

DLR - Institute of Vehicle Concepts

Scenarios for the Market-development of Electrified Vehicles

September 28, 2010

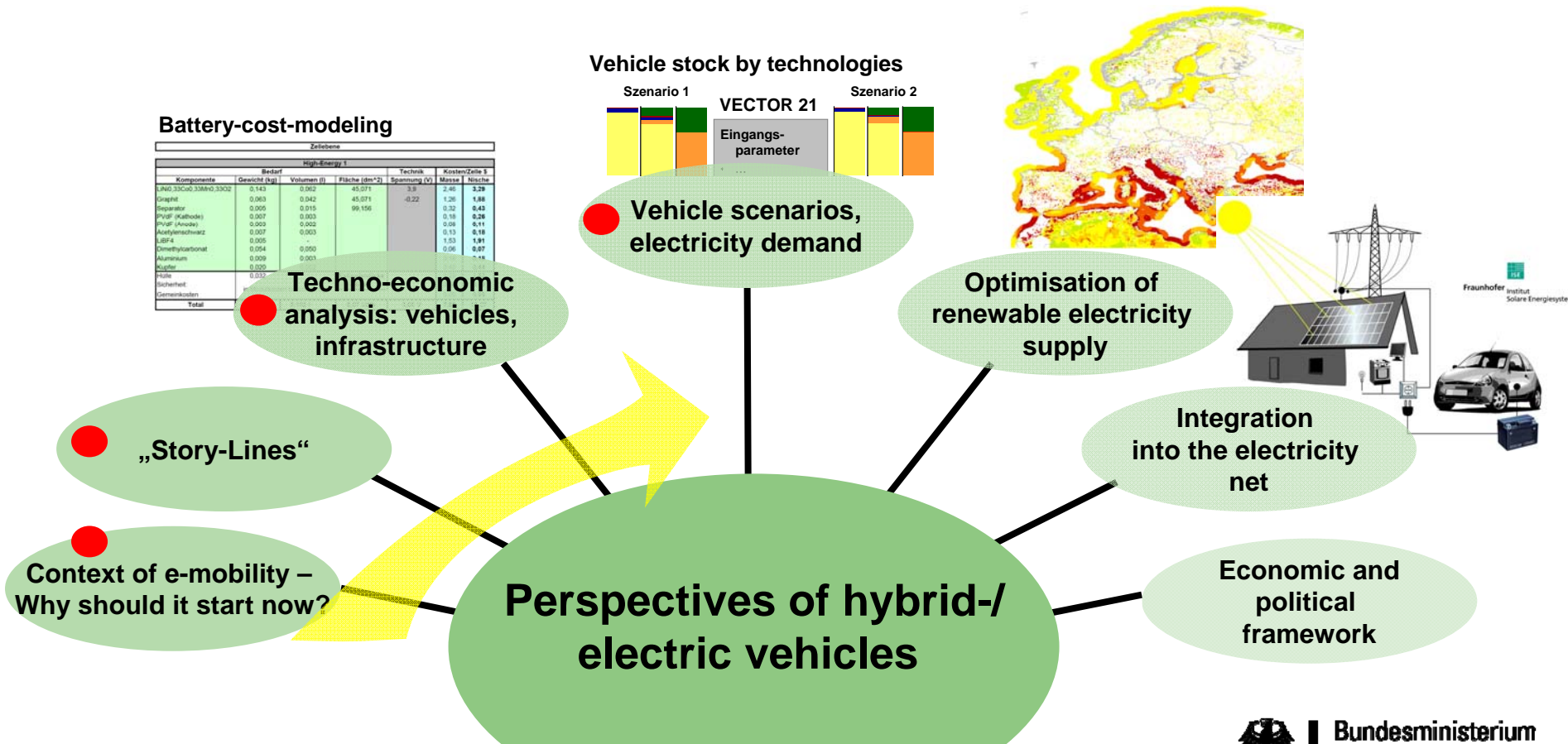
Stephan A. Schmid, Bernd Propfe

Content

- Overview on the project
- Vehicle technology scenario model – VECTOR21
- Scenario results
- Conclusions

Overview of the project

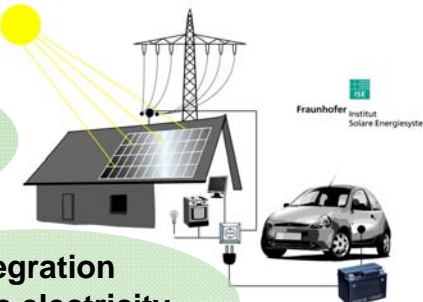
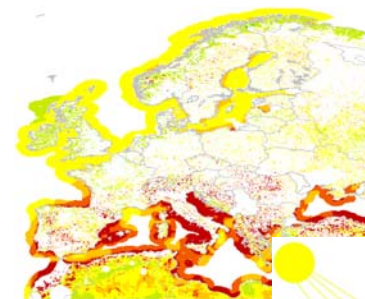
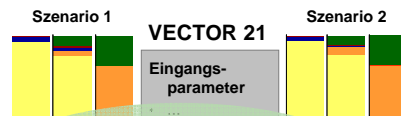
„Perspectives of hybrid-/electric vehicles in an energy system with a high share of renewable electricity“



