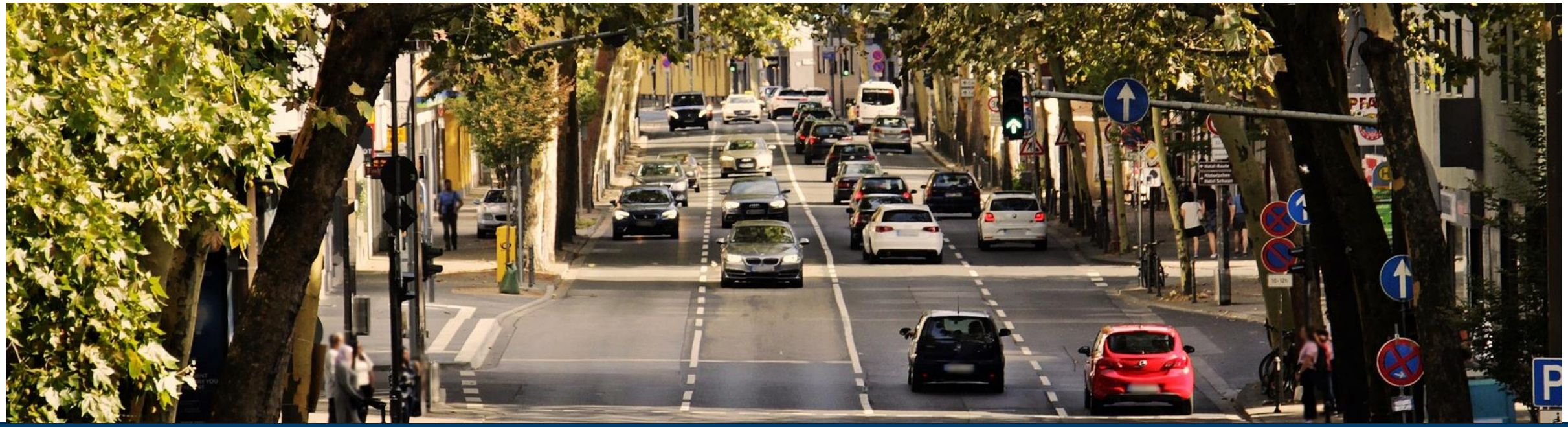

E-MOBILITY FROM A MULTI-ACTOR POINT OF VIEW

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SYSTEMS ANALYSIS AND TECHNOLOGY EVALUATION (IEK-STE)

