A pathway design framework for sectoral deep decarbonization: the case of passenger transportation

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Séminaire PSL en Economie de l'Energie

Introduction

- Net-zero CO_2 emissions required by mid century to meet the well-below 2C objective of the Paris Agreement (IPCC, 2018)
- Transport sector : around 25% of total energy CO_2 emissions - deep decarbonization of this sector critical
- From -50% to -90% emission reductions in 2050 compared to 2010 in existing 1.5C scenarios
- However, current NDCs (including most recent updates) unsufficient to meet the long term goal and with limited pledges for the transport sector
- Recent Net-zero emissions pledges by main emitters (70% global emissions and GDP) but generally not supported by detailed policies and roadmaps often without even a long term strategy (economy-wide and sectoral)

Introduction

- Need for **long term low GHG emission development strategies** :
  - Designed at country level
  - To reconcile medium term action with long term objectives
  - Economy-wide systemic perspective with detailed sectoral transformations
- Passenger transport : **a mix of common options accross countries** (rapid diffusion of efficient low carbon vehicles and decarbonised fuels, modal shift towards public and non-motorised transport - cycling and walking, and changes to urban systems design and use to reduce mobility needs) but practical implementation and **detailed sequencing over time still unexplained in policy debates** (Creutzig et al., 2015)
- **'Backcasting' pathways** from a desired future towards present conditions to identify the underlying **drivers and enabling conditions for the transformations** needed, and the required **policy packages** to address **inertia**, **lock-ins** and **innovation** (Waisman et al., 2019)

Introduction

Policy relevant decarbonization pathways for passenger transportation should :

- **Explore a broad range of drivers** including individual behaviours, lifestyles, societal and spatial organisation (social dynamics underlying mobility of passengers), infrastructures and technological change
- **Articulate visions/expectations of multiple stakeholders** (individual consumers, urban planners, car industry, etc.) differing in aim and scope
- **Explicit linkages with non-climate goals** (access to affordable mobility, improvement to quality of life, etc.)

Objectives of the paper

1. Develop a design and comparison framework of deep decarbonization pathways for passenger transportation
2. Show illustrative application to four countries (Japan, the UK, Mexico and France) to derive cross-cutting insights

Methodological challenges

- A rich literature on national decarbonization scenarios for the transport sector (Gota et al., 2018) mostly derived from **integrated assessment models** (IAMs), **energy-economy models** with transport modules or **transport-energy models** (Pietzcker et al., 2014 ; Yeh et al., 2017)
- Provide insights on a range of low carbon futures based on the **Avoid-Shift-Improve** (ASI) paradigm (Bongardt et al., 2013)
- But narratives and modelling **focus on technological transformations** and underlying drivers **ignoring key drivers related to social practice, spatial organisation, and infrastructure change** ; emphasis on supply-side technological solutions with limited contribution from reduced mobility demand and modal shift (Edelenbosch et al., 2017)
- A limited number of modelling studies have explored the impact of demand-side drivers on decarbonization (Anable et al., 2012 ; Brand et al., 2018 ; Girod et al., 2013a)(AIE, 2021)
- **Limitations for direct use of modelling studies in policy/stakeholders debates** : 'black box' effect, difficulty to reflect qualitative narratives, lack of flexiblity to reflect alternative visions

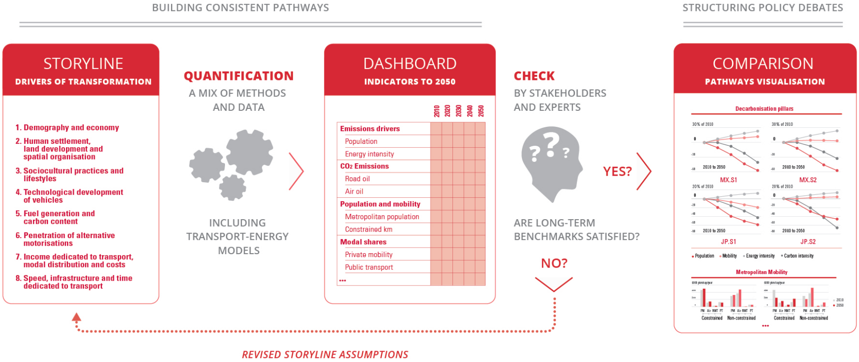
Methodological challenges

Combined qualitative-quantitative participatory methods to address challenges :