Battery-cost-modeling

Zielbereich						
Bedarf			Technik		Kosten/Zeile 1	
Komponente	Gewicht (kg)	Volumen (l)	#Zelle (dm ²)	Spannung (V)	Masse	Nische
LiNo.33Co.33Mn.33Co2	0.143	0.062	45.071	3.9	2.46	3.29
Graphit	0.063	0.042	45.071	-0.22	1.26	1.88
Separator	0.005	0.015	99.156		0.32	0.43
PVAF (Kathode)	0.007	0.003			0.18	0.26
PVAF (Anode)	0.003	0.002			0.08	0.11
Acetylen-schwarz	0.007	0.003			0.13	0.18
SBFA	0.005				1.53	1.91
Dimethylcarbonat	0.054	0.050			0.96	0.87
Aluminium	0.009	0.001				
Kupfer	0.005					
Welle	0.001					
Sicherheit						
Gemeinkosten						
Total						

Vehicle stock by technologies



Fraunhofer ISE Institut Solare Energiesysteme



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Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft Institut für Technische Thermodynamik (Coordinator) Institut für Fahrzeugkonzepte



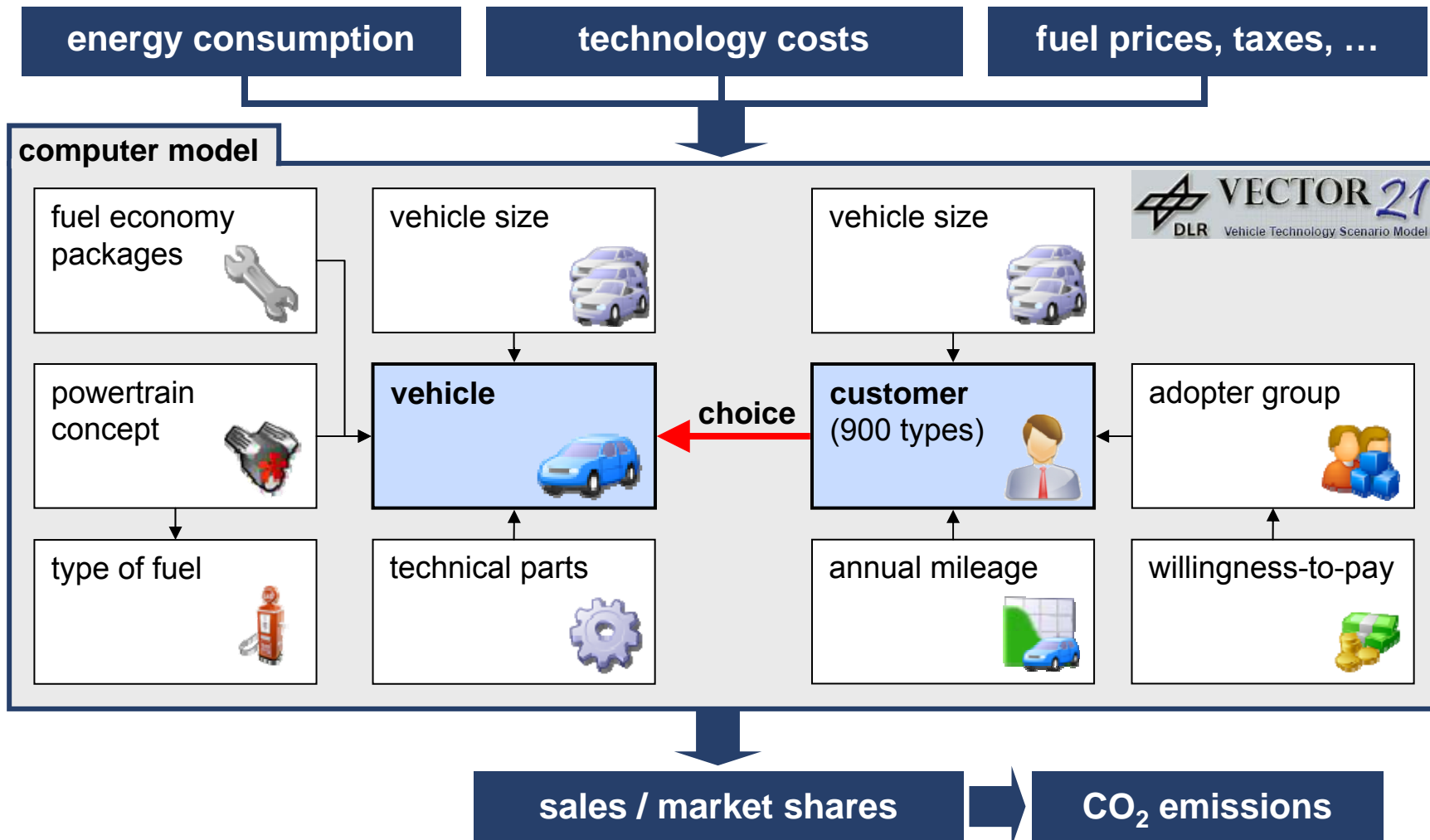
Bundesministerium für Wirtschaft und Technologie



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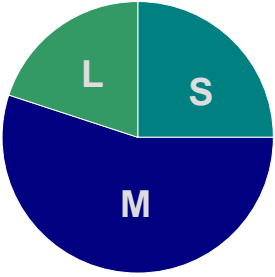
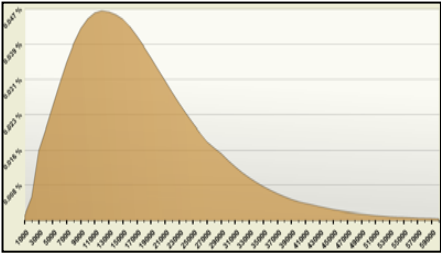

