



Challenges in accelerating net-zero transitions: insights from transport electrification in Germany and California

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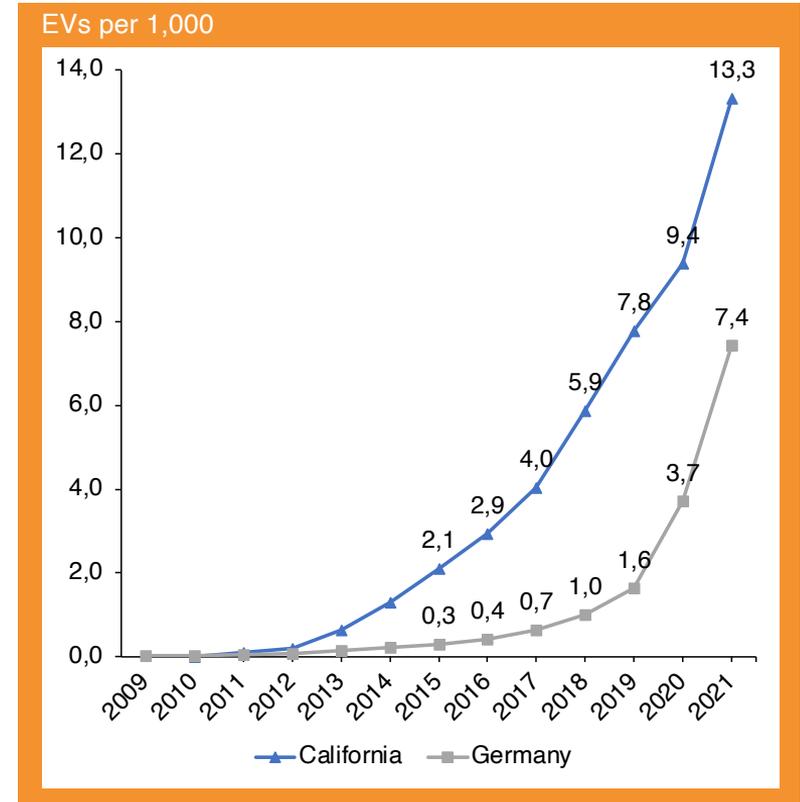
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Motivation & case introduction

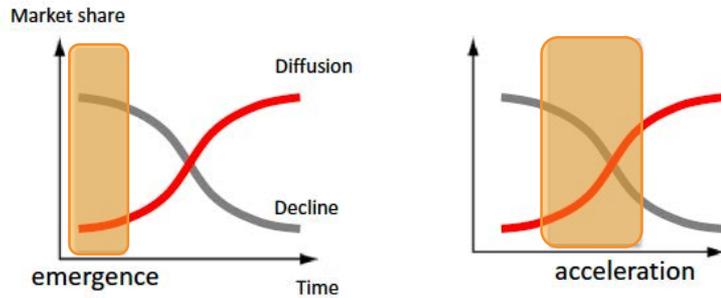
Electrification of passenger-based transport in Germany and California

- Climate neutrality calls for transport sector decarbonisation, with limited progress so far
- Electrification as key net-zero strategy
- Germany and California are
 - often viewed as climate policy leaders
 - with ambitious e-mobility targets
 - but differences in automotive incumbency
 - EV adoption is **accelerating** (but still low level)



What are acceleration challenges?

Markard, Geels and Raven (2020)



- Whole system change
- Interactions between multiple systems
- Decline and resistance
- Consumers and social practises
- Governance

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Challenges in the acceleration of sustainability transitions

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Table 1. Overview of acceleration challenges.

Five challenges	Description	Example	Policy implication
Whole systems change	Major changes in system architecture	Decentralization of electricity supply	Focus on entire systems instead of singular innovations
Interaction between multiple systems	Increasing changes in the interaction of multiple systems	Electrification of transport, heating, industry etc.	Overarching missions; non compartmentalized policy making
Decline and resistance	Decline of existing industries and businesses	Traditional car industry, coal fired power generation	Create social acceptance; forge winning coalitions; compensate losers
Consumers and social practices	Major changes in consumer practices and demand patterns	Sharing economy	Stimulate technology adoption, behavioral change and learning-by-using processes
Governance	Increasing complexity of governance	Multi-level governance between European Commission and member states in Energy Union package	Context specific policy mixes; policy sequencing; stronger vertical and horizontal policy coordination

3 additional acceleration challenges

Extending Markard, Geels and Raven (2020)

- **Expansion and contestation**

(Meadowcroft, 2009; Geels, 2014; Raven et al. 2016; Lockwood 2016; Rohde and Hielscher, 2021; Kivimaa and Rogge 2022)

- **International dynamics**

(Binz and Truffer, 2017; Kern and Rogge, 2016; Meckling et al., 2015)

- **Justice**

(Heffron and McCauley, 2018; Green, 2018; Abram et al., 2022; Stark et al., 2023)