OUTLINE

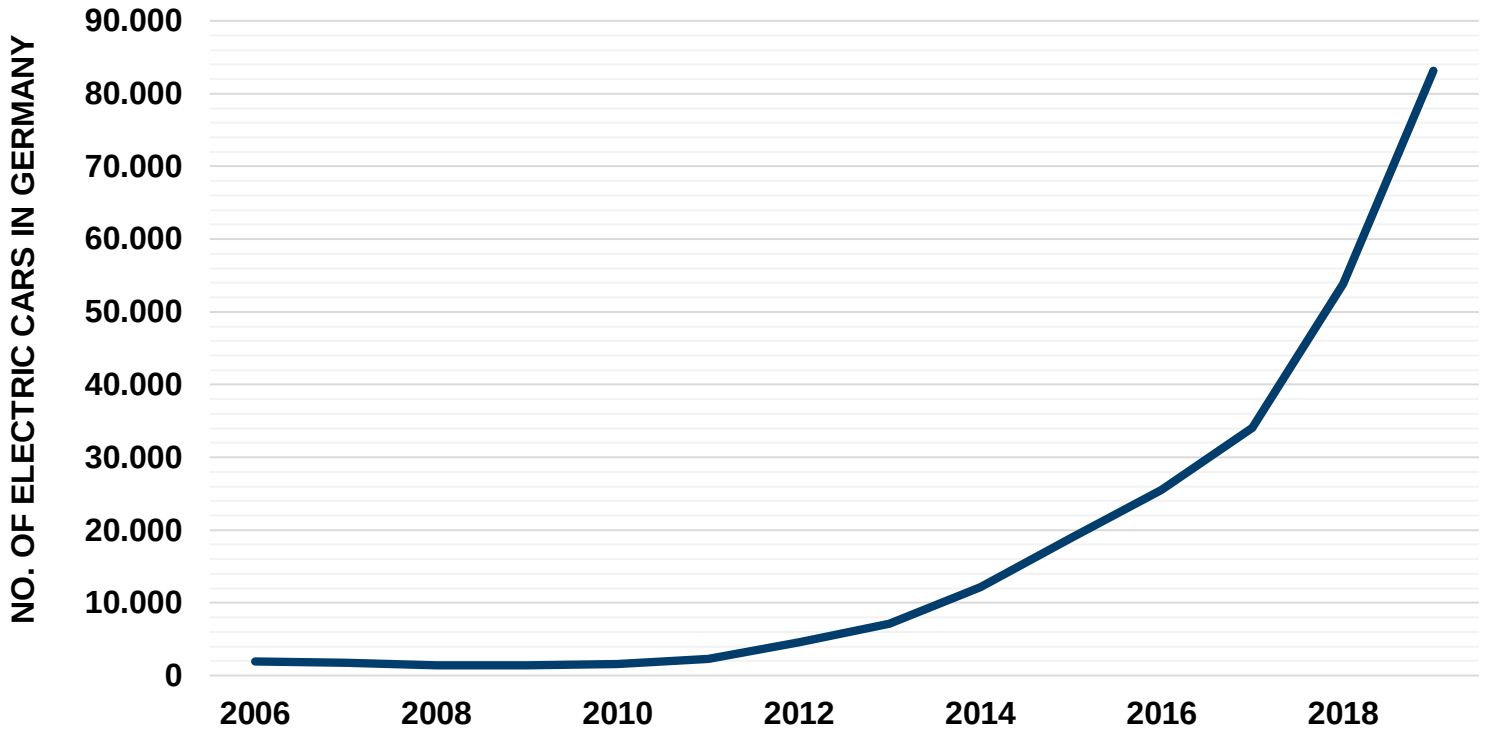
1. Introduction
2. Method
3. Results
4. Conclusions

BACKGROUND

German Government targets: 1 million e-vehicles by 2020 & 6 million by 2030

Policies supporting e-mobility:

- Purchase grant
- Financial support for charging infrastructure
- Tax incentives



Source: www.kba.de

➔ Slow diffusion of e-vehicles in Germany

INTRODUCTION

Hypothesis: A successful deployment of e-mobility requires support by a broad range of actors (including car-manufactures, government, car- users and utilities) whereas each actor has its specific interests

➔ **Multi-Actor Multi-Criteria Problem**

Research questions:

- Which factors underlie an actor's decision in favour of a particular technology?
- What has to change to effect a shift from one technology to another?
- How is a stakeholder's decision influenced by the position of other stakeholders?

2. METHOD

Multi-Actor Multi-Criteria Approach

Assumptions:

- 4 actors: car users, government, car manufacturers and electricity suppliers, who each must choose one mobility option

- 3 Mobility options:
  - Internal combustion engine vehicles (ICE)
  - Hybrid vehicles (HEV)
  - E-vehicles (EV)

2. METHOD

MCDA - Steps

(1) Identification of factors being relevant for decision of actors

(2) Specification of actor-specific weighting factors

(3) Assignment of values to characteristics of technology options

(4) Normalization [0-1]