VECTOR 21 – Vehicle Technology Scenario Model

Modeling both technology supply and customer demand



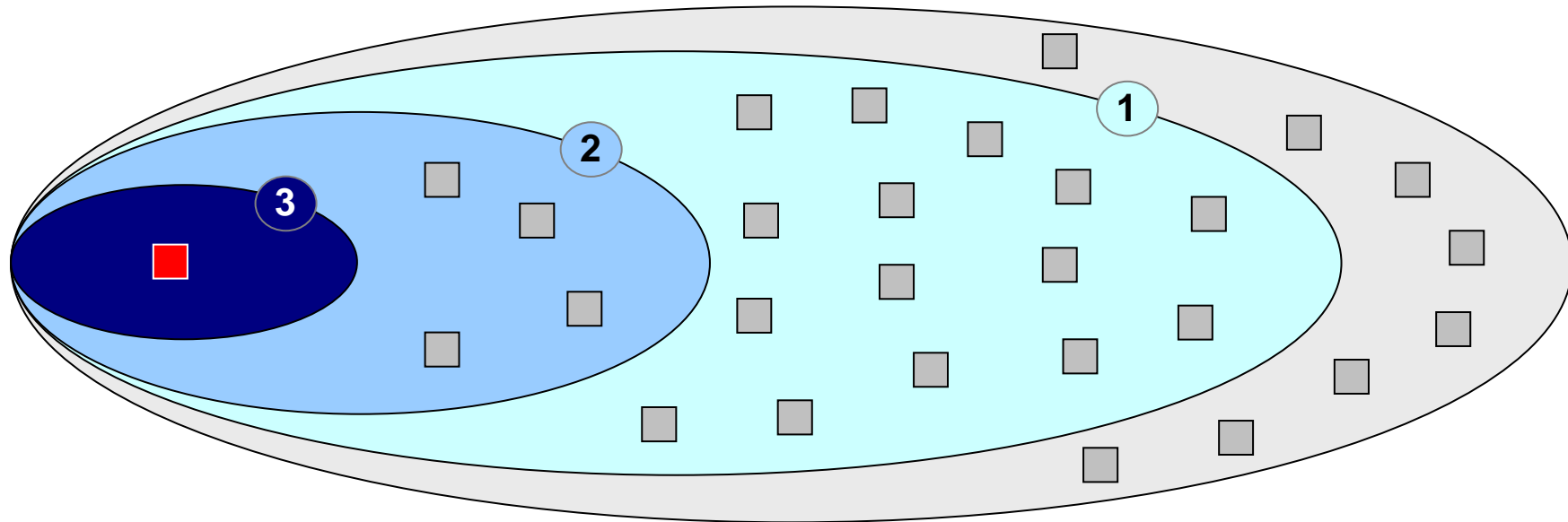
VECTOR 21 – Vehicle Technology Scenario Model

Within the model, 900 different types of customers are simulated

Vehicle segment		<ul style="list-style-type: none"> ➤ 3 vehicle sizes: small, medium, large ➤ Input based on historical data of the German Federal Motor Transport Authority 	3
----- X			
Annual driving distance		<ul style="list-style-type: none"> ➤ Different distributions for the driving distances, depending on the vehicle size ➤ Data based on the survey „Mobilität in Deutschland 2008 (MiD)“ 	60
----- X			
Adopter group		<ul style="list-style-type: none"> ➤ Five different attitudes towards innovations ➤ Based on theory from Rogers ➤ Crucial for willingness-to-pay of customers 	5
			<hr/> 900