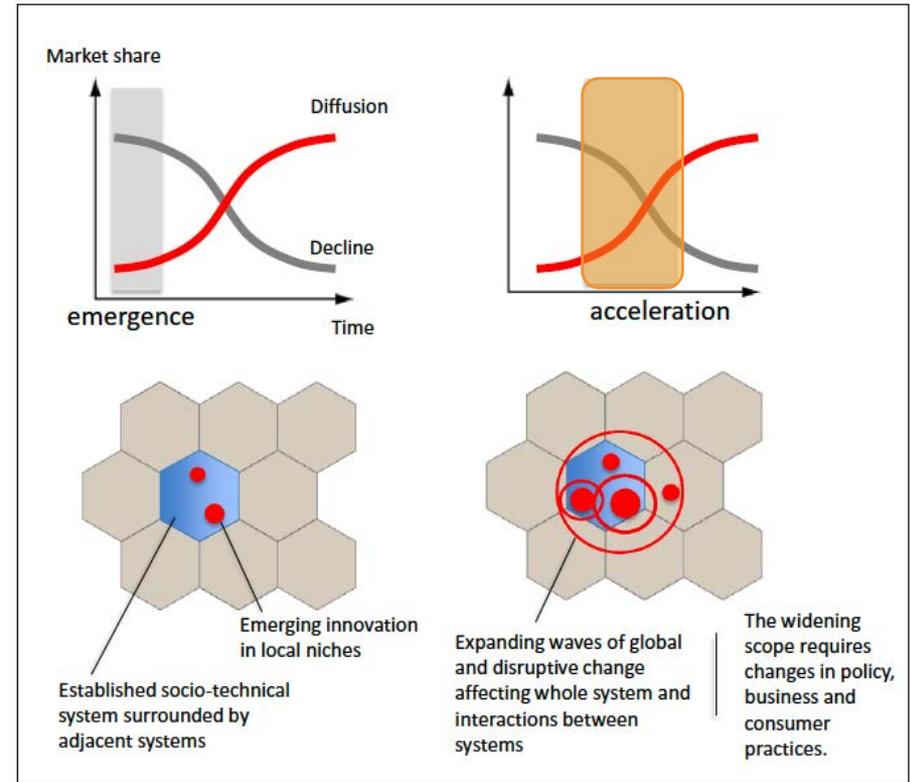


Figure 1. Differences between emergence and acceleration in transitions.

Analytical framework

Extended typology of challenges in the acceleration phase of net-zero transitions

No	Challenge type	Description	Examples	Policy implications
1	Whole systems change	Major changes in system: complementary interactions between multiple innovations, fundamental changes in system architecture	Decentralization and intermittency of electricity supply (e.g., PV) requiring enabling technologies (e.g. storage, grids)	Focus on entire systems instead of singular innovations, support experimentation with socio-technical system change instead of sole focus on technology change
2	Multi-system interactions	Increasing changes in the interaction of multiple systems, with a focus on tensions in multi-system interactions	Electrification of transport, heating, industry; digitalisation of vehicles and grids; mining impact of shift to EVs	Overarching, cross-cutting missions; non-compartmentalized, more integral policy making; multi-system task forces
3	Decline and resistance	Decline of existing industries and businesses, and multi-actor resistance to such decline	Petroleum industry, traditional combustion engine supply chain, and impacted shareholders, regions, unions, and politicians	Support structural change and reskilling of work force, create social acceptance, forge winning coalitions, compensate losers
4	Expansion and contestation	Contestations around the expanding trajectory, incl. framework conditions for new mass markets, securing future market shares and gains	Debates around ownership of charging stations and battery data, friction around manufacturers' focus on large EVs	Update electricity market designs, regulate data access, set product standards, incentivize faster portfolio shifts to clean tech
5	Consumers and social practices	Major changes in consumer practices and demand patterns	Home charging instead of refuelling at petrol station, car sharing, shifting from car-only towards multi-modal transport	Stimulate technology adoption, behavioural change and learning-by-using processes; enable new business models; adjust planning
6	Justice	Multi-dimensional justice implications of system changes and affordability of new technologies for low-income households	Access to affordable charging for multi-unit housing, availability of affordable EVs (e.g., used car market)	Include a broad justice approach in policy design and evaluation, tailor policies to low-income households
7	International dynamics	Global interplay driven by international competition, pioneering countries, geopolitical risks, and changes in global value chains	IRA incentivizing US battery production, Chinese OEMs entering foreign EV markets, securing critical raw materials	Renewed focus on green industrial policy, strategic resource partnerships, free trade clubs among like-minded partners
8	Governance	Increasing complexity of governance, policy paradigm change towards greater policy intervention	Multi-level collaboration in charging infrastructure roll-out; new e-mobility tasks for electricity market and grid regulators	Stronger vertical and horizontal policy coordination, governance reform, policy mixes for creative destruction, policy sequencing

Source: Building upon and extending Markard et al. 2020

Acceleration phase meets multi-system case

Electrification of passenger-based transport in Germany and California

- **Qualitative, comparative case study on perceived acceleration challenges**
- **Main data source: expert interviews in autumn 2022**
 - **California: 19**
 - **Germany: 16**
- **Guiding question: *“What are the 2-3 most pressing issues, which, if resolved, would help accelerate the widespread electrification of private-vehicle transportation?”***
- **Analytical steps:**
 - **bottom-up coding, challenge identification, clustering**
 - **top-down coding (challenge types)**
 - **comparative analysis**

