EU-Commission
JRC Contribution to EVE IWG:
In-vehicle battery durability

38th Meeting of the GRPE Informal Working Group
Electric Vehicles and the Environment (EVE)

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Webex, 8-9th October 2020

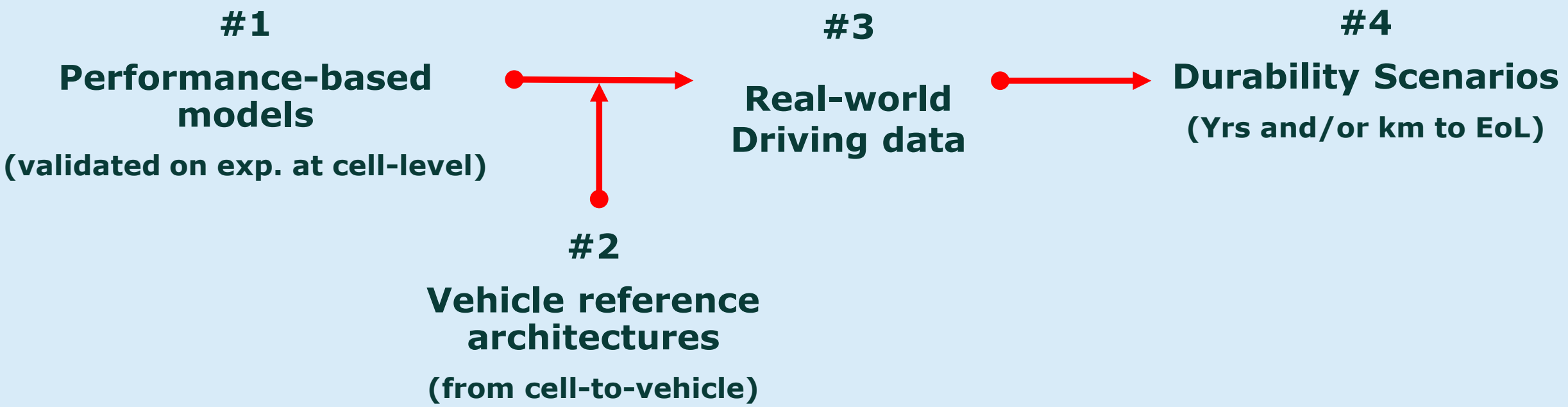
Presentation Summary

Follow-up of the JRC contribution to the EVE IWG “in-vehicle battery ageing” topic:

- Capacity fade at 5 and 100,000km and 8 years and 160,000km

in support to the definition of the minimum performance requirements (MPR)

Summary of the JRC TEMA logical passages



Performance based models (SotA)

	Capacity fade		Power fade	
	Calendar	Cycle	Calendar	Cycle
$LiFePO_4$	Sarasketa-Zabala et Al. (2013/14);	Wang et Al. (2011);	Sarasketa-Zabala et Al. (2013);	
		Sarasketa-Zabala et Al. (2013);		
		Sarasketa-Zabala et Al. (2015);		
NCM + spinel Mn	Wang et Al. (2014);		-	Wang et Al. (2014);
NCM – LMO	-	Cordoba-Arenas et Al. (2014);	-	Cordoba-Arenas et Al. (2015);

Calendar + Cycle (4 Combinations):

#1 (LiFePO4): Sarasketa-Zabala et Al. (2013/14) model for calendar plus Wang et Al. (2011) model for cycle;

#2 (LiFePO4): Sarasketa-Zabala et Al. (2013/14) model for calendar plus Sarasketa-Zabala et Al. (2015) model for cycle;

#3 (NCM + Spinel Mn): Wang et Al. (2014) for calendar plus Wang et Al. (2014) for cycle;

#4 (NCM-LMO): Wang et Al. (2014) for calendar plus Cordoba-Arenas et Al. (2015) for cycle

Implementation of the performance based models into JRC TEMA (assumptions 1/2)

Vehicle Electric Architectures (examples)

PHEV 1 PHEV 2 PHEV 3 BEV 1 BEV 2 BEV 3 BEV 4

	Vehicle Type	Battery Size [Wh]	Battery Shape	No. of Cells [#] and Type	Reference Voltage [V]	Electric Architecture	Usable Energy at BoL [Wh]	Usable Energy at EoL [Wh]	Reserve [% of battery capacity]	Energy consumption [Wh/km]
HP PHEV	PHEV 1	16,000	T-shaped	192 – pouch	365	2P-96S	12,000	9,600	25%	205
Mid-sized PHEV	PHEV 2	8,800	Parallelepiped	95-Prismatic	351	95S	6,600	5,280	25%	160
Mid-sized PHEV	PHEV 3	12,000	Parallelepiped	80-Prismatic	300	80S	9,000	7,200	25%	194
Mid-sized BEV	BEV 1	24,000	Parallelepiped	192 – pouch	360	48S-2P-2S	18,000	14,400	15%	210
HP large-sized BEV	BEV 2	85,000	Flat	6,912 - cylindrical	345	16S-72P-6S	63,750	51,000	15%	235
HP large-sized BEV	BEV 3	75,000	Flat	4,416 - cylindrical	345	4S-46P-23|25S	56,250	45,000	15%	180
HP large-sized BEV	BEV 4	95,000	Flat	432 – pouch	396	4P-108S	71,250	57,000	15%	262

Minimum performance requirements (MPR)

- JRC TEMA can support the definition of the minimum performance requirements
  - Different vehicle segments and technology
  - Different battery chemistries and architectures
  - Different km driven per month based on real-world data
  - Different European geographical areas
  - Several recharging strategies

Recharging strategies and vehicle segments

- Recharge strategies adopted (16 available in TEMA)

  - Str. 1 = Long Stop Random AC;
  - Str. 2 = Short-Stop Random DC;
  - Str. 3 = Night AC
  - Str. 4 = Smart AC;
  - Str. 5 = Long-Stop AC 3-phases;

- Vehicle segments adopted:

  - B-segment BEV
  - 3 D-segment premium BEV
  - B-D segment PHEVs

- Additional run explored:

  - A-segment BEV
  - D-segment SUV BEV

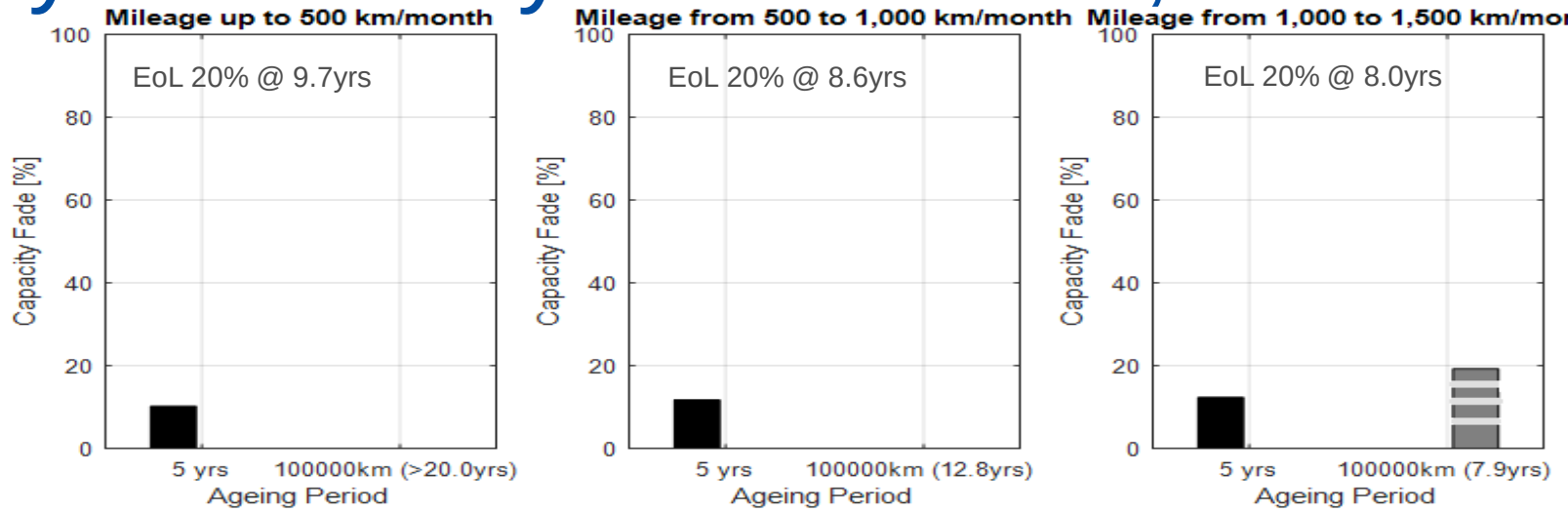
Capacity fade at 5 and 8 years and 100,000km and 160,000km

Legend
- Capacity fade above and equal 20%
- Capacity fade above or equal to 10% and below 20%;
- Capacity fade below 10%