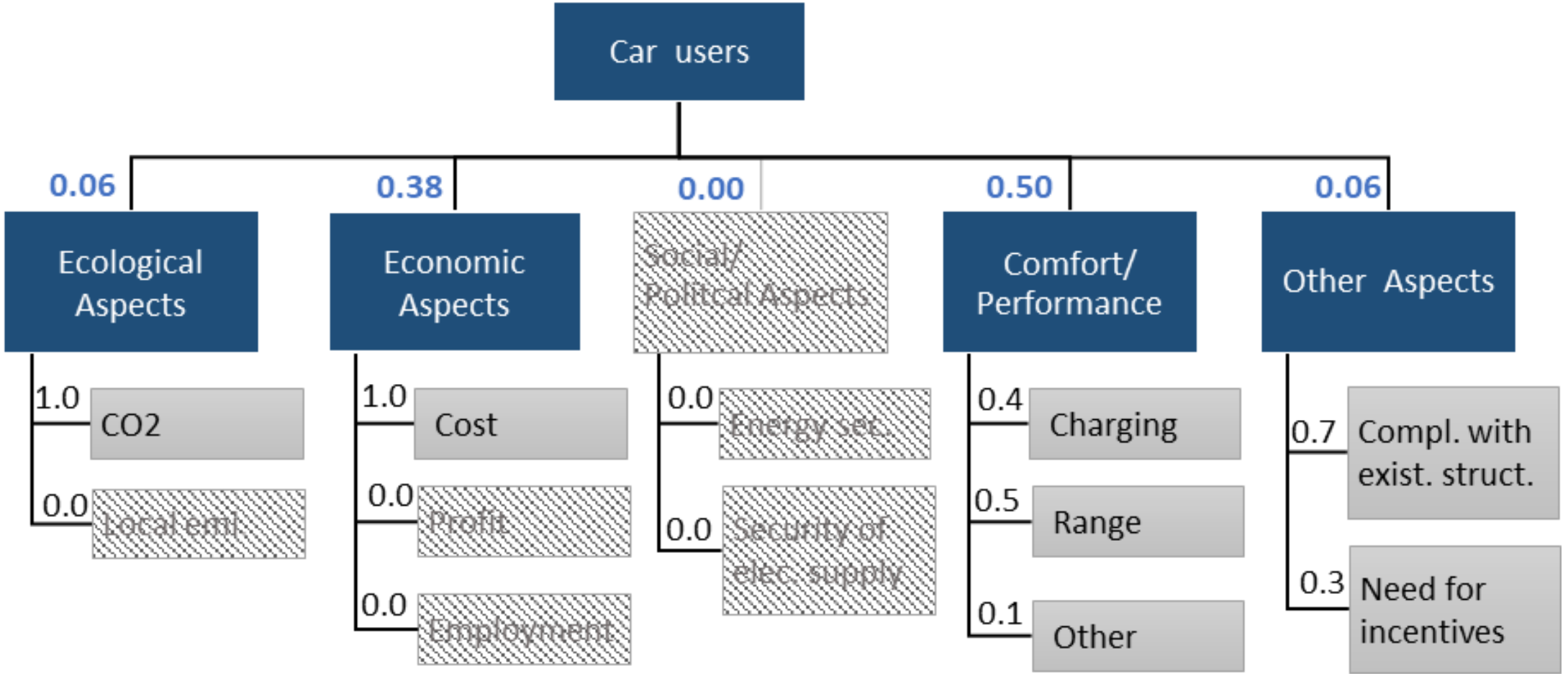
(5) Weighting and summing up ➔ Selection of the option with best performance

Extension: Externalities as additional factors

2. METHOD - FACTORS BEING RELEVANT FOR ACTORS

Characteristics	Car user	Car manufactures	Electricity suppliers	Government
ECOLOGICAL FACTORS				
CO_2 emissions	X	X	X	X
Local emissions				X
ECONOMIC FACTORS				
Cost of ownership	X	X		
Profit		X	X	X
Employment		X		X
SOCIAL/POLITICAL FACTORS				
Impact on import dependency			X	X
Impact on the security of electricity supply			X	X
Comfort/Performance				
Charging time	X	X	X	
Range	X	X	X	
Other	X			
OTHER FACTORS				
Complementarity with existing structures	X	X	X	X
Need for incentives	X	X	X	X