Identification, analysis and cross-case comparison of acceleration challenges

California

Germany

#	Theme	Subtheme	ID	Interviews	Name of real-world acceleration challenge
1	Policy	Policy strategy (cross-cutting)	DE.P.1	15	Limited implementation (and weakening of transport) policy strategies
2	Policy	Policy strategy (cross-cutting)	DE.P.2	8	Need to rethink industrial policy for climate-neutral global competitiveness
3	Policy	Policy strategy (cross-cutting)	DE.P.3	4	Acceleration requires dealing with various trade-offs (e.g. nature protection, energy security)
4	Policy	Policy making	DE.P.4	6	Complaints about limited stakeholder participation (timing, format, inclusiveness)
5	Policy	Policy making	DE.P.5	6	Complex multi-system transition requires changes in mindset, organisation and policy style
6	Policy	Policy making	DE.P.6	5	Strong lobbying power of various incumbents weakening policy mix
7	Policy	Governance	DE.P.7	13	Weaker policy mix due to within government cross-party conflict (mainly BMWV-BMDV)
8	Policy	Governance	DE.P.8	4	Challenges for ministers in multi-system transitions (silos, coordination delays, skills, learning)
9	Policy	Governance	DE.P.9	3	Low mobility acceleration penetration from multiple well-coordinated vertical governance levels
10	Vehicle-side	Policy strategy (specific)	DE.V.1	6	Reaching target of 15 million EVs by 2030 requires acceleration
11	Vehicle-side	Instruments	DE.V.2	8	Design changes and partial phase-out of EV premium with unclear effects ("Umweltbonus")
12	Vehicle-side	Instruments	DE.V.3	7	New EU fleet emission standards increase urgency in 2025, and higher interim ambition unlikely
13	Vehicle-side	Instruments	DE.V.4	5	Path security through EU E-co phase-out 2035 (but hampered through e-fuels loophole)
14	Vehicle-side	Instruments	DE.V.5	4	Tax privileges for company cars insufficiently drive EV adoption and over-incentivise plug-in hybrids
15	Vehicle-side	Instruments	DE.V.6	2	EURO 7 norm limiting exhaust emissions is contested, but could indirectly benefit EVs
16	Vehicle-side	EV supply	DE.V.7	9	Limited supply of smaller EVs (aparticularly by German OEMs)
17	Vehicle-side	EV supply	DE.V.8	7	Long delivery times of EVs (and limited model variety)
18	Vehicle-side	EV supply	DE.V.9	7	Short-term and long-term supply chain issues for EVs
19	Vehicle-side	Batteries	DE.V.10	8	Building and catching up EU based battery production
20	Vehicle-side	Batteries	DE.V.11	6	Rare material dependency as key challenge
21	Vehicle-side	Batteries	DE.V.12	3	Building up battery recycling as future industry
22	Vehicle-side	Transformation	DE.V.13	6	Transformation of automotive industry to smart e-mobility
23	Vehicle-side	Transformation	DE.V.14	2	Uncertainty about Chinese OEMs competing in German/European market
24	Vehicle-side	Transformation	DE.V.15	5	Political debate about e-fuels increasing EV investment uncertainty
25	Vehicle-side	Transformation	DE.V.16	2	Maintaining German competitiveness and market shares in global markets
26	Vehicle-side	EV demand	DE.V.17	6	Increasing costs for EVs and electricity limit attractiveness
27	Vehicle-side	EV demand	DE.V.18	5	While car is socio-culturally embedded, ongoing urban mobility niche experiments
28	Vehicle-side	EV demand	DE.V.19	5	Acceptance issues for EVs, but largely limited to non-users
29	Charging	Policy strategy (specific)	DE.C.1	8	Contestation around undifferentiated 1 million charge points target by 2030
30	Charging	Policy strategy (specific)	DE.C.2	2	Contestations around updated national grid roadmap for charging ("Masterplan 2")
31	Charging	Infrastructure	DE.C.3	15	Building up (public) charging infrastructure major, multi-faceted and contested task
32	Charging	Infrastructure	DE.C.4	2	Supply chain issues affect charging infrastructure expansion
33	Charging	Infrastructure	DE.C.5	2	Minimal technical requirement increases equipment costs
34	Charging	Infrastructure	DE.C.6	6	Local governance level juggling multiple challenges around charging with limited resources
35	Charging	Governance	DE.C.7	5	Contestation and delays around fast charging ("Deutschlandnetz")
36	Charging	Governance	DE.C.8	2	Inefficient provision of public spaces for charging (despite online tool)
37	Charging	Smart charging	DE.C.9	6	Bi-directional charging: from buzzword to implementation for enhanced flexibility
38	Charging	Smart charging	DE.C.10	4	Regulation needed for enabling flexible charging
39	Charging	Buildings	DE.C.11	5	Charging at multi-family housing ("Letztgenossenschaft")
40	Charging	Buildings	DE.C.12	2	Buildings upgrading to enable full participation in new cross-sectoral business models
41	Grid-side	Expansion	DE.G.1	5	Urgent need and need for storytelling supporting grid optimisation and extensions
42	Grid-side	Expansion	DE.G.2	2	Long timelines and delays for transmission grid extensions (not only due to slow permitting processes)
43	Grid-side	Expansion	DE.G.3	2	Need to improve public acceptance for grid expansion projects
44	Grid-side	Expansion	DE.G.4	3	Hampering the potential of digitalisation in smart grids
45	Grid-side	Expansion	DE.G.5	4	Acceleration complicated by high number of distribution system operators
46	Grid-side	Governance	DE.G.6	2	Need for fast, digital, and simple distribution grid access
47	Others	Electricity generation	DE.O.1	9	Ambitious renewables expansion targets but many challenges on the ground
48	Others	IT	DE.O.2	4	Balance data security demands with advancing (the delayed) smart meter roll-out
49	Others	IT	DE.O.3	4	EU data act needed for level playing field in electrification of transport
50	Others	IT	DE.O.4	1	Shortcomings of digital strategy for e-mobility
51	Others	Equity	DE.O.5	6	Affordability of EVs important to ensure a just transition
52	Others	Equity	DE.O.6	4	Slow start of market for used EVs (and few small cars)
53	Others	Equity	DE.O.7	1	Public funding programs for transport electrification mainly benefit affluent households
54	Others	Equity	DE.O.8	1	Shifting to a resource based economy has global justice implications
55	Others	Labour	DE.O.9	6	Shortage of skilled labour and possibility of just transition through reskilling
56	Others	Labour	DE.O.10	2	Difficult for politicians that some companies may not survive structural change