VECTOR 21 – Vehicle Technology Scenario Model

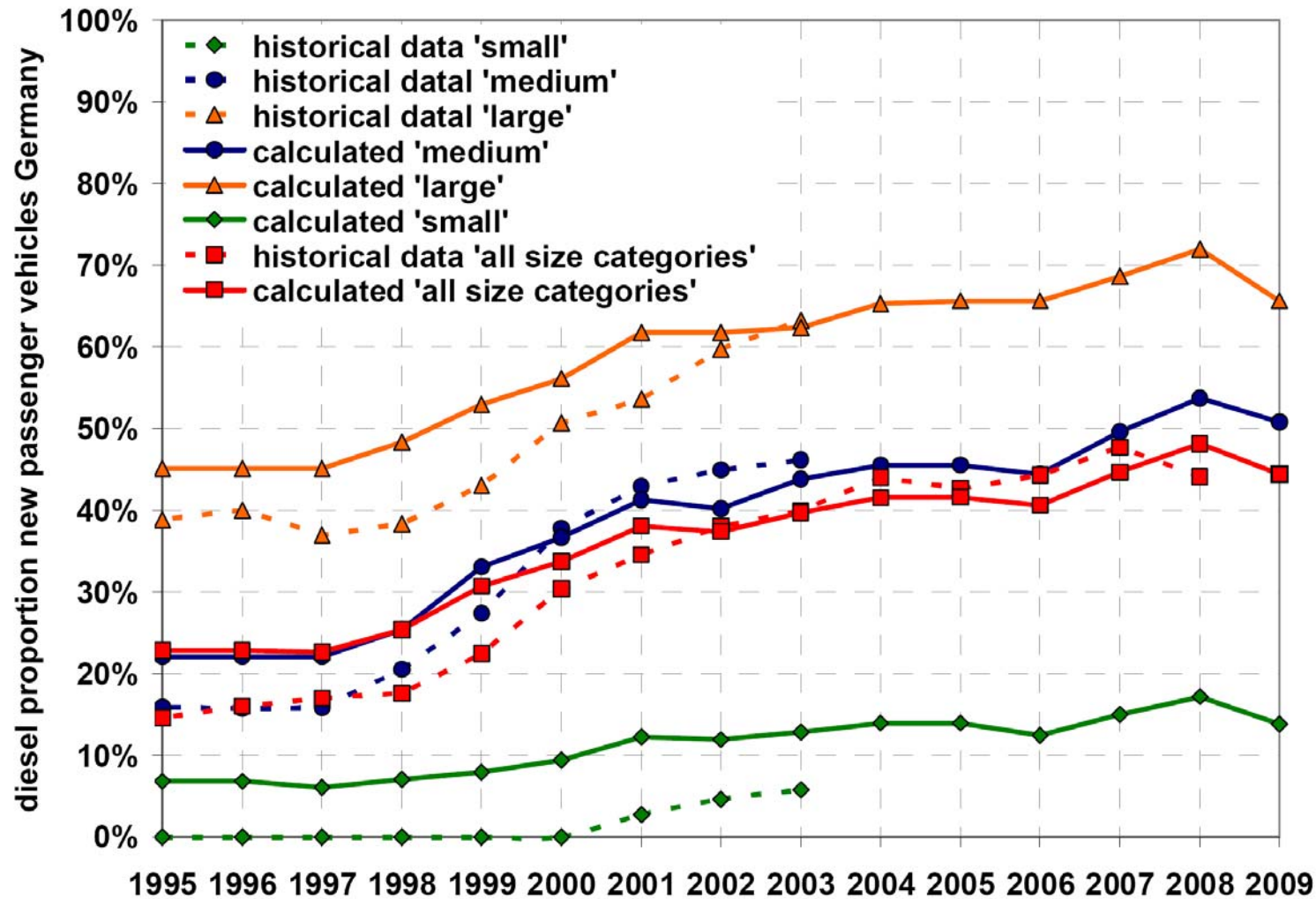
The buying-decision is implemented in a three step approach



- **vehicle variants** (combination of vehicle technology and fuel)
- ① **step 1: filter for vehicle size category and general compulsory requirements**
- ② **step 2: choose lowest relevant cost of ownership (RCO)**
- ③ **step 3: choose lowest well-to-wheel CO₂ emissions**

VECTOR 21 – Vehicle Technology Scenario Model

The model has been validated using historical data for market penetrations of Diesel-vehicles on the German market



