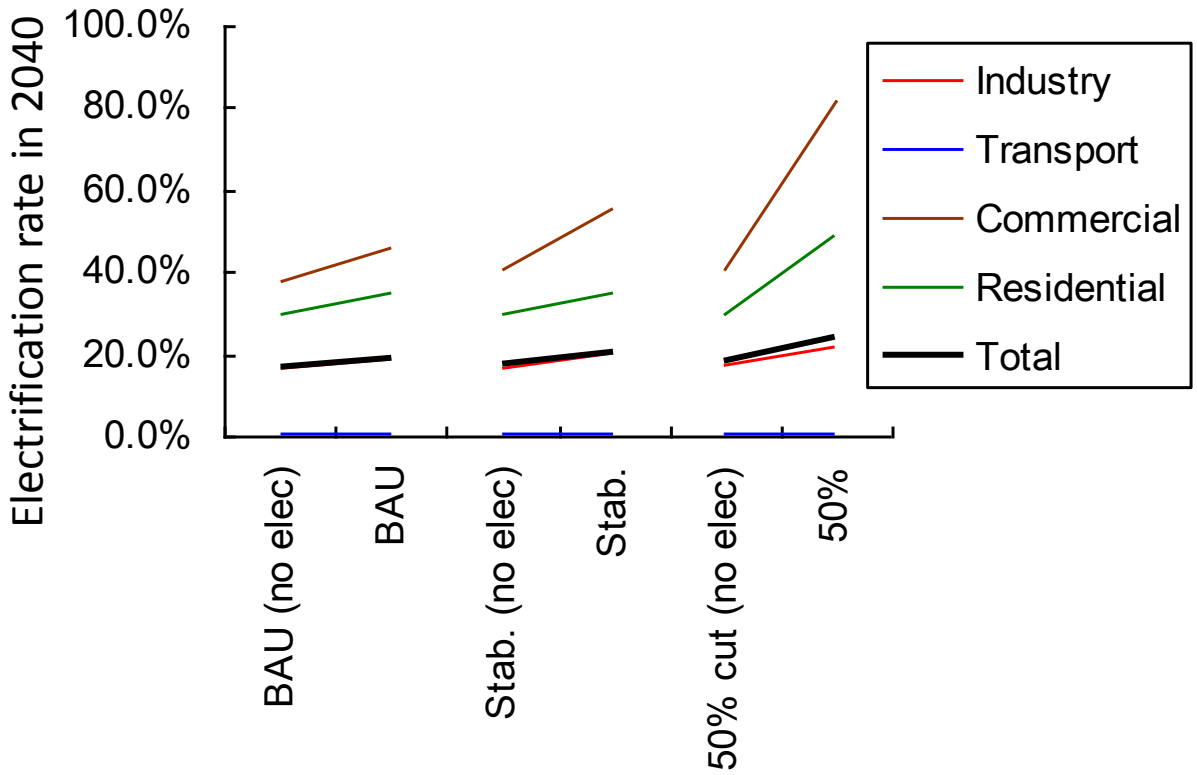
- Simultaneously, electricity supply would be decarbonized



- Without electric technologies, CO2 marginal cost becomes prohibitively high in 2050



- If efficient electric technologies (HP and EV) are excluded, electrification rates remain relatively low



Why is it hard to electrify the transport sector? Sensitivity analysis on electric vehicles