- **Narratives**, as coherent stories of the future, allow the creative process of investigating contrasted futures driven by alternative combinations of drivers and policies and identifying causal linkages and interdependencies (Banister and Hickman, 2013 ; Soria-Lara and Banister, 2018, 2017)
- **Quantification of the narratives**, including the description of the physical, economic and social characteristics of pathways can be based on numerical models (Fortes et al., 2015 ; Garb et al., 2008 ; Robertson, 2016) or other quantitative techniques (Varho and Tapio, 2013)
- In practice : participatory construction of narratives, identification of drivers and translation into quantitative parameters to use in models (Venturini et al., 2019)

→ Towards a framework with enhanced features for iterative development and quantitative assessment of scenarios + exploring transportation pathways that explicitly recognise underlying demand-side and technological drivers together, under transitions towards deep decarbonization

A pathway design framework for passenger transport deep decarbonization



Building qualitative storylines considering the full set of decarbonization drivers

- Based on existing storylines methods adapted to deep decarbonization context
- **Address ASI pillars** : What role for a reduction of mobility demand ? Reduction of energy intensity of mobility due to vehicle efficiency, modal shift, higher occupancy rate of vehicles ? Decarbonization of fuels ?
- **Go deeper in exploring complex underlying drivers accross ASI pillars** for a richer discussion of the policy-relevant conditions, option levers, uncertainties and potential transformations over time : For which household situations, in which geographical context, for which trip purpose, for which distances, and at which speed and cost, would people shift from private car to public transport ?
- **Connect to non-climate objectives** : mobilility access, quality of life, affordability, health, etc.
- **Eight categories of influencing drivers**

→ A detailed and consistent description of the interactions between drivers and their impacts towards deep decarbonization of transport

Deriving full quantified pathways

- **No single energy-transport model usually captures all dimensions of the storylines** : demographic profile, the geography of urban spaces, urban planning, consumer preferences and their impact on travel demand, etc.
- Using a **comprehensive data template with variables accross all dimensions informed from various sources** : a combination of modelling runs and out-of-the box assessments and expert-based assumptions
- Examples :
  - Travel surveys to project future patterns of mobility demand
  - Modal choice model (Pye and Daly, 2015)
  - Energy model to explore the transport supply side (vehicle stock, fuel use, etc.)
- Quantitative implications of qualitative drivers sometimes based on proxies
- Full quantitative information collated in the data template designed to be self-consistent (check points for consistency amongst intermediate indicators)
- Flexible approach for transparent sensitivity analysis of main uncertain aspects

Using a standardised quantitative dashboard for iterative backcasting and comparison

Characteristics

- **Summary description of quantitative pathways** using policy-relevant indicators
- **Align accounting measures** to get common understanding and comparables results
- **Inform key questions posed by different stakeholders**(beyond ASI decomposition) : e.g. about mobility patterns across geographies, evolution of car sales, individual transport budget, etc.

Objectives

- **A tool for transparent dialog between stakeholders** : comparing how different policy objectives are met under alternative pathways, framing policy interventions, discussion on the plausibility of transformations
- **The corner stone for an iterative construction of pathways**
- Summary of pathways in a common language for **comparisons, benchmarking and learning accross country** perspectives

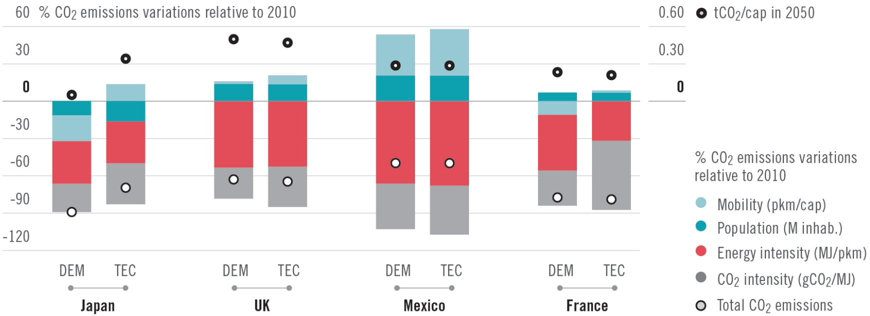
Using a standardised quantitative dashboard for iterative backcasting and comparison