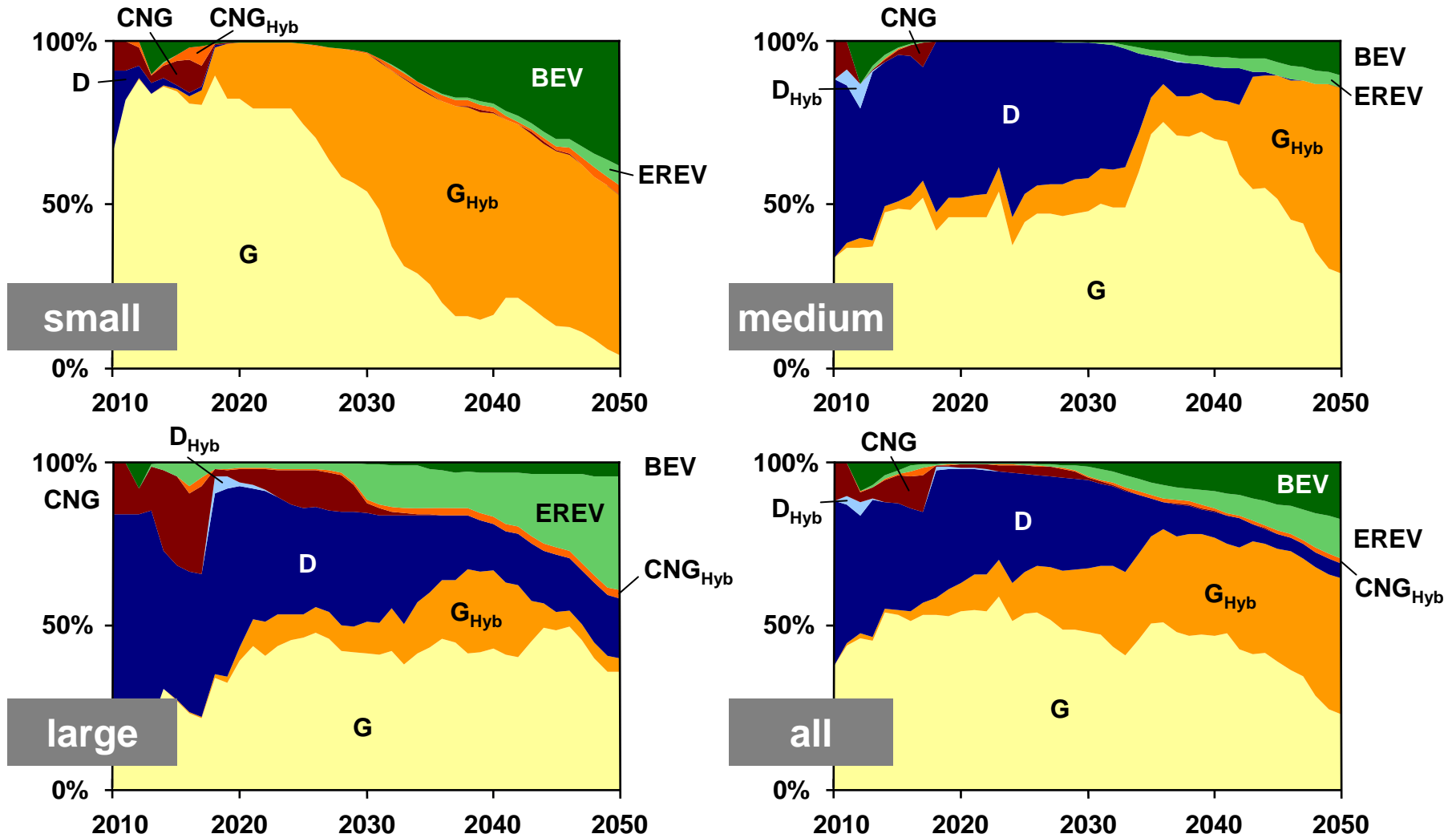
VECTOR 21 - Scenario 1

For the first scenario, 'business-as-usual' assumptions have been defined

Scenario assumptions		2010	2020	2030	2040	2050	Source
Oil price	[€/bbl]	60	80	100	120	130	
CNG fuel tax	[%]	20	starting in 2018: 100				Legislation
Electricity price	[€/kWh]	21,5	34,1	37,3	36,4	35,7	„Leitszenario 2010“ 100% EE
H ₂ -price	[€/kWh]	16,4	39,0	37,6	36,5	35,5	Calculation
Percentage H ₂ produced by electrolysis	[%]	(2015 ► 2020) : (0 ► 100)					DLR analysis
CO ₂ -emissions electricity	[g/kWh]	21					„Leitszenario 2010“, 100% EE (BMU)