2. METHOD – WEIGHTINGS (CAR-USERS)



Source: Own compilation based on [Esch, 2016]

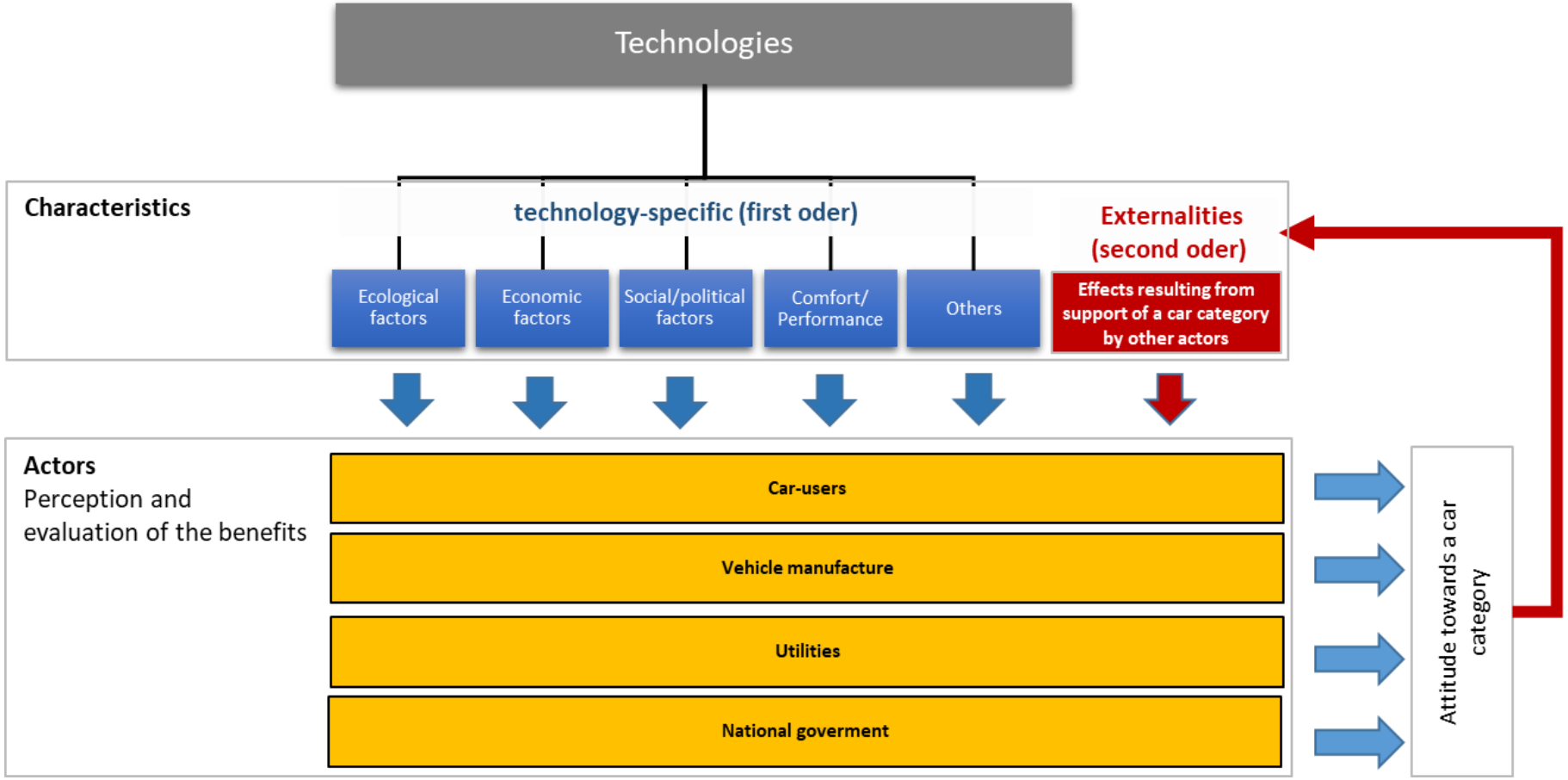
2. METHOD CHARACTERISTICS OF OPTIONS

Characteristics	unit	Electric Car	Car with internal combustion	Hybrid Car
ECOLOGICAL FACTORS				
CO_2 emissions*	-	63**	100	78
Local emissions*	-	0	100	79
ECONOMIC FACTORS				
Cost of ownership*	-	107	100	101
Profit*	-	50	100	90
Employment*	-	26	100	104
SOCIAL/POLITICAL FACTORS				
Impact on import dependency	-	very low	very high	high
Impact on the security of electricity supply	-	moderate	very low	very low
Comfort/Performance				