Comparative analysis

Acceleration challenges
shared by
Germany and California

Acceleration challenges
unique to
Germany

Acceleration challenges
unique to
California

Note on robustness: only challenges with at least 5 mentions included in analysis

Many acceleration challenges shared by Germany and California

Examples

- Establishing domestic battery production capacity
- Fast upgrading and expanding of grids

Similar problem structure

Themes	Sub-themes	Real-world acceleration challenges similar in Germany and California (mentioned by at least 5 interviewees)	ID	Interviews
Policy (cross-cutting)	Policy making	Incoherency resistance to making acceleration more difficult Strong lobbying power of various incumbents weakening policy mix Resistance from oil and gas companies continues to be strong	DE.P.6 CA.P.4	5 3
	Governance	Complexity of transition requires effective policy coordination Challenges for ministries in multi-system transitions (silos, coordination delays, skills, learning) E-mobility acceleration dependent from multiple, well-coordinated vertical governance levels Ensuring effective coordination of increasingly complex policy mixes	DE.P.8 DE.P.9 CA.P.6	4 3 4
	Instruments	Political difficulties with (faster) ratcheting up GHG emission standards Next EU fleet emission standards increase only in 2025, and higher interim ambition unlikely Ratcheting up GHG emissions and fuel efficiency standards	DE.V.3 CA.V.12	7 3
	EV supply	Supply chain issues are negatively impacting EV production Short-term and long-term supply chain issues for EVs Supply chain issues impacting vehicle production Focus on large / premium cars limits model variety and availability Long delivery times of EVs (and limited model variety) Big car culture increases electrification challenges	DE.V.9 CA.V.4 DE.V.8 CA.V.15	7 5 7 1
Vehicle-side	Batteries	Building up domestic battery production capacity Building and catching up EU based battery production On-shoring of battery production Concerns around critical raw materials availability Raw material dependency as key challenge (and geopolitical dependency) Supply chain issues impacting battery production Limited supply of rare minerals for battery production as potential bottleneck	DE.V.10 CA.V.6 DE.V.11 CA.V.5 CA.V.7	8 5 6 6 1
	EV demand	EV vs ICE competitiveness issues due to higher upfront costs and uncertainties regarding operating costs Increasing costs for EVs and electricity limit attractiveness Higher upfront costs of electric vehicles compared to ICEs disincentivizes their adoption Socio-cultural embeddedness of car limits broader shifts in demand While car is socio-culturally embedded, ongoing urban mobility niche experiments Automobile lock-in making broader transport transitions unlikely Consumer acceptance remains a key challenge	DE.V.17 CA.V.11 DE.V.18 CA.V.14 DE.V.19	8 5 5 4 5
	Infrastructure	Supply chain issues impacting charging infrastructure build up Supply chain issues affect charging infrastructure expansion Supply chain issues impacting supply of charging equipment Buy America provisions could impact supply chains	DE.C.4 CA.C.3 CA.C.4	2 5 2
	Governance	Local governance level struggling with additional tasks arising from charging infrastructure build up Local governance levels juggling multiple challenges around charging with limited resources Speed up and streamline permitting processes of charging stations	DE.C.6 CA.C.6	6 9
Charging	Buildings	Enabling charging solutions for EV users in multi-family housing Charging at multi-family housing ("Laterrenparken") Enabling charging at multi-family housing	DE.C.11 CA.C.13	5 11
	Smart charging	Enabling flexible and smart charging for limiting load peaks Bidirectional charging: from buzzword to implementation for enhanced flexibility Regulation needed for enabling flexible charging Passive load management through price signals Active load management through demand response	DE.C.9 DE.C.10 CA.C.10 CA.C.12	6 4 14 2
	Expansion	Need to update and extend grids to handle electrification of transport Initial neglect and need for storytelling supporting grid optimisation and extensions Grid upgrades in transmission, distribution, and integration, among others due to load growth Long timelines for grid investments (transmission grids, interconnectors, etc.) Long timelines and delays for transmission grid extensions (not only due to slow permitting processes) Long timelines for grid investments, especially interconnections and permitting Supply chain issues impacting grid equipment (e.g., transformers)	DE.G.1 CA.G.2 DE.G.2 CA.G.1 CA.G.3	5 7 2 7 5
	Equity	Affordability of the electrification of private vehicle transport Affordability of EVs important to ensure a just transition Access to affordable charging at multi-family housing Access to affordable DC fast charging	DE.O.5 CA.O.5 CA.O.6	6 3 3
Other	Labour	Markets for used cars underdeveloped but key for just transitions Slow start of market for used EVs (and few small cars) Enabling markets for used EVs Ensuring supply of (re)skilled labor meets (increasing) demand Shortage of skilled labour and possibility of just transition through reskilling Increasing demand of skilled labor could become a bottleneck	DE.O.6 CA.O.4 DE.O.9 CA.O.8	4 5 6 3

Several acceleration challenges unique to Germany

Examples

- Weaker policy mix due to within government cross-party conflicts
- Building up charging infrastructure contested