CO ₂ -emissions H ₂	[g/kWh]	98	25				Calculation
CO ₂ -target	[g CO ₂ /km]	2015: 130	118	100	90	80	Legislation, BMU
CO ₂ -penalty	[€/ (g CO ₂ /km)]	95					Legislation, DLR analysis
Willingness-to-pay	[%]	0-20					Customer analysis
Distribution vehicle segments	[S/M/L %]	(25/55/20)	(28/50/22)	(30/45/25)			KBA

VECTOR 21 - Scenario 1 - New vehicle fleet

Alternative vehicle concepts will not be able to dominate the market



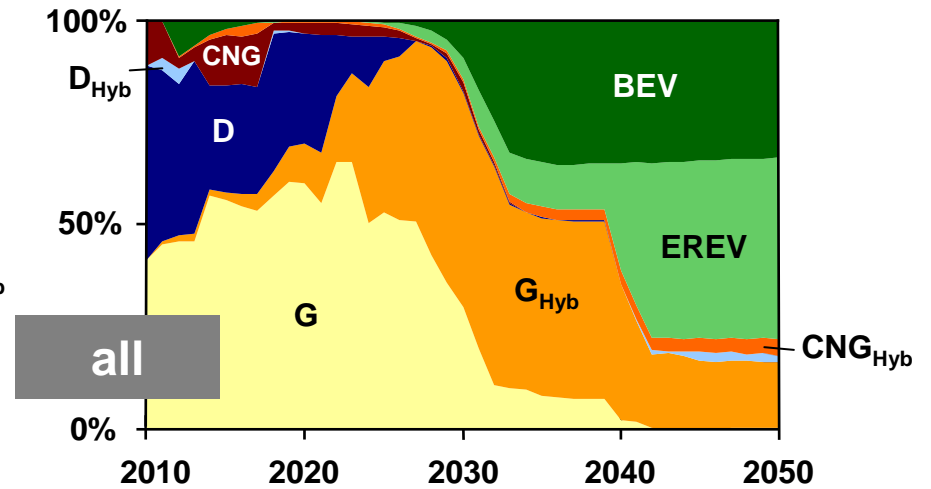
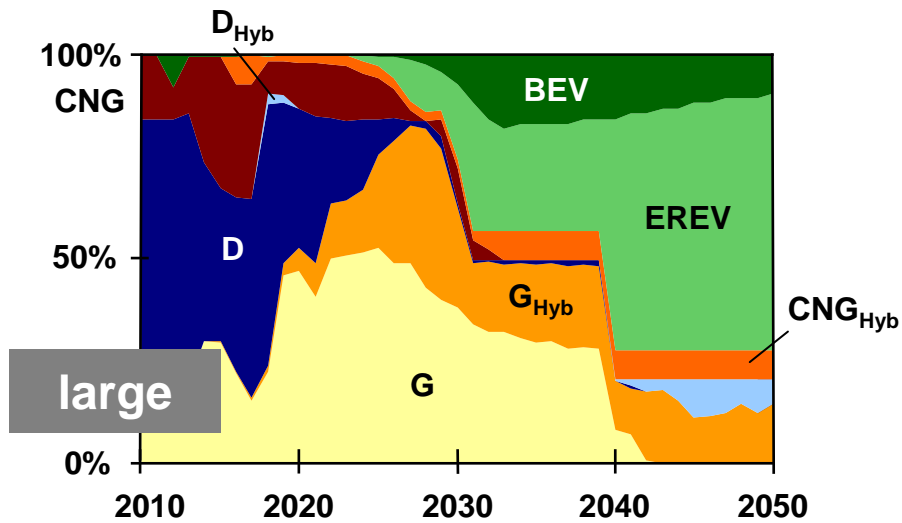
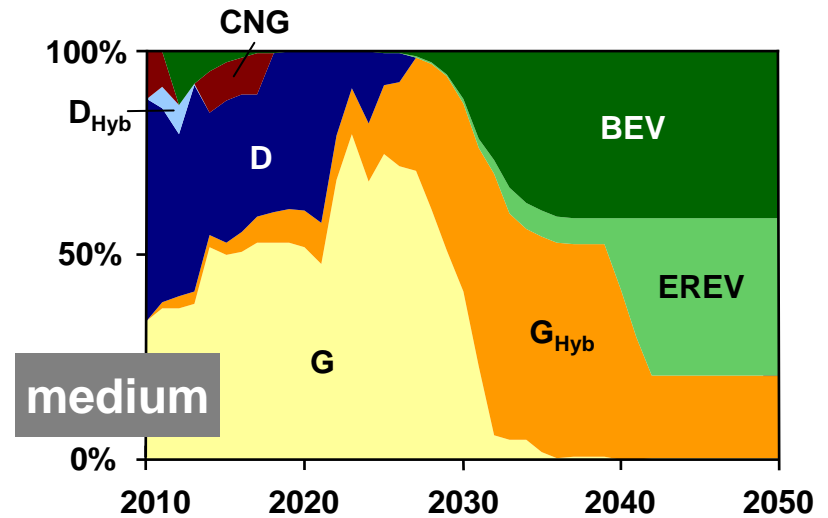
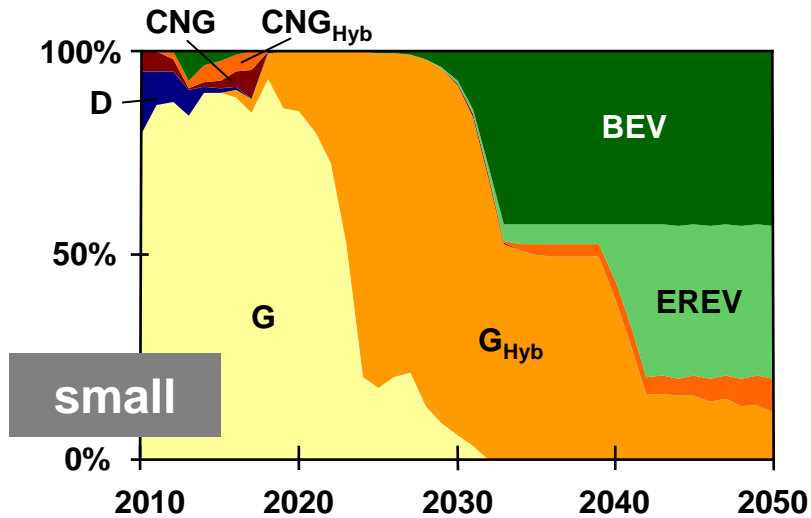
VECTOR 21 - Scenario 2