Charging time	-	very bad	very good	very good
Range	km	350	900	1000
Other[2]		Good	very good	very good
OTHER FACTORS				
Complementarity with existing structures		very low	very good	very good
Need for incentives		very high	very low	low

Remarks: * Standardized ICE = 100, ** Calculated based on data on average CO2-emissions/kWh in Germany, sources: Own compilation based on [Esch, 2016, NISSAN Center Europe, 2018, Toyota Deutschland, 2018]

2. METHOD – EXTENSION

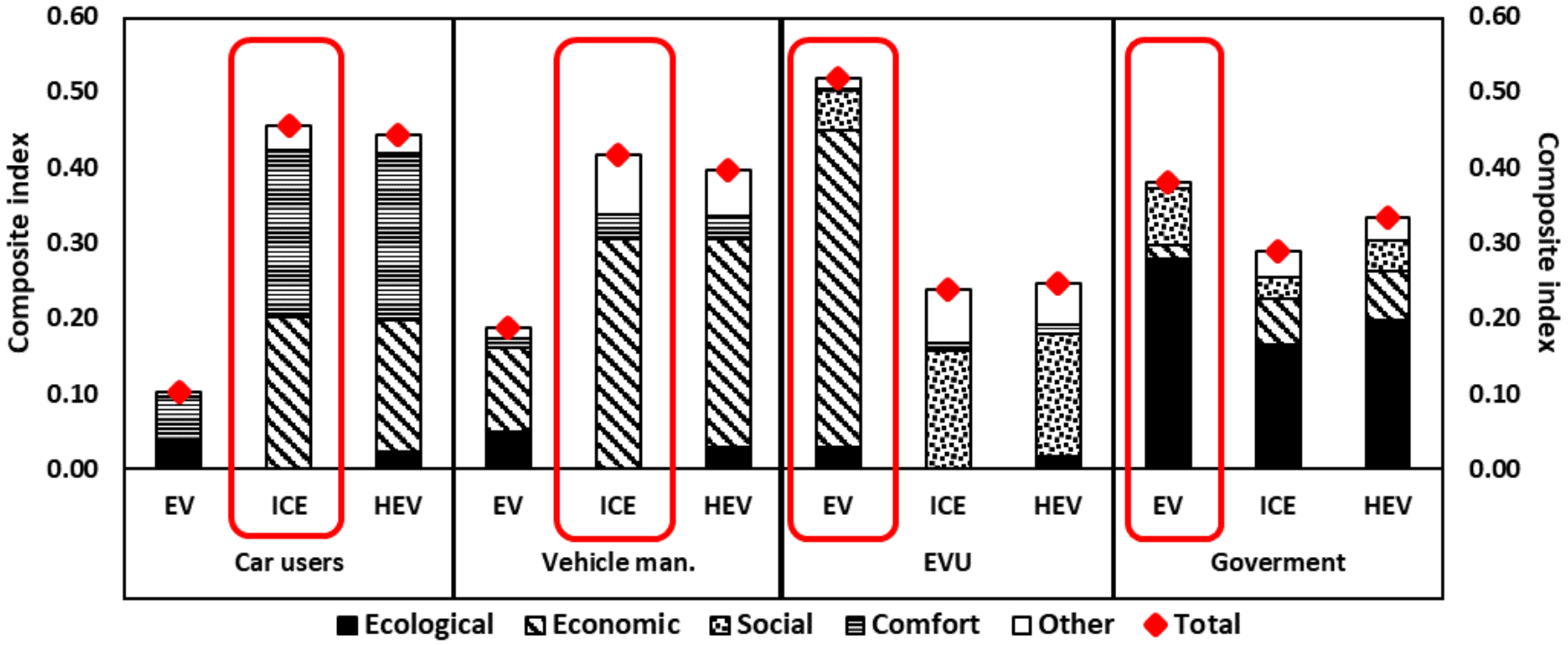
Indirect effects and externalities can change certain stakeholders' decisions