More contested
 climate policy

Themes	Sub-themes	Real-world acceleration challenges unique to Germany (mentioned by at least 5 interviewees)	ID	Interviews
Policy (cross-cutting)	Policy strategy	Limited implementation (and weakening of transport) policy strategies	DE.P.1	15
		Need to rethink industrial policy for climate-neutral global competitiveness	DE.P.2	8
	Policy making	Complaints about limited stakeholder participation (timing, format, inclusiveness)	DE.P.4	6
		Complex multi-system transition requires changes in mindset, organisation and policy style	DE.P.5	6
	Governance	Weaker policy mix due to within government cross-party conflict (mainly BMWK-BMDV)	DE.P.7	13
Vehicle-side	Policy strategy	Reaching target of 15 million EVs by 2030 requires acceleration	DE.V.1	6
	Instruments	Design changes and partial phase-out of EV premium with unclear effects ("Umweltbonus")	DE.V.2	8
		Path security through EU ICE phase out 2035 (but harmed through e-fuels loophole)	DE.V.4	5
	EV supply	Limited supply of smaller EVs (particularly by German OEMs)	DE.V.7	9
	Transformation	Transformation of automotive industry to smart e-mobility	DE.V.13	6
		Uncertainty about Chinese OEMs competing in German/European market	DE.V.14	5
Political debate about e-fuels increasing EV investment uncertainty		DE.V.15	5	
Charging	Policy strategy	Contestation around undifferentiated 1 million charge points target by 2030	DE.C.1	8
		Contestations around updated national policy roadmap for charging ("Masterplan 2")	DE.C.2	5
	Infrastructure	Building up (public) charging infrastructure major, multi-faceted and contested task	DE.C.3	11
	Governance	Contestation and delays around fast charging ("Deutschlandnetz")	DE.C.7	5
Insufficient provision of public spaces for charging (despite online tool)		DE.C.8	5	
Other	Electricity	Ambitious renewables expansion targets but many challenges on the ground	DE.O.1	9

Some acceleration challenges unique to California

Examples

- Contestations around ownership of charging stations ('make-readies')
- Weak business models for public charging, not aligned w/ public interest

More technocratic
 climate policy

Themes	Sub-themes	Real-world acceleration challenges unique to California (mentioned by at least 5 interviewees)	ID	Interviews
Policy (cross-cutting)	Governance	Regulatory patchwork resulting from electricity being governed at state-level	CA.P.7	12
Vehicle-side	Transformation	EV investment uncertainty faced by OEMs, likely addressed by IRA	CA.V.9	5
Charging	Infrastructure	Contestations around ownership of charging stations	CA.C.1	9
		Low reliability of charging stations endangers consumer acceptance	CA.C.2	9
	Smart charging	Business models for charging services still weak and diverse, and not necessarily aligned with public interests	CA.C.11	11

Cross-cutting nature of challenges

“Real-world” acceleration challenges do not neatly fit into a single challenge type

- On average: each empirical challenge associated with approx. 4 (of 8) types
- Identification of main challenge type: most dominant

Type of acceleration challenge	Germany						California					
	Multiple			Dominant			Multiple			Dominant		
	#	%	Rank	#	%	Rank	#	%	Rank	#	%	Rank
1 - WHO: whole system change	31	55%	3	1	2%	8	28	54%	4	1	2%	8
2 - MSI: multi-system interaction	31	55%	3	9	16%	4	32	62%	3	7	13%	3
3 - DEC: decline and resistance	26	46%	6	10	18%	3	18	35%	6	4	8%	7
4 - EXP: expansion and contestation	46	82%	2	12	21%	1	41	79%	1	12	23%	1
5 - CON: consumers and social practises	29	52%	5	2	4%	7	23	44%	5	5	10%	5
6 - JUS: justice	16	29%	8	4	7%	6	8	15%	8	5	10%	5
7 - INT: international dynamics	24	43%	7	7	13%	5	10	19%	7	6	12%	4
8 - GOV: governance	50	89%	1	11	20%	2	37	71%	2	12	23%	1

➤ **TOP1: 'governance' & 'expansion and contestation' (in DE & CA)**

➤ **Making future winners & losers in new multi-system regime**



Reflections on our extended analytical framework of acceleration challenges

- **Similar** nature of challenges (with one exception):
 - Most **prominent**: AC4 **'expansion and contestation'** (!) and **AC8 'governance'** (state, policy mix)
 - **Prevalent** (3/5th): AC2 **'multi-system interaction'** - TE case, new cross-system capacities needed
 - **Hidden** everything: AC1 **'whole system change'** - cross-cutting $\sqrt{}$, main: car lock-in vs rethink
 - **Limited** & nuanced: AC5 **'consumers and social practises'** - 50%; mass mkts vs user narrative
 - **Shared** & different: AC6 **'international dynamics'** - supply chains & materials; OEM, IRA & CN
 - Most **overlooked**: AC5 **'justice'** - affordability; mainly dedicated experts, neglect could backfire
- Main **difference**: AC3 **'decline and resistance'** stands out for **DE** (OEM incumbency)



Conceptual reflections

Extended typology of acceleration challenges

- **Extension confirmed:** all 8 challenge types play a role in transport electrification
- **Key clarification:** **cross-cutting** nature of "real-world" acceleration challenges
- **Similar** nature of challenges (with nuances and one key exception)



The acceleration phase of electrifying transport is associated with a unique set of *challenges*



However, we observe divergence in the political modes that shape acceleration.

- Germany is characterized by more **contested** climate policymaking.
- California is characterized by more **technocratic** climate policymaking.

What could explain the differences between Germany and California?

Explanation 1

There is more incumbency
resistance in Germany.



Explanation 2

California has stronger
regulatory institutions.



Explanation 3

Sectoral differences in
electricity market regulation.



Limitations



Main research limitations

- **Static analysis in highly dynamic environment just entering acceleration phase**
- **Robustness (5+ experts) vs minority insights**
- **Technology substitution vs broader mobility transitions**



Conclusions



Implications for future research

- **Dual nature of politics of transitions:**
investigate contestations around decline AND expansion
- **Multi-system acceleration capacity** (analytical, operational, political)
- **Role of international dynamics** for accelerating transitions



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Looking forward to your comments and questions !