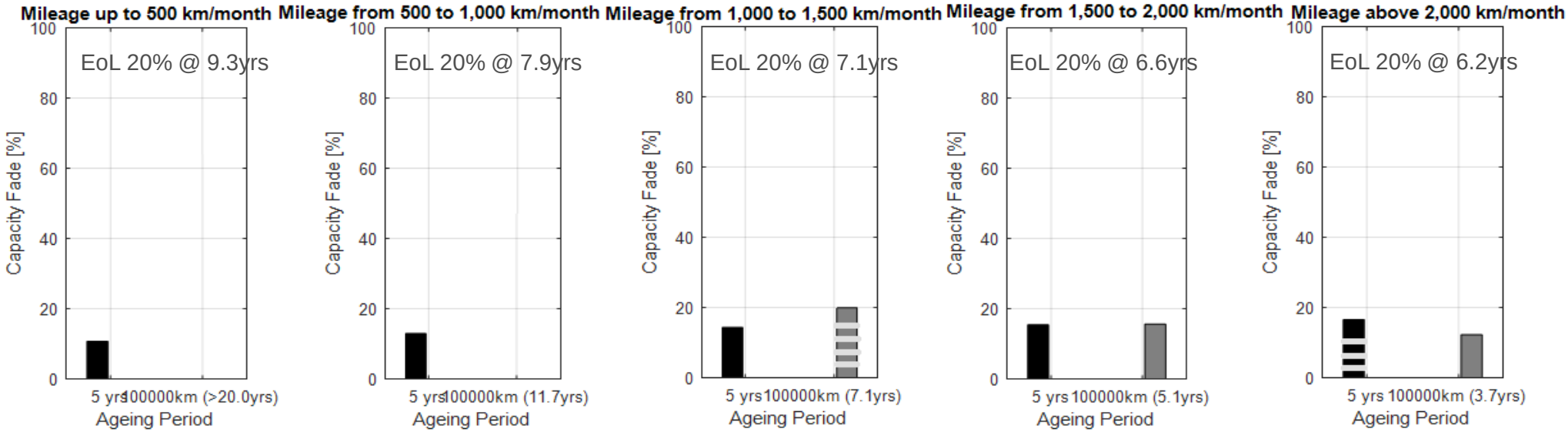
Capacity fade in [%] at 5 years and 100,000km at 8 years and 160,000km Years Driving to Set Threshold Li-Ion NCM-LMO (2015)			0 - 500 km/month							500 – 1,000 km/month							1,000 -1,500 km/month							1,500 – 2,000 km/month							2,000+ km/month						
			5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #1	PHEV-1			4.9	≥ 60	≥ 60	18.2	≥ 25	≥ 25		3.2	12.5	22.3	20.6	14.2	22.8																				
	BEV-1		10.2	16.9	55.2	≥ 60	9.7	≥ 25	≥ 25	11.7	18.7	27.6	38.8	8.6	12.8	20.5	12.4	19.5	19.3	28.3	8.2	7.9	12.6													
	BEV-2	Modena Prov.	7.5	13.5	40.0	≥ 60	12.1	≥ 25	≥ 25	6.9	12.7	17.8	26.4	12.7	11.2	17.9	6.2	11.8	10.0	16.5	13.6	6.9	11.1	5.4	10.8	5.5	11.0	14.7	5.0	8.1	4.6	9.7	2.3	7.0	16.1	3.9	6.3
	BEV-3		8.0	14.1	41.2	≥ 60	11.9	≥ 25	≥ 25	8.2	14.3	19.5	28.7	12.3	11.1	17.8	8.2	14.3	12.1	19.3	12.8	6.8	10.9	8.2	14.3	8.0	14.1	13.5	4.9	7.9	8.1	14.2	5.2	10.6	14.4	3.8	6.1
	BEV-4		9.3	15.7	22.7	≥ 60	10.2	≥ 25	≥ 25	10.3	17.0	22.7	32.7	9.7	11.2	17.9	10.8	17.6	15.5	23.4	9.6	6.9	11.1	11.2	18.1	11.5	18.5	9.8	5.1	8.2	11.6	18.6	8.5	14.9	10.0	3.9	6.3
Recharge Strategy #2	BEV-1		10.7	17.5	51.8	≥ 60	9.3	≥ 25	≥ 25	13.0	20.3	27.6	38.8	7.9	11.7	18.7	14.4	22.1	20.0	29.1	7.1	7.1	11.4	15.4	23.4	15.6	23.6	6.6	5.1	8.1	16.6	24.8	12.3	19.6	6.2	3.7	6.0
	BEV-2	Modena Prov.	8.0	14.1	41.5	≥ 60	11.6	≥ 25	≥ 25	8.2	14.4	19.5	28.6	11.4	11.0	17.7	8.3	14.5	12.2	19.3	11.3	6.8	10.8	8.4	14.6	8.0	14.1	11.2	4.8	7.7	8.4	14.6	4.3	9.4	11.2	3.4	5.4
	BEV-3		8.1	14.3	41.7	≥ 60	11.5	≥ 25	≥ 25	8.5	14.7	19.9	29.1	11.3	11.0	17.6	8.7	14.9	12.5	19.8	11.1	6.8	10.8	8.8	15.1	8.4	14.6	11.0	4.8	7.7	9.0	15.3	4.5	9.7	10.9	3.3	5.3
	BEV-4		9.4	15.9	44.9	≥ 60	9.8	≥ 25	≥ 25	10.6	17.4	23.0	33.1	8.6	11.0	17.7	11.4	18.4	15.7	23.8	8.0	6.8	10.8	12.1	19.2	11.6	18.6	7.5	4.8	7.8	12.8	20.1	7.8	13.9	7.1	3.4	5.4
Recharge Strategy #3	PHEV-1			4.8	42.1	≥ 60	18.3	≥ 25	≥ 25		2.6	9.2	18.1	21.5	12.3	19.8				3.9	30.2	7.7	12.3														
	BEV-1		10.4	17.0	50.9	≥ 60	9.6	≥ 25	≥ 25	11.9	18.9	25.9	36.6	8.5	11.7	18.7	12.5	19.7	17.8	26.4	8.2	7.2	11.5	12.7	20.0	13.3	20.7	8.0	5.2	8.4							
	BEV-2	Modena Prov.	7.5	13.5	40.5	≥ 60	12.1	≥ 25	≥ 25	6.9	12.7	17.6	26.3	12.7	11.1	17.7	6.2	11.8	9.7	16.2	13.7	6.8	10.9	5.4	10.8	5.2	10.6	14.8	4.9	7.9	4.6	9.8	2.5	7.2	16.0	4.0	6.4
	BEV-3		8.0	14.1	41.7	≥ 60	11.9	≥ 25	≥ 25	8.2	14.3	19.5	28.6	12.3	11.0	17.7	8.2	14.3	12.0	19.1	12.8	6.8	10.8	8.2	14.3	7.9	13.9	13.6	4.9	7.8	8.1	14.2	4.8	10.1	14.6	3.7	5.9
	BEV-4		9.3	15.7	44.8	≥ 60	10.2	≥ 25	≥ 25	10.3	17.0	22.6	32.5	9.7	11.1	17.7	10.9	17.7	15.2	23.1	9.6	6.8	10.9	11.2	18.1	11.2	18.1	9.8	5.0	8.0	11.5	18.5	8.9	15.4	9.9	4.1	6.6
Recharge Strategy #5	PHEV-1			6.6	41.5	≥ 60	16.3	≥ 25	≥ 25		8.3	15.0	25.5	13.3	11.5	18.5		9.0	6.7	15.0	14.1	7.0	11.1	2.1	9.2	1.9	9.0	13.9	4.9	7.9	2.1	9.2		5.2	13.9	3.9	6.2
	BEV-1		10.7	17.5	50.3	≥ 60	9.3	≥ 25	≥ 25	12.9	20.2	26.7	37.6	7.9	11.3	18.0	14.2	21.8	19.2	28.1	7.2	6.9	11.0	15.2	23.1	15.0	22.8	6.8	4.9	7.9	16.2	24.4	11.6	18.7	6.3	3.6	5.8
	BEV-2	Modena Prov.	7.9	14.0	41.7	≥ 60	11.7	≥ 25	≥ 25	8.0	14.1	19.1	28.1	11.6	11.0	17.6	8.0	14.0	11.7	18.7	11.6	6.8	10.8	7.9	13.9	7.5	13.4	11.7	4.8	7.7	7.6	13.6	3.2	8.1	12.0	3.3	5.2
	BEV-3		8.1	14.2	42.1	≥ 60	11.6	≥ 25	≥ 25	8.4	14.6	19.7	28.9	11.4	11.0	17.6	8.6	14.8	12.4	19.7	11.4	6.8	10.8	8.7	15.0	8.3	14.5	11.4	4.8	7.7	8.8	15.1	4.1	9.2	11.5	3.2	5.1
	BEV-4		9.4	15.8	45.2	≥ 60	9.9	≥ 25	≥ 25	10.6	17.3	22.9	32.9	8.8	11.0	17.6	11.3	18.3	15.6	23.6	8.3	6.8	10.8	11.9	19.0	11.5	18.5	7.9	4.8	7.7	12.7	19.9	7.3	13.3	7.5	3.3	5.2