Passenger Transport Indicators	Units	2010	2020	2030	2040	2050
Aggregated drivers of decarbonization						
Average individual emissions due to 1km-trip	gCO2 / pkm	105	82	55	38	26
Average yearly distance travelled per capita	pkm / cap	13 787	13 519	12 879	11 986	11 182
Average individual energy consumption due to 1km-trip	MJ / pkm	1.4	1.2	0.9	0.7	0.6
Average carbon emissions due to 1J of energy consumption	gCO2/MJ	73	70	62	53	42
Energy supply transformations						
Oil consumption	EJ	1.2	0.9	0.6	0.4	0.2
Electricity consumption	TWh	6.5	9.7	21.6	32.3	40.3
Natural gas consumption	EJ	0.00	0.00	0.00	0.01	0.005
Hydrogen consumption	EJ	0.00	0.00	0.00	0.00	0.000
Biofuels consumption (biodiesel, bioethanol, biomethane, biokerosene)	EJ	0.03	0.06	0.08	0.08	0.083
Modal transformations						
NMT (non motorized)	% of total pkm	2%	4%	7%	9%	11%
Public mode (bus, rail)	% of total pkm	13%	15%	19%	21%	23%
Private mode (car, 2/3W)	% of total pkm	72%	69%	64%	61%	57%
Air	% of total pkm	12%	12%	11%	10%	9%
Contrained mobility and spatial organization						
Individual daily average distance travelled	km/day/cap	15.8	15.0	14.1	12.7	11.5
Individual daily average travelling time	min/day/cap	34.6	35.0	36.3	34.0	32.4
Household revenue share dedicated to mobility	% of household revenues	17%	17%	13%	10%	8%
Infrastructures						
Gas refueling stations	1000's of units	0.008	0.026	0.111	0.185	0.210
Charging stations	1000's of units	1009.5	1501.4	3359.0	5011.7	6266.4
New mobility capacity created	New Gpkm capacity / 10-year period	0	-629	-1228	-2751	-4274
Zoom on private car mobility transformations						
Average number of vehicles per 1000's inhab.	Nb of veh / 1000's inhab.	510	500	434	373	319
Low Carbon Car stock (under 4l / 100 km, eq. 100gCO2/vkm)	Mio vehicle	0.0	0.8	5.2	18.4	19.9
Share of electric vehicles in low carbon vehicle stock	% of electric in low carbon stock	0%	100%	97%	49%	60%
Household revenue share dedicated to CAR mobility	% of household income	16%	17%	12%	10%	7%
Zoom on Metropolitan areas transformations						
Metropolitan daily average distance travelled	km / day / cap	13.1	12.6	12.1	11.3	10.7
Metropolitan daily average travelling time	min / day / cap	35.8	36.3	37.1	35.3	34.1
New urban spaces allocated to public road + parking	km2	0.00	-15.00	-15.00	-15.00	-15.00
New urban spaces allocated to BRT + NMT	km2	0.00	0.22	0.29	0.27	0.28
PPMC indicators						
CO2 emissions of Metropolitan areas	MtCO2	19	15	10	7	5
Electricity carbon content	gCO2 / kWh	64.9	40.5	25.0	21.9	21.9
Private car - wtw emission intensity	gCO2 / vkm	168	139	98	67	42
Rail - wtw emission intensity	gCO2 / pkm	12	10	7	6	4
Aviation - wtw emission intensity	gCO2 / pkm	139	136	126	119	115
Car mobility demand	Gvkm	417	375	326	295	263
CO2 price	$ / tCO2	0	30	100	230	360