The second scenario assumes more progressive parameters towards e-mobility

Scenario assumptions		2010	2020	2030	2040	2050	Source
Oil price	[€/bbl]	60	100	130			
CNG fuel tax	[%]	20	starting in 2018: 100				Legislation
Electricity price	[€/ct/kWh]	20,7	36,7	40,2	38,3	37,7	„Leitszenario 2010“ 100% EE
H ₂ -price	[€/ct/kWh]	16,4	42,5	41,5	39,0	38,2	Calculation
Percentage H ₂ produced by electrolysis	[%]	(2015 ► 2020) : (0 ► 100)					DLR analysis
CO ₂ -emissions electricity	[g/kWh]	511	450	264	110	82	„Leitszenario 2010“, 100% EE (BMU)
CO ₂ -emissions H ₂	[g/kWh]	353	540	317	132	98	Calculation
CO ₂ -target	[g CO ₂ /km]	2015: 130	110	72	35		Legislation, BMU
CO ₂ -penalty	[€/ (g CO ₂ /km)]	2015: 95	105	110	120		Legislation, DLR analysis
Willingness-to-pay	[%]	0-20					Customer analysis
Distribution vehicle segments	[S/M/L %]	(25/55/20)	(28/50/22)	(30/45/25)			KBA

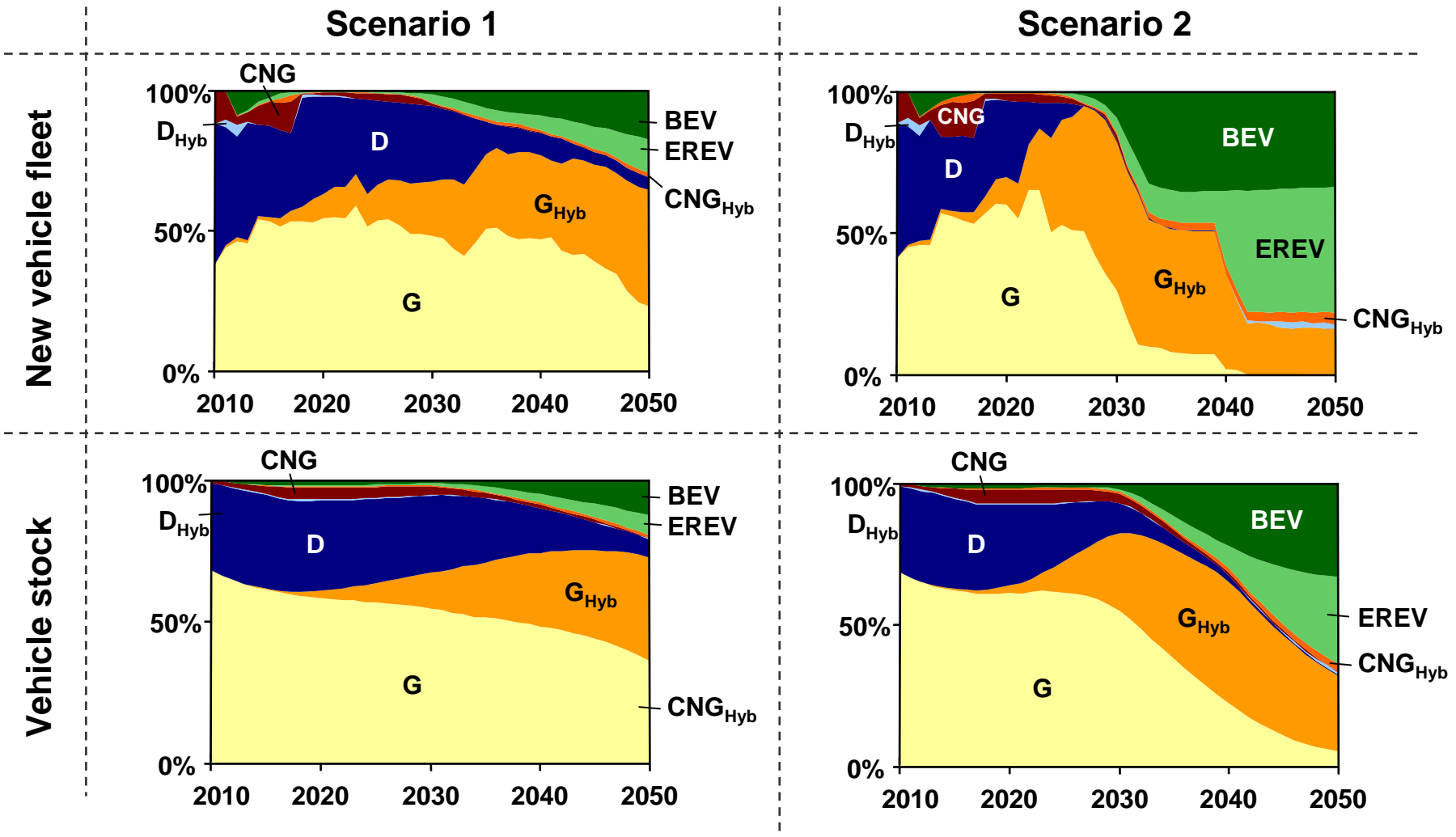
VECTOR 21 - Scenario 2 - New vehicle fleet

Due to severe CO₂-penalties, alternative vehicle concepts will succeed



VECTOR 21 - Scenario 1 vs Scenario 2

The changes will have a slow impact on the entire vehicle stock



Conclusion

VECTOR21 facilitates the ex-ante analysis of the future passenger car market, taking into account technology developments and external factors