Capacity fade at 5 years and 100,000km - BEV-1

Recharge Strategy 1



Recharge Strategy 2

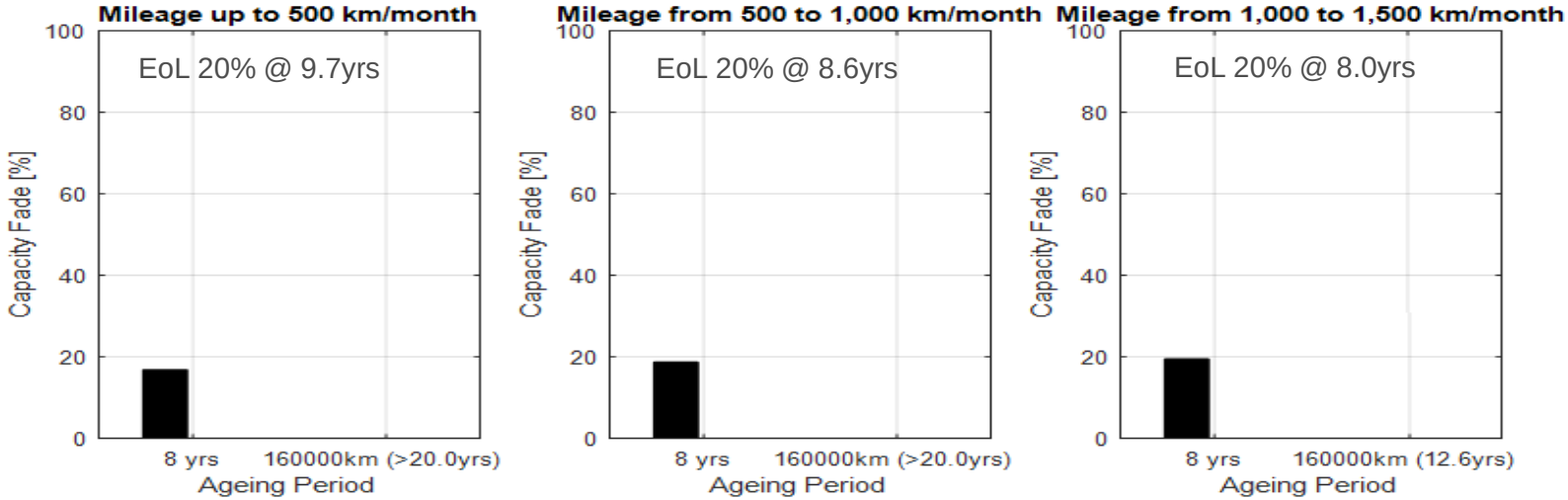


Li-Ion NCM-LMO (2015)
Modena province area

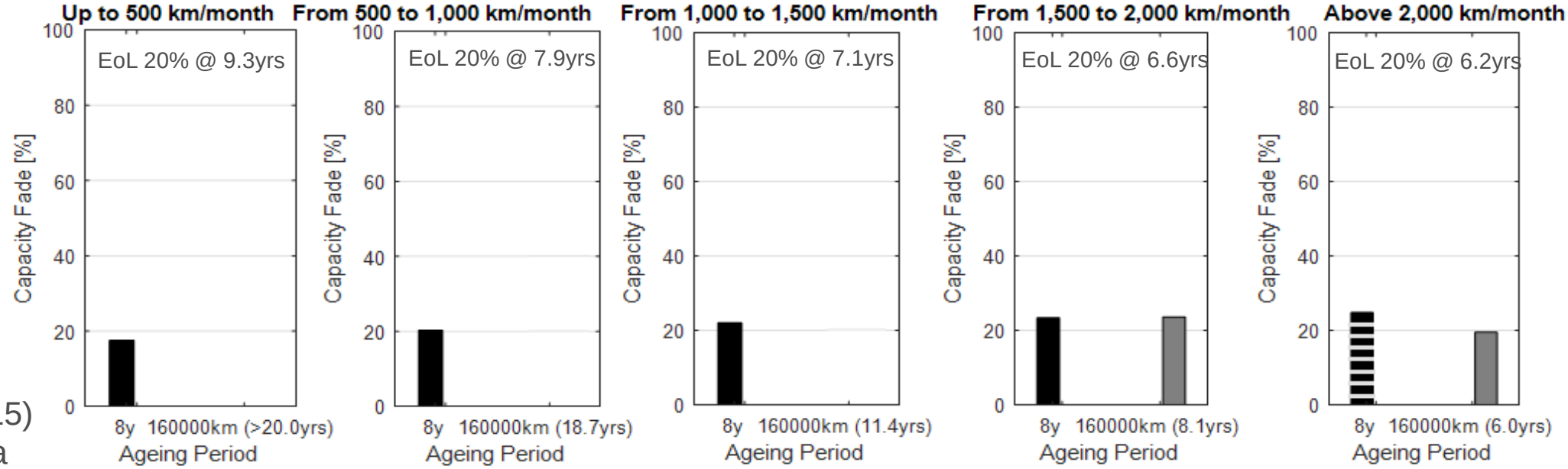
European Commission

Capacity fade at 8 years and 160,000km - BEV-1

Recharge Strategy 1



Recharge Strategy 2



Li-Ion NCM-LMO (2015)
Modena province area

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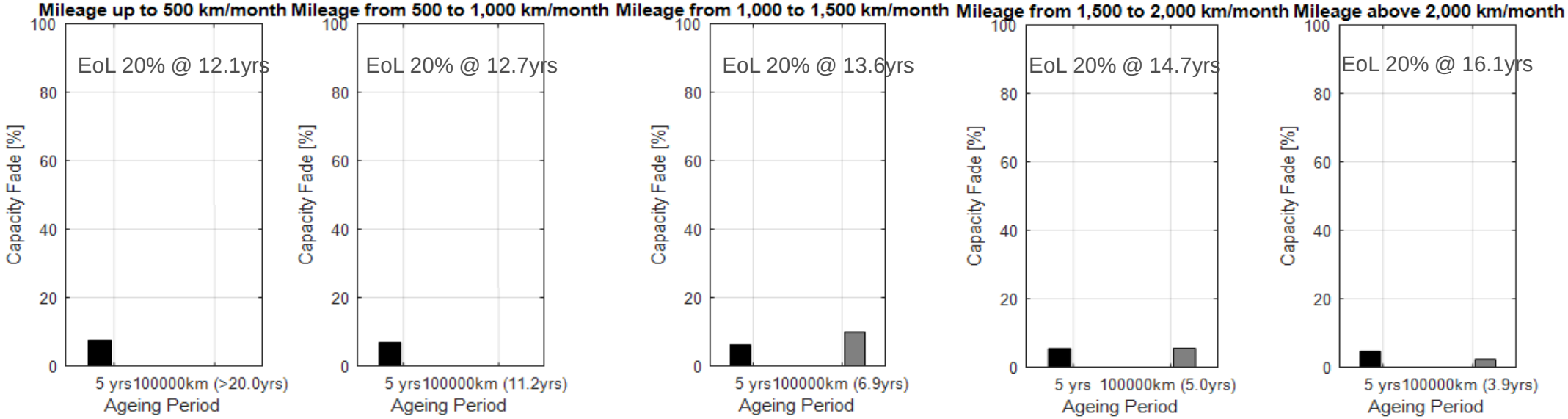
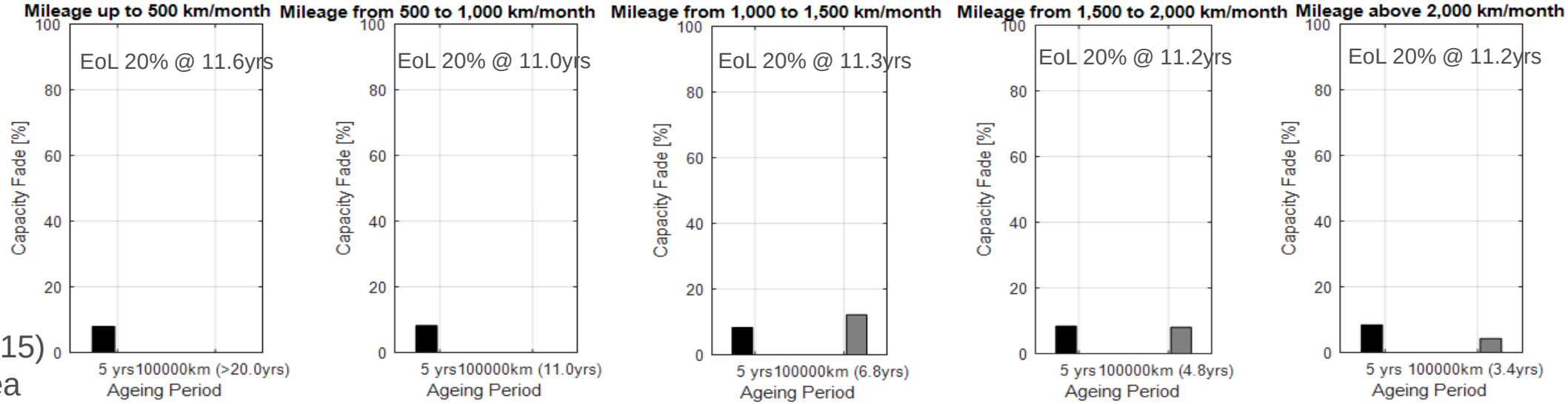
Capacity fade at 5 years and 100,000km - BEV-2