Externalities:
Learning effect, reduction in cost, increases in comfort and improvements in charging infrastructure as side effects/ancillary benefits

3. RESULTS AND SENSITIVITY ANALYSIS

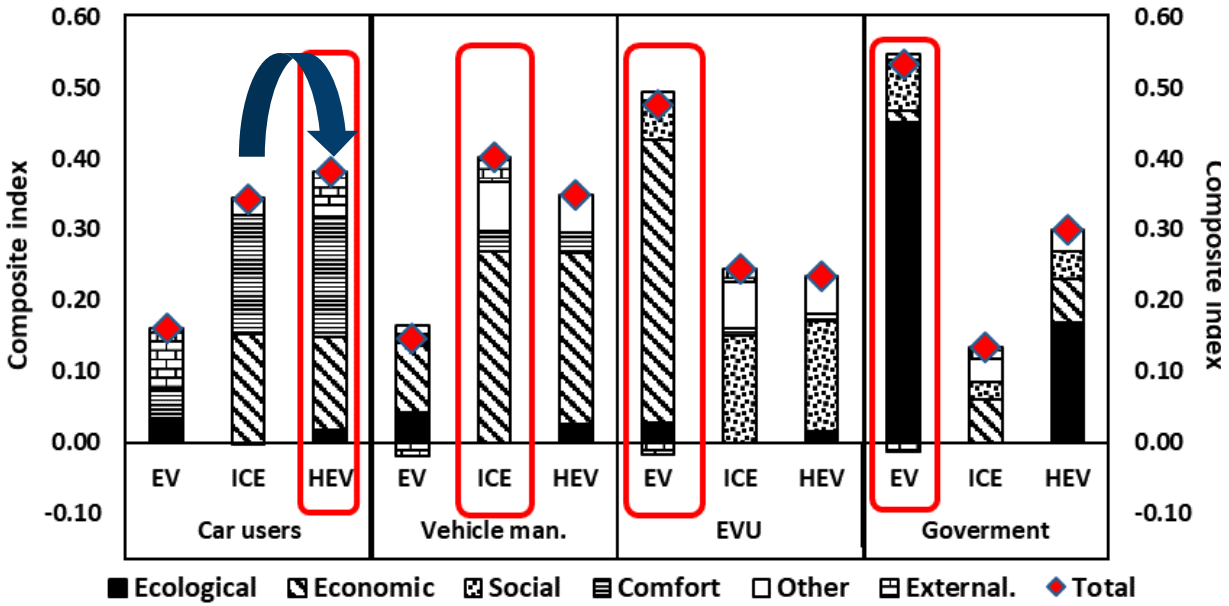
Without externalities



Government and electricity suppliers prefer e-vehicles; manufacturers and car users prefer ICE