**Deutsches Zentrum
für Luft- und Raumfahrt e.V.**

in der Helmholtz-Gemeinschaft

Institut für Fahrzeugkonzepte

BACK UP



Scenario calculations

Scenario 1 (Baseline) – Assumptions

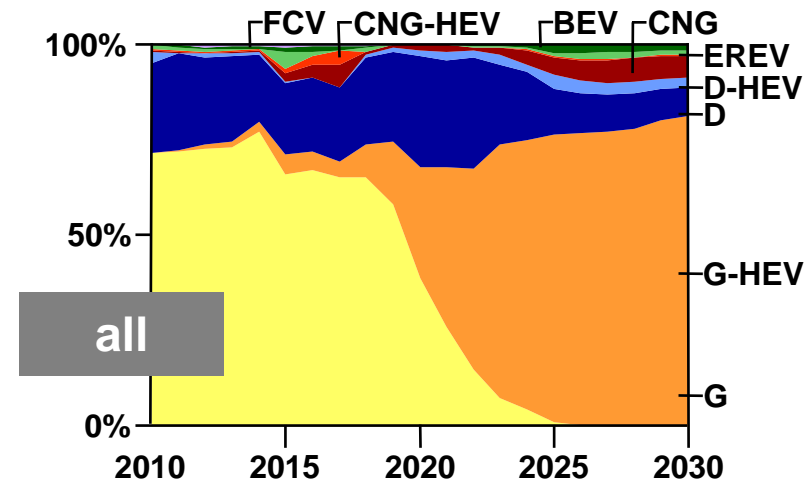
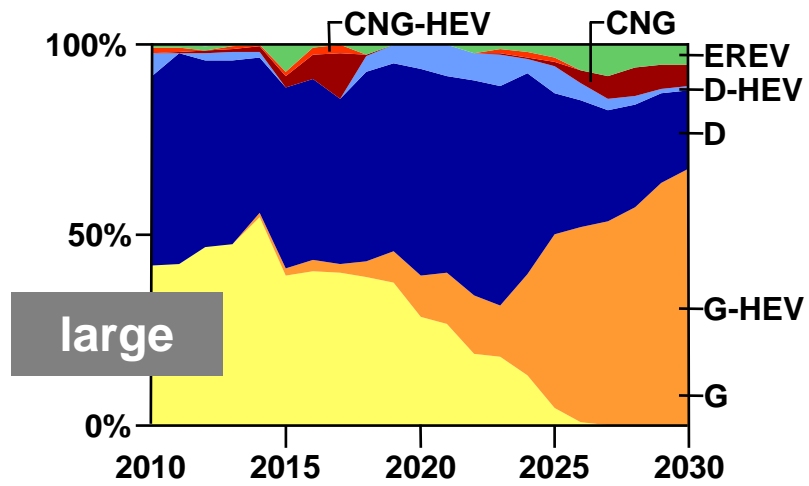
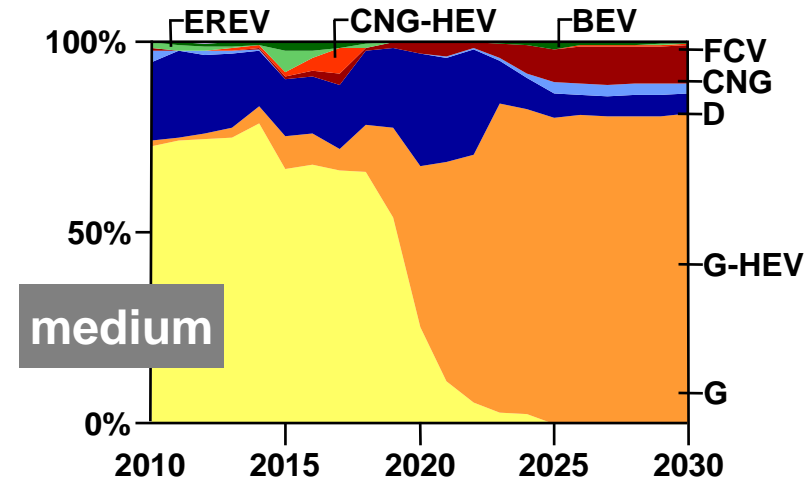
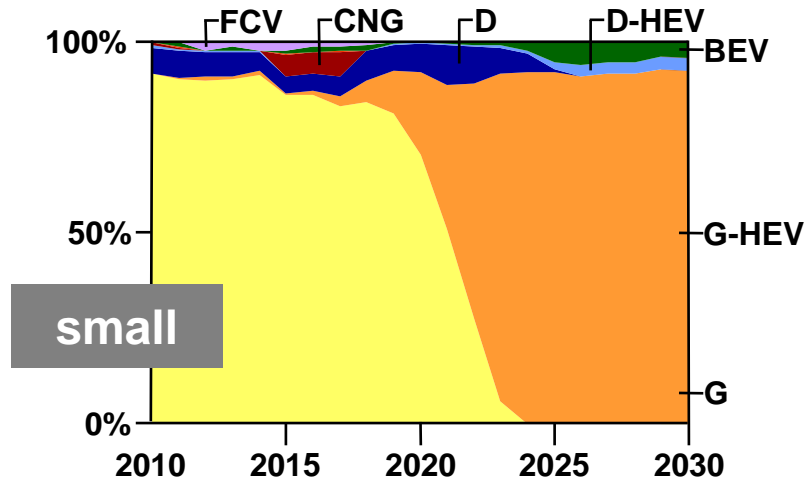
Backup

	2010	2015	2020	2025	2030
Oil price [€/bbl]	54	52	50	58	65
Share of biofuels [%]	0-8	4-11	8-13	11-14	15
Electricity – Source	German mix				
Electricity – CO₂ intensity [g/kWh]	600	610	620	590	550
Electricity – price [€/kWh]	0.18	0.18	0.35	0.35	0.35
Hydrogen – source	natural gas		electricity		
Hydrogen – CO₂ intensity [g/kWh]	350	350	740	700	650
Hydrogen – price [€/kWh]	0.16	0.16	0.35	0.35	0.35
CO₂ – target value new vehicles [g/km]	---	140	125	113	113
CO₂ – penalty for exceeding target [€/g/km]	---	95	95	95	95
Customers – willingness to pay for fuel economy [%]	0-10	0-10	0-10	0-10	0-10
Vehicle size categories (small / medium / large) [%]	25/55/20	26/52/21	28/50/23	29/47/24	30/45/25

VECTOR 21 – Vehicle Technology Scenario Model

Szenario 2 (Business-As-Usual) – Neufahrzeugflotte

Backup



Scenario calculations

Scenario 2 (Climate Protection) – Assumptions

Backup

	2010	2015	2020	2025	2030
Oil price [€/bbl]	54	52	50	58	65
Share of biofuels [%]	0-8	6-14	13-18	19-21	25
Electricity – Source	renewables				
Electricity – CO ₂ intensity [g/kWh]	20	20	20	20	20
Electricity – price [€/kWh]	0,21	0,21	0,37	0,37	0,37
Hydrogen – source	electricity				
Hydrogen – CO ₂ intensity [g/kWh]	25	25	25	25	25
Hydrogen – price [€/kWh]	0,21	0,21	0,38	0,38	0,38
CO ₂ – target value new vehicles [g/km]	---	140	113	95	76
CO ₂ – penalty for exceeding target [€/g/km]	---	95	105	113	120
Customers – willingness to pay for fuel economy [%]	0-20	0-20	0-20	0-20	0-20
Vehicle size categories (small / medium / large) [%]	25/55/20	26/52/21	28/50/23	29/47/24	30/45/25

VECTOR 21 – Vehicle Technology Scenario Model

Szenario 2 (Climate Protection) – Neufahrzeugflotte