Recharge Strategy 1



Recharge Strategy 2



Li-Ion NCM-LMO (2015)
Modena province area

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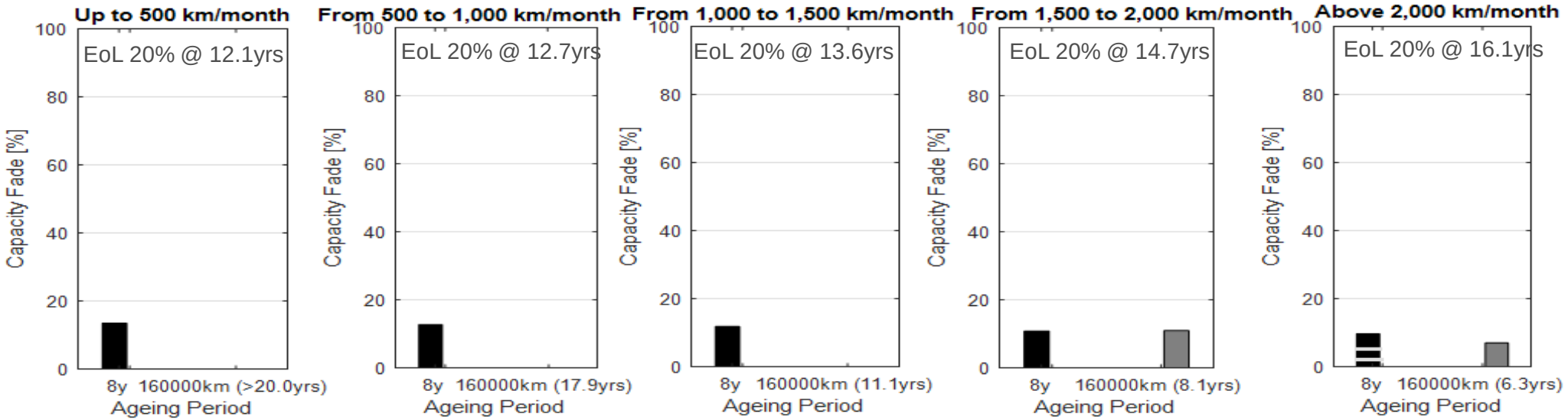
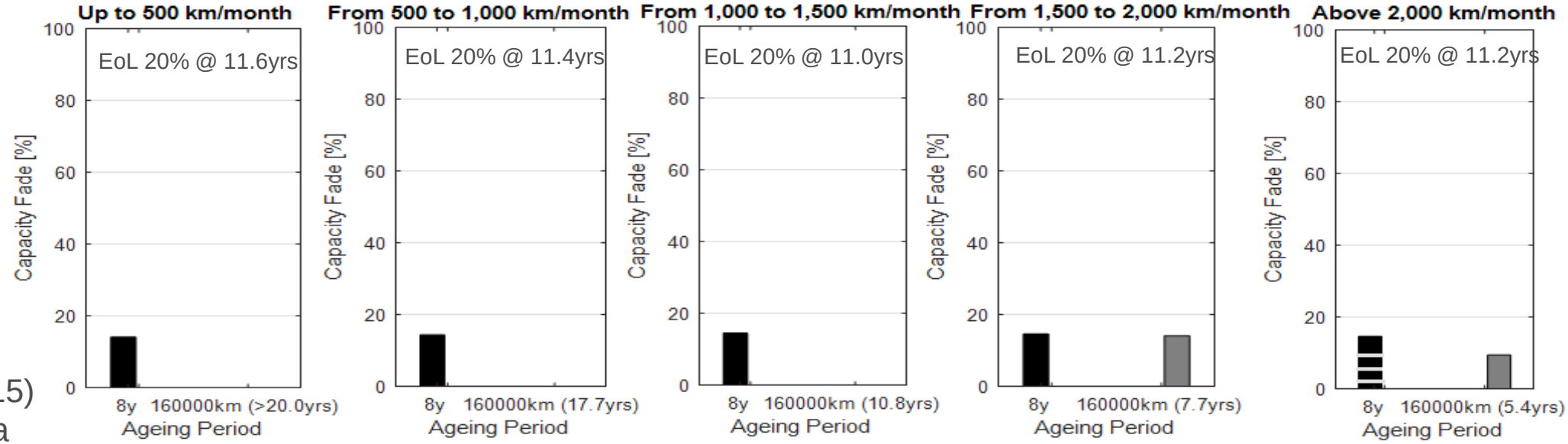
Capacity fade at 8 years and 160,000km - BEV-2

Recharge Strategy 1



Recharge Strategy 2



Li-Ion NCM-LMO (2015)
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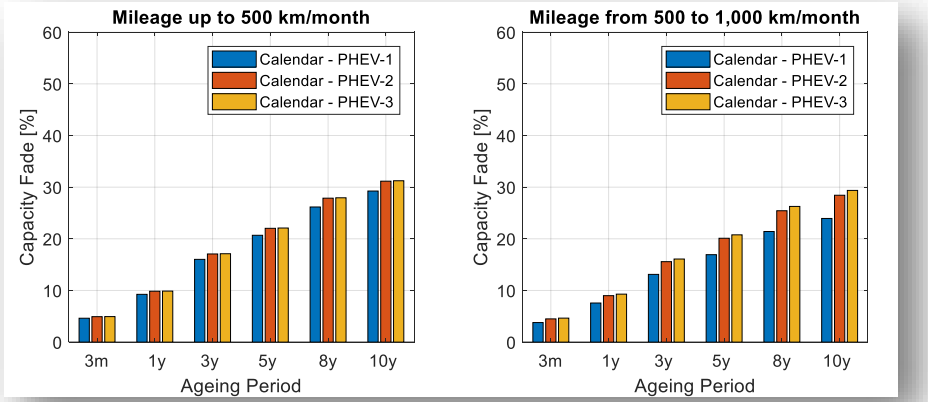
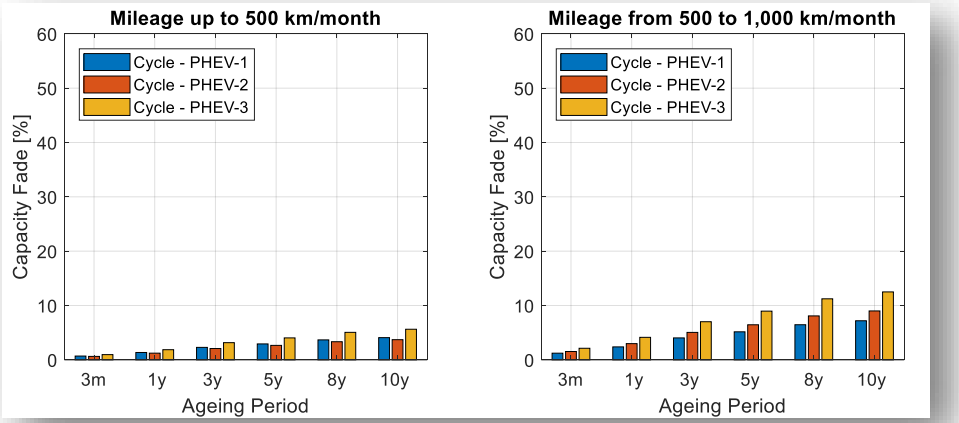
Capacity fade **different PHEVs** – visualisation