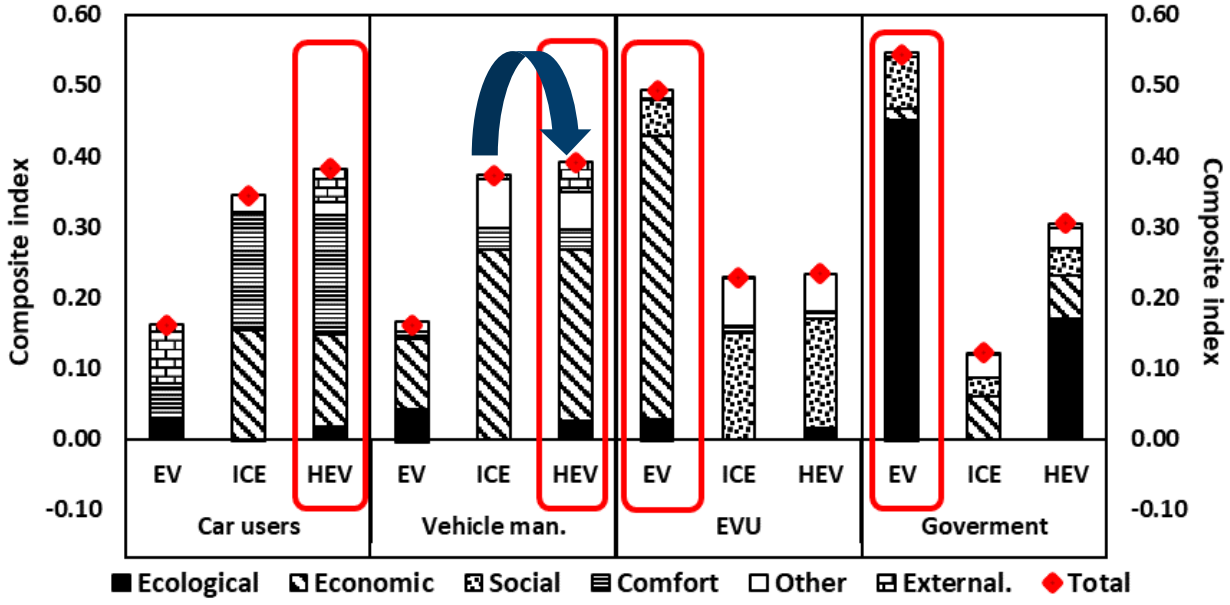
3. RESULTS AND SENSITIVITY ANALYSIS

Round 1: Including externalities: i.e. government & supplier support e-vehicles ➔ impacts on car-users (e.g. improvement in recharging infrastr.)



The inclusion of externalities causes car users to shift from ICEs to hybrid vehicles

Round 2: Second Order externalities included



Manufacturers shift to hybrid vehicles if the positive attitude of car users towards hybrids is included

SENSITIVITY ANALYSIS

What would cause manufacturers to switch to e-vehicles?

Scenario "EV": CO_2 emissions 73 g/100 km*

ECOLOGICAL FACTORS (0: not relevant, 10: very important)	ECONOMIC FACTORS (0: not relevant, 10: very important)										
	0	1	2	3	4	5	6	7	8	9	10
0	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE
1	HV	HV	HV	HV	HV	HV	HV	ICE	ICE	ICE	ICE
2	HV	HV	HV	HV	HV	HV	HV	HV	HV	HV	HV
3	HV	HV	HV	HV	HV	HV	HV	HV	HV	HV	HV
4	EV	EV	EV	HV	HV	HV	HV	HV	HV	HV	HV
5	EV	EV	EV	EV	EV	EV	EV	HV	HV	HV	HV
6	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
7	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
8	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
9	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV

Scenario "Variant: EV with zero CO_2 emissions"