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Introduction to EMPOCI Project

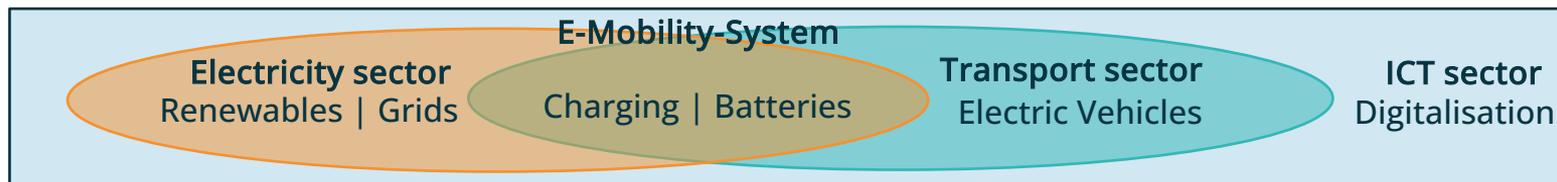
Research Question



How can the global low-carbon transition in the increasingly interconnected energy and mobility systems be accelerated on a regional and national level?

Accelerating multi-system transitions to net-zero: governing the electrification of transport

Focus 'sector coupling': increasing interconnection of electricity, transport and ICT sectors into e-mobility system



Zooming in on case study deep dives within the project: one of these is US-DE comparison of acceleration challenges



Team & cases

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“Real-world” acceleration challenges



From interview transcripts to two list of acceleration challenges

5 Themes: challenges associated with

- policy
- vehicle-side
- charging
- grid-side
- other
(electricity, IT, equity, labour)

Excerpt from bottom-up coding system

bottom-up: AC themes	6
> policy (cross-cutting)	159
> vehicle-side	239
▼ charging	0
> AC_contested 1 mio charge points target	18
> AC_building up (public) charging infrastructure	30
> AC_contestations around national charging plan (Masterplan 2)	15
> AC_contestations around build up of Deutschlandnetz	10
> AC_insufficient provision of public spaces for charging	10
> AC_payment requirements increase equipment costs	12
> AC_problems with municipal level (resources, competition, etc)	14
> AC_charging at multi-family housing, incl. "Laternenparker"	15
> AC_regulation needed for enabling flexible charging	6
> AC_enabling bidirectional charging for enhanced flexibility	14
> AC_supply chain issues also affect charging infrastructure	2
> AC_buildings need to be upgraded to fully participate in new BM	2
> CONTEXT: Europe-wide build up of megawatt charging for trucks	4
> CONTEXT: electric vs hydrogen	1
> grid-side	59
▼ other	0
> electricity	33
> IT	34
> equity	24
> labour	12

Distribution of acceleration challenges



Number of identified acceleration challenges by theme and similarity in Germany and California

By theme: TOP2 vehicle & charging

Comparison: many similar challenges

Themes	Real-world acceleration challenges (all)				Real-world acceleration challenges... (mentioned in at least 5 interviews)					
	Germany		California		... similar in Germany and California		... unique in Germany		... unique in California	
	#	%	#	%	#	%	#	%	#	%
Policy (cross-cutting)	9	16%	8	15%	2	11%	5	28%	1	20%
Vehicle-side	19	34%	16	31%	8	42%	7	39%	1	20%
Charging	12	21%	14	27%	4	21%	5	28%	3	60%
Grid-side	6	11%	4	8%	2	11%	0	0%	0	0%
Other	10	18%	10	19%	3	16%	1	6%	0	0%
SUM	56	100%	52	100%	19	100%	18	100%	5	100%

56 vs 52 challenges (all)

19 vs 18 vs 5 challenges (robust)

Many acceleration challenges shared by **Germany and California**

Examples

- Establishing domestic battery production capacity
- Fast upgrading and expanding of grids

Similar problem structure

Even more acceleration challenges unique to **Germany**

Examples

- Weaker policy mix due to within government cross-party conflicts
- Building up charging infrastructure contested

More contested climate policy

Only some acceleration challenges unique to **California**

Examples

- Contestations around ownership of charging stations ('make-readies')
- Weak business models for public charging, not aligned w/ public interest

More technocratic climate policy

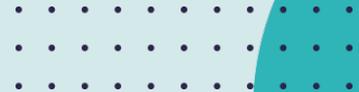
Conceptual implications



Based on the empirical findings from Germany and California

- Power market designs significantly shape acceleration challenges: they shape both the preferences of powerful actors (e.g. utilities) and the issues of conflict (e.g. demand charges).
- Power market designs vary significantly within the U.S. as well as between the U.S. and Europe. We therefore expect that acceleration challenges will vary significantly between the U.S./California and Germany.
- The framework proposed by Markard et al. (2020) is agnostic to how sector-specific political institutions (e.g., power market designs) condition acceleration challenges.

Sector-specific institutions might play a more important role than country-specific institutions.