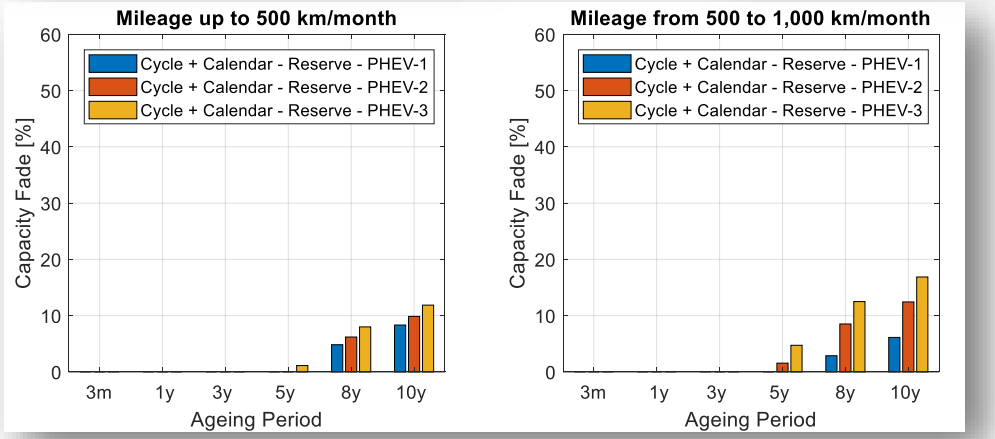
Calendar ageing



Cycle ageing



Cycle + Calendar - Reserve ageing



Recharge Strategy 1

Li-Ion NCM-LMO (2015) - Modena province area

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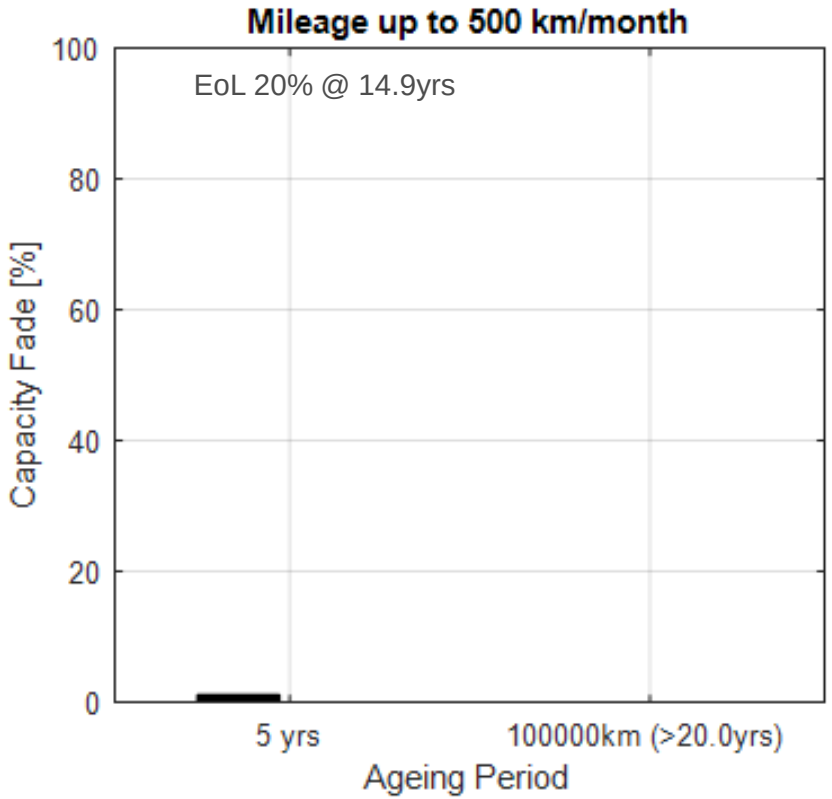
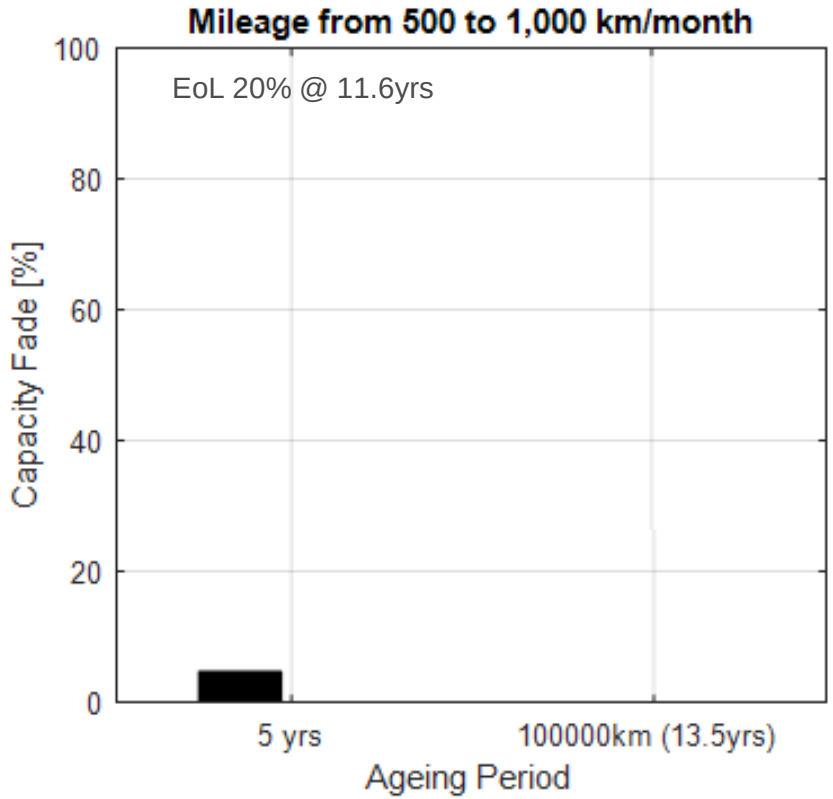
Capacity fade at 5 years and 100,000km – PHEV -3

Recharge Strategy 1





Li-Ion NCM-LMO (2015) - Modena province area

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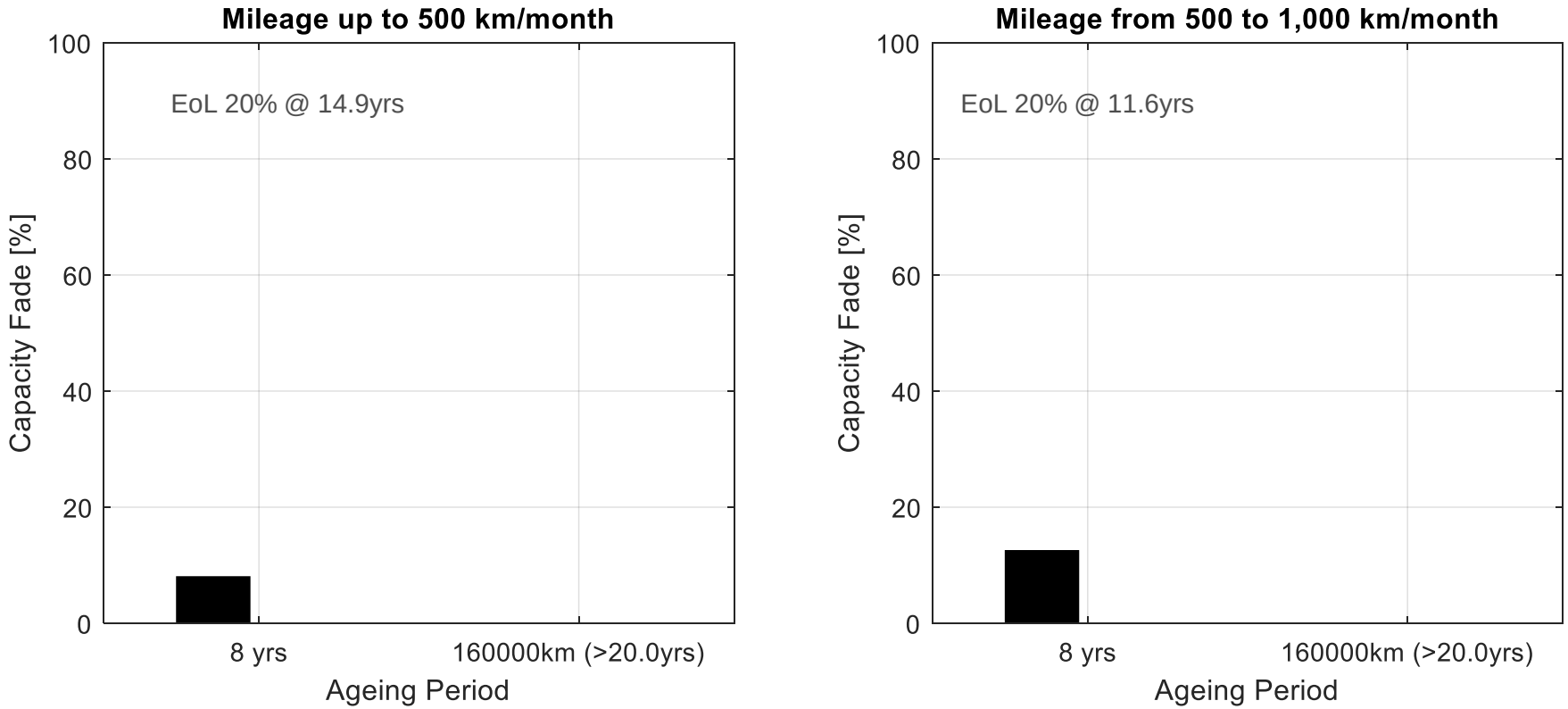
Capacity fade at 8 years and 160,000km – PHEV -3