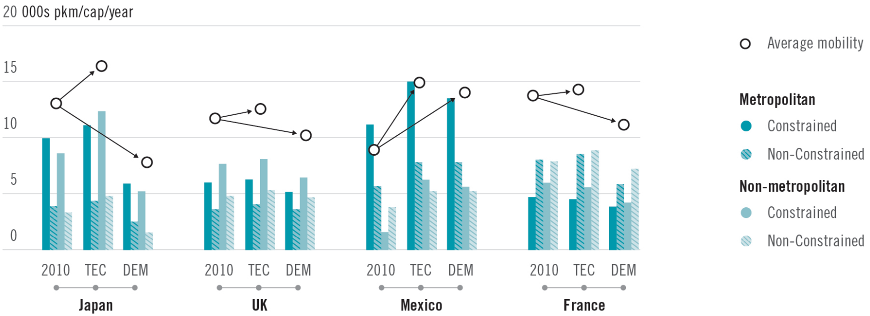
Application to Japan, the UK, Mexico and France

Country	Scenario type	Scenario name in country study	Brief description	CO_2 red. in 2050 (rel. 2010)
Japan	TEC	AdvancedTech (ADV)	Focuses on technical transformations in the transport and energy sector, with restricted consideration of societal demand-side changes	-69%
	DEM	Balanced (BAL)	Similar to ADV, but with an emphasis on social changes, such as urban structure, lifestyle and infrastructure	-89%
UK	TEC	Freedom to Roam (F2R)	Supply side focused rooted in the development of new technologies (notably autonomous vehicles) with patterns of mobility demand similar to those seen today	-65%
	DEM	No Place Like Home (NPLH)	Technology development shifts mobility trends towards a sharing services model with greater use of other modes of transport, particularly in metropolitan areas	-63%
Mexico	TEC	Technological (TEC)	Focuses on technological options, but not demand reduction measures, as in DEM	-50%
	DEM	Demand (DEM)	Focuses on demand reduction from changes in urban organisation and accessibility, inequality reduction, and behaviour of commuters on top of technologies	-50%
France	TEC	Technology-First (TECH-F)	Assumes current mobility trends and favours technological innovations and low carbon technologies over systemic change	-79%
	DEM	Mobility-First (MOB-F)	Prioritises social, organisational and technical transformations of the mobility systems while subsequently exploring technological contribution to deep decarbonization	-77%