Results

Germany

#	Theme	Subtheme	ID	Interviews	Name of real-world acceleration challenge
1	Policy	Policy strategy (cross-cutting)	DE.P.1	15	Limited implementation (and weakening of transport) policy strategies
2	Policy	Policy strategy (cross-cutting)	DE.P.2	8	Need to rethink industrial policy for climate-neutral global competitiveness
3	Policy	Policy strategy (cross-cutting)	DE.P.3	4	Acceleration requires dealing with various trade-offs (e.g. nature protection, energy security)
4	Policy	Policy making	DE.P.4	6	Complaints about limited stakeholder participation (timing, format, inclusiveness)
5	Policy	Policy making	DE.P.5	6	Complex multi-system transition requires changes in mindset, organisation and policy style
6	Policy	Policy making	DE.P.6	5	Strong lobbying power of various incumbents weakening policy mix
7	Policy	Governance	DE.P.7	13	Weaker policy mix due to within government cross-party conflict (mainly BMWK-BMDV)
8	Policy	Governance	DE.P.8	4	Challenges for ministries in multi-system transitions (silos, coordination delays, skills, learning)
9	Policy	Governance	DE.P.9	3	E-mobility acceleration dependent from multiple, well-coordinated vertical governance levels
10	Vehicle-side	Policy strategy (specific)	DE.V.1	6	Reaching target of 15 million EVs by 2030 requires acceleration
11	Vehicle-side	Instruments	DE.V.2	8	Design changes and partial phase-out of EV premium with unclear effects ("Umweltbonus")
12	Vehicle-side	Instruments	DE.V.3	7	Next EU fleet emission standards increase only in 2025, and higher interim ambition unlikely
13	Vehicle-side	Instruments	DE.V.4	5	Path security through EU ICE phase out 2035 (but harmed through e-fuels loophole)
14	Vehicle-side	Instruments	DE.V.5	4	Tax privileges for company cars insufficiently drive EV adoption and over-incentivize plug-in hybrids
15	Vehicle-side	Instruments	DE.V.6	2	EURO 7 norm limiting exhaust emissions is contested, but could indirectly benefit EVs
16	Vehicle-side	EV supply	DE.V.7	9	Limited supply of smaller EVs (particularly by German OEMs)
17	Vehicle-side	EV supply	DE.V.8	7	Long delivery times of EVs (and limited model variety)
18	Vehicle-side	EV supply	DE.V.9	7	Short-term and long-term supply chain issues for EVs
19	Vehicle-side	Batteries	DE.V.10	8	Building and catching up EU based battery production
20	Vehicle-side	Batteries	DE.V.11	6	Raw material dependency as key challenge
21	Vehicle-side	Batteries	DE.V.12	3	Building up battery recycling as future industry
22	Vehicle-side	Transformation	DE.V.13	6	Transformation of automotive industry to smart e-mobility
23	Vehicle-side	Transformation	DE.V.14	5	Uncertainty about Chinese OEMs competing in German/European market
24	Vehicle-side	Transformation	DE.V.15	5	Political debate about e-fuels increasing EV investment uncertainty
25	Vehicle-side	Transformation	DE.V.16	2	Maintaining German competitiveness and market shares in global markets
26	Vehicle-side	EV demand	DE.V.17	8	Increasing costs for EVs and electricity limit attractiveness
27	Vehicle-side	EV demand	DE.V.18	5	While car is socio-culturally embedded, ongoing urban mobility niche experiments
28	Vehicle-side	EV demand	DE.V.19	5	Acceptance issues for EVs, but largely limited to non-users
29	Charging	Policy strategy (specific)	DE.C.1	8	Contestation around undifferentiated 1 million charge points target by 2030
30	Charging	Policy strategy (specific)	DE.C.2	5	Contestations around updated national policy roadmap for charging ("Masterplan 2")
34	Charging	Infrastructure	DE.C.3	11	Building up (public) charging infrastructure major, multi-faceted and contested task
31	Charging	Infrastructure	DE.C.4	2	Supply chain issues affect charging infrastructure expansion
32	Charging	Infrastructure	DE.C.5	2	Payment terminal requirement increases equipment costs
33	Charging	Governance	DE.C.6	6	Local governance level juggling multiple challenges around charging with limited resources
35	Charging	Governance	DE.C.7	5	Contestation and delays around fast charging ("Deutschlandnetz")
36	Charging	Governance	DE.C.8	5	Insufficient provision of public spaces for charging (despite online tool)
37	Charging	Smart charging	DE.C.9	6	Bidirectional charging: from buzzword to implementation for enhanced flexibility
38	Charging	Smart charging	DE.C.10	4	Regulation needed for enabling flexible charging
39	Charging	Buildings	DE.C.11	5	Charging at multi-family housing ("Laternenparker")
40	Charging	Buildings	DE.C.12	2	Buildings upgrading to enable full participation in new cross-sectoral business models
41	Grid-side	Expansion	DE.G.1	5	Initial neglect and need for storytelling supporting grid optimisation and extensions
42	Grid-side	Expansion	DE.G.2	2	Long timelines and delays for transmission grid extensions (not only due to slow permitting processes)
43	Grid-side	Expansion	DE.G.3	2	Need to improve public acceptance for grid expansion projects
44	Grid-side	Expansion	DE.G.4	3	Harnessing the potential of digitalisation in smart grids
45	Grid-side	Governance	DE.G.5	4	Acceleration complicated by high number of distribution system operators
46	Grid-side	Governance	DE.G.6	2	Need for fast, digital, and simple distribution grid access
47	Others	Electricity generation	DE.O.1	9	Ambitious renewables expansion targets but many challenges on the ground
48	Others	IT	DE.O.2	4	Balancing data security demands with advancing (the delayed) smart meter roll-out
49	Others	IT	DE.O.3	4	EU data act needed for level playing field in electrification of transport
50	Others	IT	DE.O.4	3	Shortcomings of digital strategy for e-mobility
51	Others	Equity	DE.O.5	6	Affordability of EVs important to ensure a just transition
52	Others	Equity	DE.O.6	4	Slow start of market for used EVs (and few small cars)
53	Others	Equity	DE.O.7	3	Public funding programs for transport electrification mainly benefit affluent households
54	Others	Equity	DE.O.8	1	Shifting to a resource based economy has global justice implications
55	Others	Labour	DE.O.9	6	Shortage of skilled labour and possibility of just transition through reskilling
56	Others	Labour	DE.O.10	2	Difficult for politicians that some companies may not survive structural change