Recharge Strategy 1



Li-Ion NCM-LMO (2015) - Modena province area

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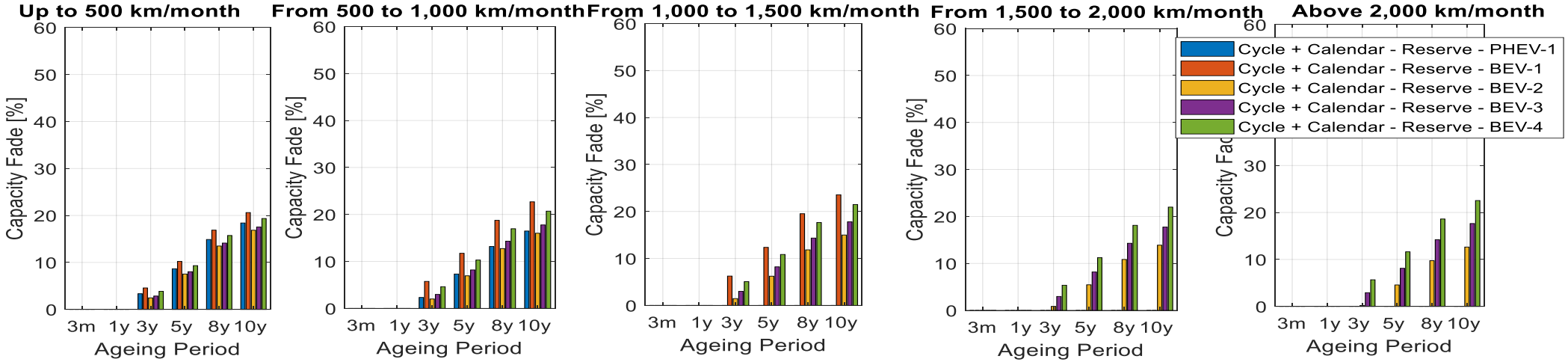
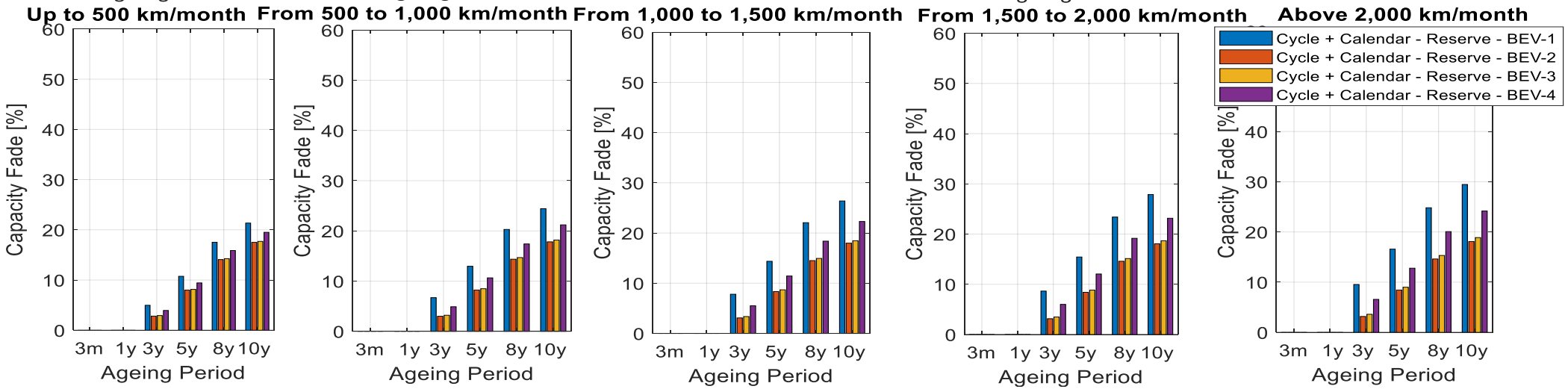
Capacity fade **different vehicle types**– visualisation

Recharge Strategy 1



Recharge Strategy 2



Li-Ion NCM-LMO (2015) - Modena province area

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Minimum performance requirements (PR) – JRC TEMA

- Minimum performance requirement according to the analysis of **all possible vehicles, battery architectures, mileage and recharging strategies as for** JRC TEMA analyses:
  - BEV: > 80% of certified capacity within 5 year or 100,000 km
    > 70% of certified capacity within 8 year or 160,000 km
  - PHEV: > 90% of certified capacity within 5 year or 100,000 km
    > 80% of certified capacity within 8 year or 160,000 km
- Analysis still pending for driving range MPR

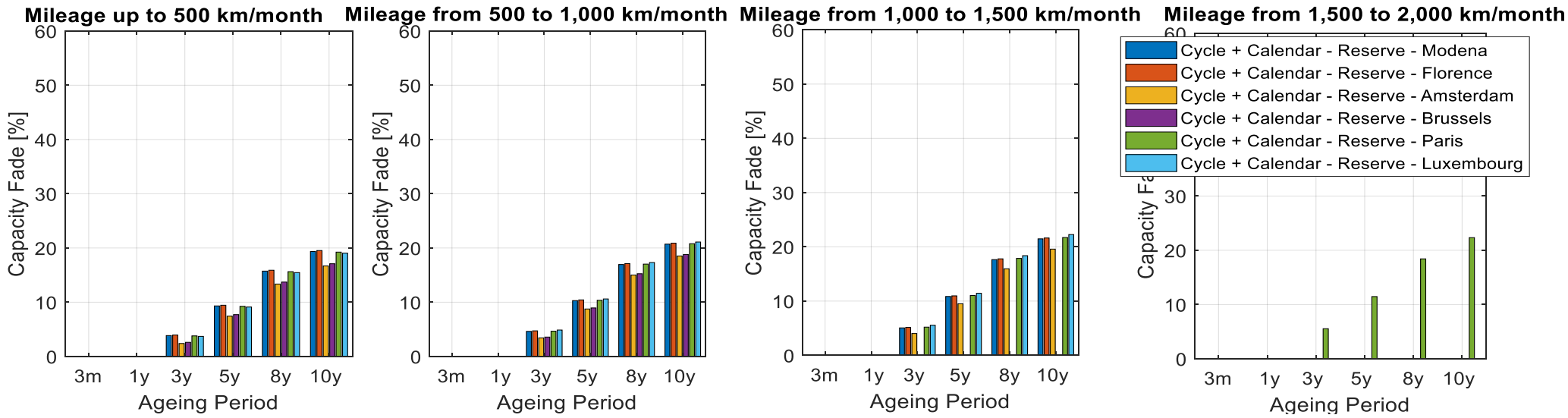
Minimum performance requirements (PR) – JRC TEMA

- Minimum performance requirement according to the analysis of the **advanced vehicles, battery architectures as for** JRC TEMA analyses:
  - BEV: > 90% of certified capacity within 5 year or 100,000 km
    > 85% of certified capacity within 8 year or 160,000 km
  - PHEV: > 95% of certified capacity within 5 year or 100,000 km
    > 90% of certified capacity within 8 year or 160,000 km
- Analysis still pending for driving range MPR

Capacity fade **different geographic area**

Capacity fade **different geographic area** – BEV-1

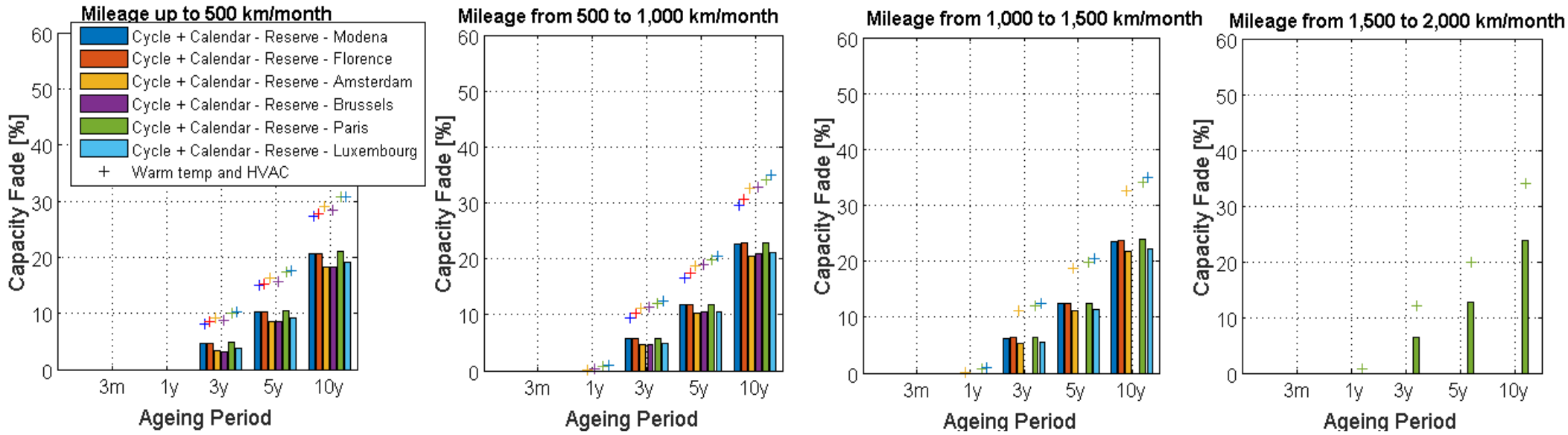
Recharge Strategy 1



Li-Ion NCM-LMO (2015)

Capacity fade **warm temperature** – BEV-1

Recharge Strategy 1



Li-Ion NCM-LMO (2015) - Modena province area

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Capacity fade **V2G**

Capacity fade **V2G** – BEV-1

Modena Database EoL @ 80% capacity fade Li-Ion NCM-LMO (2015) Years Driving to Set Threshold V2G					0 - 500 km/month			500 – 1,000 km/month			1,000 -1,500 km/month			1,500 – 2,000 km/month			2,000+ km/month		
					Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #1	V2G POI	BEV-1	0%	NCM-LMO (2015)	9.7	≥ 20	≥ 20	8.6	12.8	≥ 20	8.2	7.9	12.6						
			2%		9.5	≥ 20	≥ 20	8.6	12.8	≥ 20	8.3	7.9	12.6						
			20%		9.4	≥ 20	≥ 20	8.6	12.8	≥ 20	8.2	7.9	12.6						
Recharge Strategy #2	V2G POI	BEV-1	0%	NCM-LMO (2015)	9.3	≥ 20	≥ 20	7.9	11.7	18.7	7.1	7.1	11.4	6.6	5.1	8.1	6.2	3.7	6.0
			2%		9.1	≥ 20	≥ 20	7.7	11.7	18.7	7.0	7.1	11.4	6.6	5.1	8.1	6.1	3.7	6.0
			20%		8.5	≥ 20	≥ 20	7.3	11.7	18.7	6.8	7.1	11.4	6.5	5.1	8.1	6.2	3.7	6.0