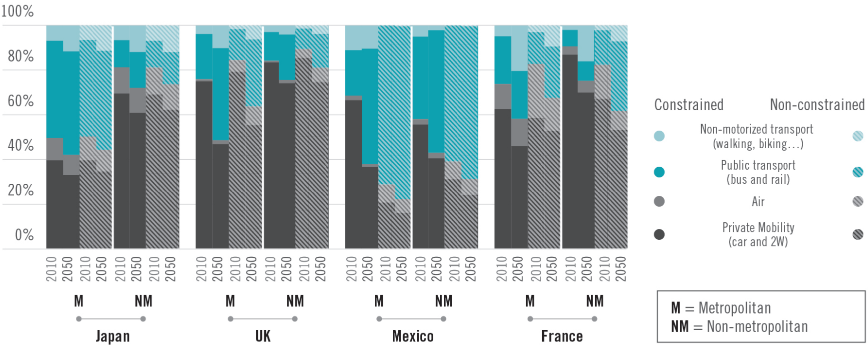
Decarbonization potential and pillars



Mobility demands

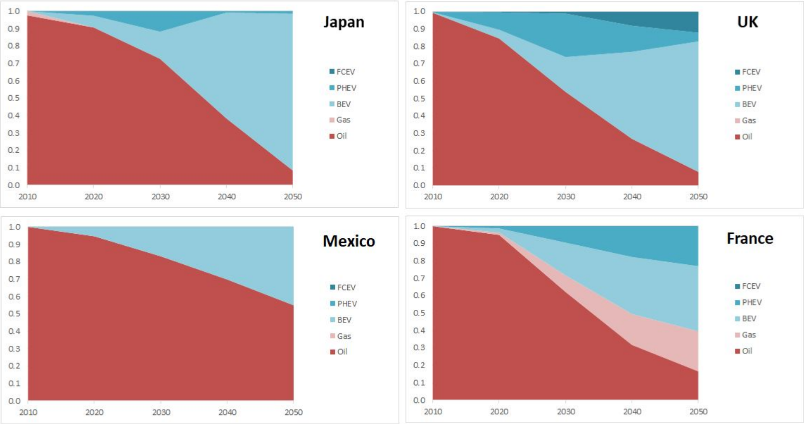


Modal shift

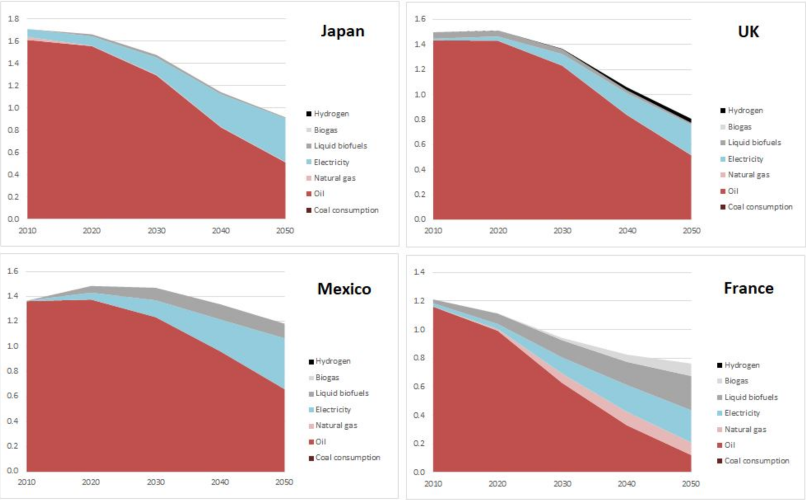


100%
80%
60%
40%
20%
0%
2010
2050
M
NM
Japan
UK
Mexico
France
Constrained
Non-constrained
Non-motorized transport
(walking, biking...)
Public transport
(bus and rail)
Air
Private Mobility
(car and 2W)
M = Metropolitan
NM = Non-metropolitan

Technology deployment : LDV fleet structure in TEC scenarios



Final energy consumption (EJ) in TEC scenarios



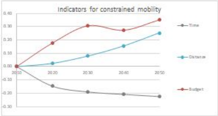
Difference of car sales and stock between TEC and DEM scenarios in the UK

TEC & DEM | **TEC** | **DEM**

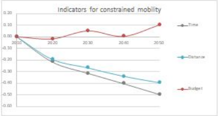
Convenience and costs

Japan

TEC

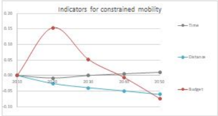


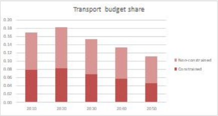
DEM



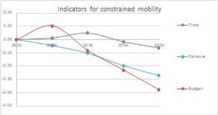
France

TEC



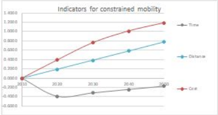


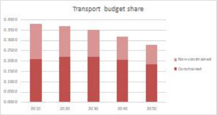
DEM



Mexico

DEM





Discussion/Conclusions

A new approach to decarbonization analysis

- Understanding deep decarbonization of the passenger transport sector requires **a novel conceptual approach that articulates metrics across diverse dimensions** (social, economic, energy, etc.) : in particular, by incorporating the factors impacting mobility trends - uncertainties around social practice or opportunities for policy to shape urban design and alternative transport systems - a much richer picture of the challenges and opportunities emerges
- *Cross-cutting insights from the application* :
  - **Significant potential for reduced mobility demand and modal shift** to reduce energy consumption and emissions - typically underexplored
  - **Decarbonization can be consistent with satisfying mobility needs in all countries**, while demand-side actions can help alleviate time and monetary burden of constrained mobility
  - **Different strategies see stronger potential in different country contexts**, according to policy and development goals, demographic characteristics, spatial organisation, and socio-cultural practices

Discussion/Conclusions

A framework to structure stakeholders and policy debates

- **Organizing principles** to enable the development of a shared definition of deep decarbonization strategies : to inform national public debates, to support planning and target-setting exercises - such as the NDCs, to be used by cities, corporations or NGOs to design their own scenarios, for international collaboration projects, etc.
- Key benefit of the approach : **transparency** which allows for a wide range of stakeholders to scrutinize assumptions and test alternatives
- **Challenges for practical co-production of pathways** in actual stakeholder processes
- **Need for an additional policy layer** in order to connect more explicitly the pathways to the specific policies consistent with meeting the goals
- Framework that could be adapted to other sectors : e.g. freight transport, industry

Merci pour votre attention !

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