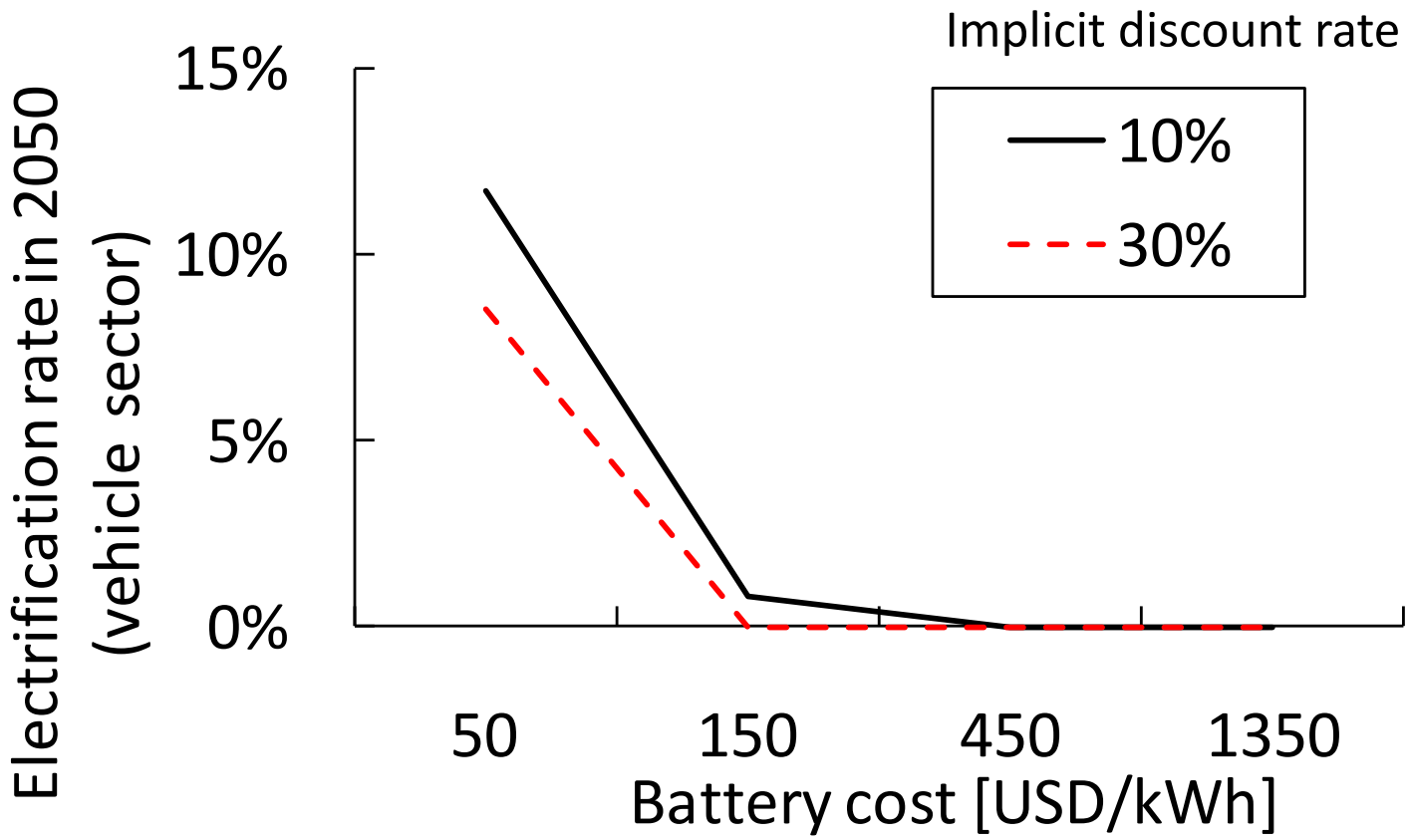
- Change battery costs (which affect HEV, PHEV, EV)

	Additional cost of vehicle (relative to conventional one) in 2050 [USD/vehicle]			
Battery price [USD/kWh]	50	150	450	1350
	NEDO target		CARB (2009) etc	Present
Example: EV (30kWh battery)	3500	6500	16000	45000

CARB: California Air Resource Board

Sensitivity analysis on vehicles: Electrification rate of transport sector

- Batteries matter - Low vehicle costs are prerequisites for electrifying transport vehicle sector



4. Conclusions

Conclusions

- More scenario analyses on electrification are necessary
- Transition from old to new models - improvement of the representation of electric end-use technologies is under way in models
- A review of global scenarios & models with emphasis on electrification would be fruitful (who does it in what coordination?)
- Comparative model runs will be fruitful for the improvement of models. (Energy Modeling Forum / other arena?)