Legend

	EoL below 5.0 years;
	EoL above or equal to 5.0 and below 10.0 years;
	EoL above or equal to 10.0 years;

Li-Ion NCM-LMO (2015) - Modena province area

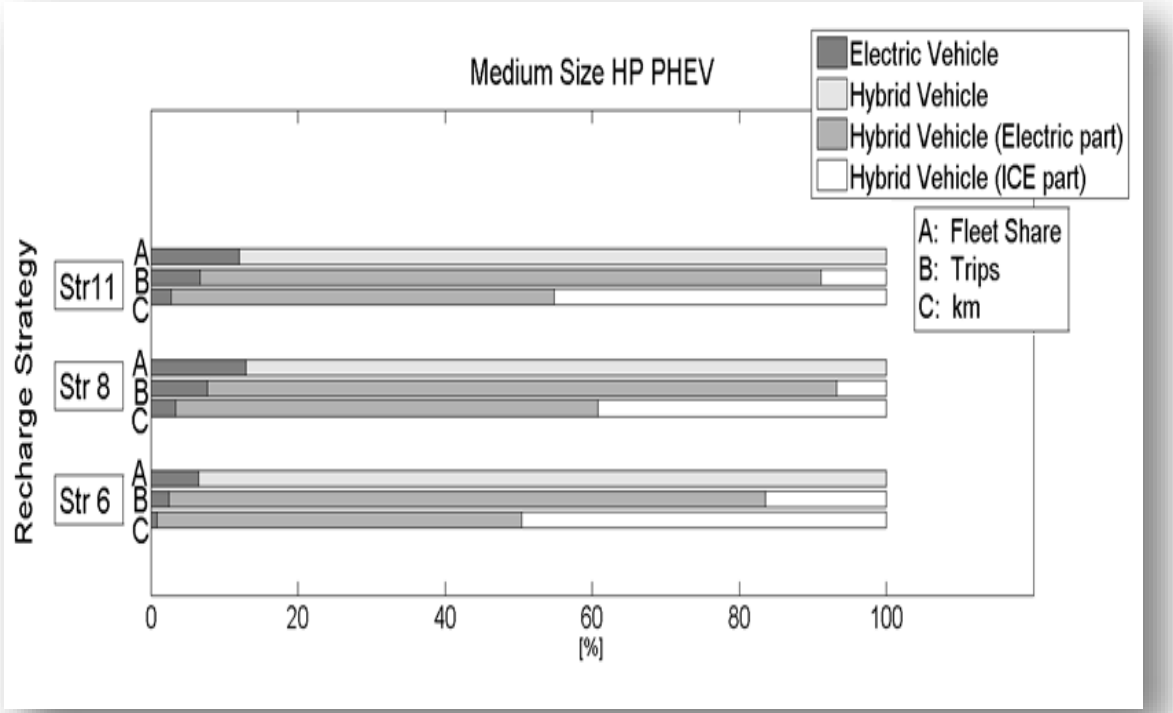
Capacity fade of PHEVs

- JRC TEMA assumed as per the utility factors calculation based on real-world driving that the first part of the trips is covered by electric driving
- Only after the full depleting of the battery the ICE will be engaged
- Percentage of electric and fuel driving is derived by TEMA simulation based on real-world data.

Trips and mileage shares PHEVs – just an example

Trips and mileage shares
Modena province

		Str. Long-Stop R-AC	Str. Night- AC	Str. Smart AC
Medium size vehicle	Electric fleet	1.97%	3.13%	3.17%
	HEV fleet	98.03%	96.87%	96.83%
	Only electric trips	0.27%	0.91%	0.94%
	HEV trips (electric)	72.97%	81.52%	82.20%
	HEV trips (ICE)	26.76%	17.57%	16.86%
	Only electric mileage	0.07%	0.24%	0.25%
	HEV mileage (electric)	49.63%	56.27%	56.92%
	HEV mileage (ICE)	50.30%	43.49%	42.84%
Medium size vehicle - high performance	Electric fleet	6.47%	13.01%	12.08%
	HEV fleet	93.53%	86.99%	87.92%
	Only electric trips	2.46%	7.73%	6.73%
	HEV trips (electric)	81.15%	85.48%	84.38%
	HEV trips (ICE)	16.39%	6.79%	8.88%
	Only electric mileage	0.90%	3.35%	2.81%
	HEV mileage (electric)	64.32%	72.55%	68.94%
	HEV mileage (ICE)	34.78%	24.10%	28.26%



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Thank you for the attention

Q&A

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Capacity fade at 5 and 8 years and 100,000km and 160,000km