Results

California

#	Theme	Subtheme	ID	Interviews	Name of real-world acceleration challenge
1	Policy	Policy strategy (cross-cutting)	CA.P.1	3	Effective and efficient implementation of adopted policies
2	Policy	Policy strategy (cross-cutting)	CA.P.2	1	Policy mix diffusion from California to other US federal states
3	Policy	Policy making	CA.P.3	3	Protecting California's legal authority to set its own GHG standards
4	Policy	Policy making	CA.P.4	3	Resistance from oil and gas companies continues to be strong
5	Policy	Policy making	CA.P.5	1	Fuel prices politically difficult to increase
6	Policy	Governance	CA.P.6	4	Ensuring effective coordination of increasingly complex policy mixes
7	Policy	Governance	CA.P.7	12	Regulatory patchwork resulting from electricity being governed at state-level
8	Policy	Governance	CA.P.8	1	Complexity and speed of transition increases implementation challenges
9	Vehicle-side	Instruments	CA.V.1	3	Ratcheting up Corporate Average Fuel Economy (CAFE) standards regulating fuel efficiency of vehicles
10	Vehicle-side	Instruments	CA.V.2	2	Ratcheting up GHG emissions standards
11	Vehicle-side	Instruments	CA.V.3	1	Harmonization of CAFE and GHG emissions standards
12	Vehicle-side	EV supply	CA.V.4	5	Supply chain issues impacting vehicle production
13	Vehicle-side	Batteries	CA.V.5	6	Supply chain issues impacting battery production
14	Vehicle-side	Batteries	CA.V.6	5	On-shoring of battery production
15	Vehicle-side	Batteries	CA.V.7	1	Limited supply of rare minerals for battery production as potential bottleneck
16	Vehicle-side	Batteries	CA.V.8	1	Costs of batteries need to decrease for EV competitiveness
17	Vehicle-side	Transformation	CA.V.9	5	EV investment uncertainty faced by OEMs, likely addressed by IRA
18	Vehicle-side	Transformation	CA.V.10	2	Conservative culture of the automotive industry contributing to EV reluctance
19	Vehicle-side	EV demand	CA.V.11	5	Higher upfront costs of electric vehicles compared to ICEs disincentivizes their adoption
20	Vehicle-side	EV demand	CA.V.12	6	Consumer acceptance requires simple and reliable EV use, otherwise backlash
21	Vehicle-side	EV demand	CA.V.13	5	Mindset and behavioral change needed around re-fueling
22	Vehicle-side	EV demand	CA.V.14	4	Automobile lock-in making broader mobility transitions unlikely
23	Vehicle-side	EV demand	CA.V.15	1	Big car culture increases electrification challenges
24	Vehicle-side	EV demand	CA.V.16	1	The danger of rebound effects if electricity remains cheap
25	Charging	Infrastructure	CA.C.1	9	Contestations around ownership of charging stations
26	Charging	Infrastructure	CA.C.2	9	Low reliability of charging stations endangers consumer acceptance
27	Charging	Infrastructure	CA.C.3	5	Supply chain issues impacting supply of charging equipment
28	Charging	Infrastructure	CA.C.4	2	Buy America provisions could impact supply chains
29	Charging	Infrastructure	CA.C.5	1	Over-emphasis on DC fast charging to address range anxiety
30	Charging	Governance	CA.C.6	11	Business models for charging services still weak and diverse, and not necessarily aligned with public interests
31	Charging	Governance	CA.C.7	9	Speed up and streamlining permitting processes of charging stations
32	Charging	Governance	CA.C.8	3	Enable work place charging
33	Charging	Governance	CA.C.9	4	Establishing technical standards and interoperability of charging requires coordination
34	Charging	Governance	CA.C.10	2	Building up charging in rural communities difficult due to low usage
35	Charging	Smart charging	CA.C.11	14	Passive load management through price signals
36	Charging	Smart charging	CA.C.12	2	Active load management through demand response
37	Charging	Buildings	CA.C.13	11	Enabling charging at multi-family housing
38	Charging	Buildings	CA.C.14	1	Harmonize the diversity of building codes
39	Grid-side	Expansion	CA.G.1	7	Long timelines for grid investments, especially interconnections and permitting
40	Grid-side	Expansion	CA.G.2	7	Grid upgrades in transmission, distribution, and integration, among others due to load growth
41	Grid-side	Expansion	CA.G.3	5	Supply chain issues impacting grid equipment (e.g., transformers)
42	Grid-side	Governance	CA.G.4	3	Conservative culture of the utility business may delay investments
43	Others	Electricity	CA.O.1	7	Ensuring reliability and affordability of electricity
44	Others	Electricity	CA.O.2	2	Reliability of electricity supply challenged by extreme weather events and forest fires
45	Others	IT	CA.O.3	1	Cyber security increasingly important
46	Others	Equity	CA.O.4	5	Enabling markets for used EVs
47	Others	Equity	CA.O.5	3	Access to affordable charging at multi-family housing
48	Others	Equity	CA.O.6	3	Access to affordable DC fast charging
49	Others	Equity	CA.O.7	1	Affordability of EVs amplified for low-income households
50	Others	Equity	CA.O.8	1	Inequities exacerbating behavioral challenges
51	Others	Labour	CA.O.9	3	Increasing demand of skilled labor could become a bottleneck
52	Others	Labour	CA.O.10	3	Finding a good balance for training requirements