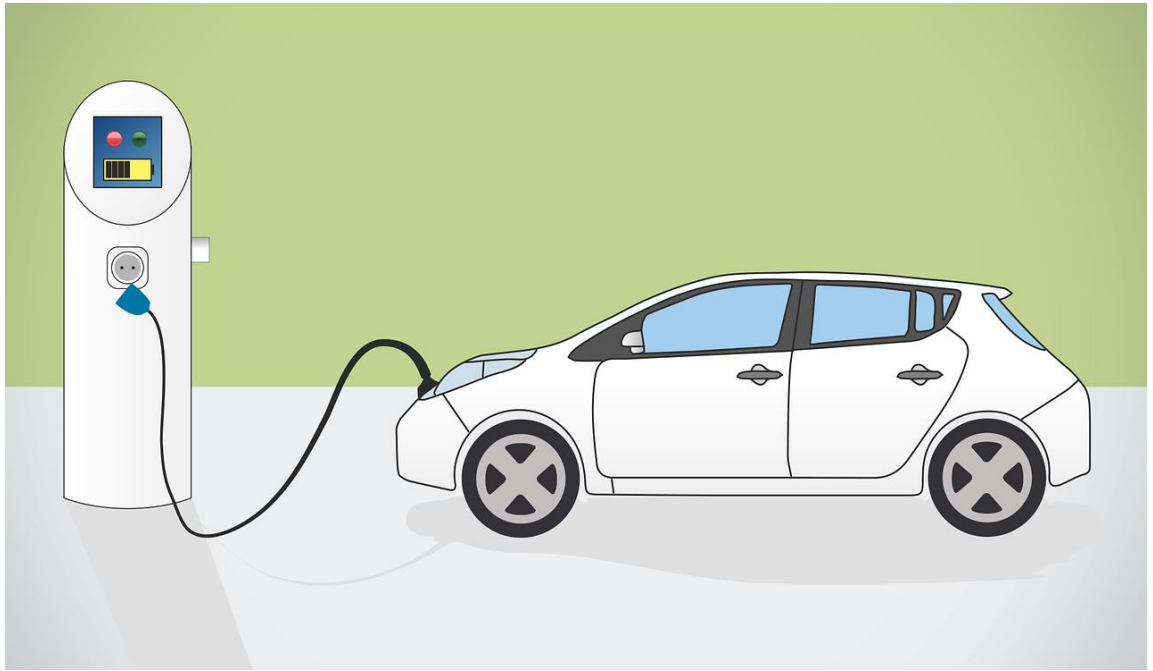
ECOLOGICAL FACTORS (0: not relevant, 10: very important)	ECONOMIC FACTORS (0: not relevant, 10: very important)										
	0	1	2	3	4	5	6	7	8	9	10
0	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE
1	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE
2	EV	EV	EV	EV	EV	EV	HV	HV	ICE	ICE	ICE
3	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
5	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
6	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
7	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
8	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
9	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV

Remarks: * Calculated based on data on average g CO_2-emissions/kWh in Germany, values in red indicates results from default setting

- Higher weighting for ecological factors and/or improvement of CO_2 footprint of electricity used in e-vehicles
- Harmonization of profit margins among all vehicles

SENSITIVITY ANALYSIS

What would cause users to switch to e-vehicles?



Lower importance of comfort and performance: e-vehicles do better

Source: www.smarter-fahren.de/elektroautos-laden)

More importance for ecological factors (i.e. thanks to greater awareness)

Source: www.spiegel.de/fotostrecke/fridays-for-future-die-bewegung-in-bildern-fotostrecke-169421-3.html

CONCLUSIONS

- It is important to consider co-benefits associated with policies to understand the position of each decision maker
- Car users and manufacturers show the most resistance to e-vehicles, but this resistance can be reduced through externalities
- It is possible to cause car users to switch to hybrid vehicles, a switch to e-vehicles seems to be difficult
- Profitability is the biggest hurdle for manufacturers to go for e-vehicles
- Next steps: Consideration of different groups of car users