Capacity fade in [%] at 5 years and 100,000km at 8 years and 160,000km Years Driving to Set Threshold Li-Ion NCM-LMO (2015)			0 - 500 km/month							500 – 1,000 km/month							1,000 -1,500 km/month							1,500 – 2,000 km/month							2,000+ km/month						
			5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #1	PHEV-1	Modena Prov.		4.9	≥ 60	≥ 60	18.2	≥ 25	≥ 25		3.2	12.5	22.3	20.6	14.2	22.8																				
		Amsterdam Prov.		3.5	≥ 60	≥ 60	20.1	≥ 25	≥ 25		2.9	12.1	21.8	21.1	14.2	22.7																				
		Brussels Prov.		3.6	≥ 60	≥ 60	19.8	≥ 25	≥ 25		2.6	12.7	22.6	21.4	15.0	23.9																				
		Luxembourg Prov.		4.0	≥ 60	≥ 60	19.3	≥ 25	≥ 25		2.8	10.6	19.9	21.2	13.2	21.1																				
		Paris Prov.		5.6	≥ 60	≥ 60	17.4	≥ 25	≥ 25		4.2	12.8	22.7	19.2	13.5	21.6				6.6	≥ 25	8.0	12.7														
	BEV-1	Modena Prov.	10.2	16.9	55.2	≥ 60	9.7	≥ 25	≥ 25	11.7	18.7	27.6	38.8	8.6	12.8	20.5	12.4	19.5	19.3	28.3	8.2	7.9	12.6														
		Amsterdam Prov.	8.6	14.8	52.8	≥ 60	11.1	≥ 25	≥ 25	10.2	16.8	26.9	37.9	9.7	13.9	22.3	11.1	17.9	16.9	25.3	9.0	7.5	12.0														
		Brussels Prov.	8.5	14.7	≥ 60	≥ 60	11.1	≥ 25	≥ 25	10.4	17.1	27.8	39.0	9.5	14.3	22.8																				
		Luxembourg Prov.	9.1	15.5	49.7	≥ 60	10.6	≥ 25	≥ 25	10.6	17.3	26.5	37.3	9.4	13.2	21.1	11.4	18.4	17.2	25.7	8.8	7.4	11.9														
		Paris Prov.	10.5	17.2	48.7	≥ 60	9.5	≥ 25	≥ 25	11.8	18.8	28.0	39.3	8.6	13.0	20.7	12.6	19.8	18.7	27.5	8.1	7.5	12.0	13.2	20.6	14.3	22.0	8.1	5.4	8.6							
	BEV-2	Modena Prov.	7.5	13.5	40.0	≥ 60	12.1	≥ 25	≥ 25	6.9	12.7	17.8	26.4	12.7	11.2	17.9	6.2	11.8	10.0	16.5	13.6	6.9	11.1	5.4	10.8	5.5	11.0	14.7	5.0	8.1	4.6	9.7	2.3	7.0	16.1	3.9	6.3
		Amsterdam Prov.	6.0	11.5	41.7	≥ 60	13.9	≥ 25	≥ 25	6.2	11.8	17.3	25.8	13.7	11.6	18.6	6.2	11.8	10.4	17.0	13.7	7.2	11.5	5.7	11.2	6.2	11.7	14.3	5.2	8.3	4.8	10.0	2.6	7.4	15.7	4.0	6.4
		Brussels Prov.	6.4	12.1	54.2	≥ 60	13.4	≥ 25	≥ 25	6.4	12.0	19.8	28.9	13.4	13.2	21.2	5.8	11.3	10.5	17.2	14.1	7.5	12.0														
		Luxembourg Prov.	6.4	12.0	40.3	≥ 60	13.4	≥ 25	≥ 25	6.4	12.1	17.5	26.1	13.4	11.6	18.5	6.3	11.9	10.4	17.1	13.6	7.1	11.4	5.8	11.3	6.0	11.5	14.2	5.1	8.2	5.4	10.8	3.5	8.4	14.7	4.1	6.6
		Paris Prov.	7.6	13.6	39.5	≥ 60	12.0	≥ 25	≥ 25	7.6	13.6	18.9	27.8	12.0	11.2	17.9	7.5	13.5	11.7	18.8	12.1	7.0	11.3	6.9	12.7	7.1	12.9	12.8	5.1	8.1	5.9	11.4	3.3	8.2	14.1	3.8	6.1
	BEV-3	Modena Prov.	8.0	14.1	41.2	≥ 60	11.9	≥ 25	≥ 25	8.2	14.3	19.5	28.7	12.3	11.1	17.8	8.2	14.3	12.1	19.3	12.8	6.8	10.9	8.2	14.3	8.0	14.1	13.5	4.9	7.9	8.1	14.2	5.2	10.6	14.4	3.8	6.1
		Amsterdam Prov.	6.2	11.9	42.3	≥ 60	13.8	≥ 25	≥ 25	6.7	12.4	18.0	26.7	13.5	11.6	18.6	6.9	12.7	10.8	17.6	13.4	6.9	11.1	7.0	12.8	7.1	12.9	13.7	5.0	8.1	7.0	12.8	4.1	9.3	14.4	3.8	6.1
		Brussels Prov.	6.6	12.4	54.9	≥ 60	13.3	≥ 25	≥ 25	7.0	12.8	20.4	29.7	13.2	12.9	20.7	7.1	13.0	11.9	19.0	13.6	7.4	11.8	7.0	12.8	7.6	13.6	14.3	5.3	8.4							
		Luxembourg Prov.	6.7	12.4	40.8	≥ 60	13.3	≥ 25	≥ 25	7.0	12.8	18.5	27.3	13.2	11.6	18.5	7.2	13.0	11.2	18.1	13.2	7.0	11.2	7.2	13.1	7.3	13.2	13.5	5.0	8.0	7.3	13.2	4.7	10.0	13.8	3.9	6.3
		Paris Prov.	7.9	14.0	40.2	≥ 60	11.9	≥ 25	≥ 25	8.2	14.3	19.7	28.9	11.8	11.2	17.9	8.4	14.6	12.4	19.6	11.8	6.8	10.9	8.4	14.6	8.4	14.6	12.1	5.0	8.0	8.4	14.5	5.3	10.8	12.8	3.8	6.1
	BEV-4	Modena Prov.	9.3	15.7	22.7	≥ 60	10.2	≥ 25	≥ 25	10.3	17.0	22.7	32.7	9.7	11.2	17.9	10.8	17.6	15.5	23.4	9.6	6.9	11.1	11.2	18.1	11.5	18.5	9.8	5.1	8.2	11.6	18.6	8.5	14.9	10.0	3.9	6.3
		Amsterdam Prov.	7.4	13.4	45.3	≥ 60	11.7	≥ 25	≥ 25	8.8	15.0	21.2	30.7	10.3	11.6	18.6	9.5	16.0	14.4	22.1	9.6	7.2	11.5	10.0	16.6	10.4	17.1	9.5	5.2	8.3							
		Brussels Prov.	7.7	13.7	58.2	≥ 60	11.5	≥ 25	≥ 25	8.9	15.3	24.0	34.2	10.3	13.3	21.3	9.6	16.1	15.3	23.3	10.0	7.6	12.1														
		Luxembourg Prov.	7.9	13.9	44.4	≥ 60	11.3	≥ 25	≥ 25	9.1	15.4	21.6	31.2	10.1	11.6	18.5	9.8	16.3	14.7	22.5	9.5	7.2	11.5	10.3	16.9	10.6	17.3	9.3	5.1	8.2							
		Paris Prov.	9.2	15.6	43.3	≥ 60	10.1	≥ 25	≥ 25	10.4	17.0	22.8	32.8	9.1	11.2	17.9	11.0	17.9	15.9	24.0	8.6	7.1	11.3	11.5	18.4	11.7	18.7	8.6	5.1	8.1	11.8	18.8	8.6	14.9	8.8	3.9	6.2
Recharge Strategy #2	BEV-1	Modena Prov.	10.7	17.5	51.8	≥ 60	9.3	≥ 25	≥ 25	13.0	20.3	27.6	38.8	7.9	11.7	18.7	14.4	22.1	20.0	29.1	7.1	7.1	11.4	15.4	23.4	15.6	23.6	6.6	5.1	8.1	16.6	24.8	12.3	19.6	6.2	3.7	6.0
		Amsterdam Prov.	8.6	14.8	56.5	≥ 60	11.0	≥ 25	≥ 25	10.9	17.6	27.1	38.0	9.2	13.3	21.3	12.5	19.7	18.4	27.1	8.1	7.4	11.8	13.7	21.2	14.2	21.9	7.5	5.2	8.3	14.7	22.4	11.6	18.7	7.0	4.0	6.5
		Brussels Prov.	8.6	14.9	≥ 60	≥ 60	11.0	≥ 25	≥ 25	11.3	18.2	27.7	38.8	8.9	13.2	21.1	12.9	20.2	18.3	27.1	7.9	7.1	11.4	13.7	21.3	14.1	21.7	7.4	5.1	8.2							
		Luxembourg Prov.	9.2	15.6	52.5	≥ 60	10.5	≥ 25	≥ 25	11.5	18.4	26.2	36.9	8.8	12.2	19.5	13.0	20.4	18.0	26.6	7.8	6.9	11.1	14.2	21.9	14.0	21.5	7.2	4.9	7.8	15.5	23.5	10.6	17.4	6.6	3.5	5.6
		Paris Prov.	10.6	17.4	50.3	≥ 60	9.3	≥ 25	≥ 25	12.7	19.9	27.7	38.9	8.0	12.0	19.2	14.1	21.8	19.4	28.4	7.2	7.0	11.2	15.3	23.2	15.0	22.9	6.7	4.9	7.9	16.4	24.5	11.5	18.6	6.3	3.6	5.7
	BEV-2	Modena Prov.	8.0	14.1	41.5	≥ 60	11.6	≥ 25	≥ 25	8.2	14.4	19.5	28.6	11.4	11.0	17.7	8.3	14.5	12.2	19.3	11.3	6.8	10.8	8.4	14.6	8.0	14.1	11.2	4.8	7.7	8.4	14.6	4.3	9.4	11.2	3.4	5.4
		Amsterdam Prov.	6.1	11.7	45.4	≥ 60	13.7	≥ 25	≥ 25	6.5	12.2	18.0	26.7	13.2	11.7	18.8	6.7	12.5	10.7	17.5	13.0	7.0	11.2	6.9	12.7	6.7	12.5	12.8	4.9	7.9	7.0	12.8	3.4	8.4	12.7	3.5	5.7
		Brussels Prov.	6.6	12.3	≥ 60	≥ 60	13.2	≥ 25	≥ 25	6.9	12.7	20.0	29.2	12.8	12.8	20.4	7.0	12.8	10.8	17.6	12.7	6.9	11.0	6.6	12.3	6.2	11.8	13.1	4.8	7.7	6.6	12.3	3.5	8.5	13.2	3.7	5.9
		Luxembourg Prov.	6.6	12.3	43.9	≥ 60	13.2	≥ 25	≥ 25	6.9	12.7	18.4	27.2	12.8	11.6	18.6	7.0	12.9	11.0	17.9	12.6	7.0	11.2	7.1	12.9	7.0	12.8	12.6	4.9	7.9	7.2	13.0	3.4	8.3	12.5	3.4	5.5
		Paris Prov.	7.8	13.9	41.7	≥ 60	11.8	≥ 25	≥ 25	8.1	14.2	19.6	28.8	11.5	11.3	18.0	8.2	14.4	12.1	19.3	11.4	6.8	10.9	8.3	14.4	7.9	14.0	11.3	4.8	7.7	8.2	14.3	3.1	7.8	11.4	3.0	4.8
	BEV-3	Modena Prov.	8.1	14.3	41.7	≥ 60	11.5	≥ 25	≥ 25	8.5	14.7	19.9	29.1	11.3	11.0	17.6	8.7	14.9	12.5	19.8	11.1	6.8	10.8	8.8	15.1	8.4	14.6	11.0	4.8	7.7	9.0	15.3	4.5	9.7	10.9	3.3	5.3
		Amsterdam Prov.	6.3	11.9	45.4	≥ 60	13.7	≥ 25	≥ 25	6.8	12.5	18.3	27.0	13.1	11.7	18.7	7.0	12.9	11.0	17.8	12.8	6.9	11.1	7.3	13.1	7.1	12.9	12.6	4.9	7.9	7.5	13.4	3.7	8.8	12.4	3.5	5.6
		Brussels Prov.	6.7	12.4	≥ 60	≥ 60	13.1	≥ 25	≥ 25	7.2	13.0	20.3	29.6	12.6	12.7	20.4	7.3	13.2	11.2	18.1	12.5	6.9	11.0	7.0	12.8	6.6	12.4	12.9	4.8	7.7	7.0	12.9	3.9	9.0	13.0	3.7	5.9
		Luxembourg Prov.	6.7	12.4	44.1	≥ 60	13.1	≥ 25	≥ 25	7.1	13.0	18.7	27.6	12.7	11.6	18.6	7.4	13.3	11.4	18.3	12.5	7.0	11.1	7.5	13.4	7.4	13.3	12.4	5.0	7.9	7.7	13.6	3.9	8.9	12.3	3.5	5.6
		Paris Prov.	8.0	14.0	42.2	≥ 60	11.7	≥ 25	≥ 25	8.3	14.5	20.0	29.2	11.4	11.2	18.0	8.6	14.8	12.5	19.7	11.2	6.8	10.9	8.7	14.9	8.3	14.5	11.1	4.8	7.7	8.8	15.0	3.3	8.1	11.2	3.0	4.7
	BEV-4	Modena Prov.	9.4	15.9	44.9	≥ 60	9.8	≥ 25	≥ 25	10.6	17.4	23.0	33.1	8.6	11.0	17.7	11.4	18.4	15.7	23.8	8.0	6.8	10.8	12.1	19.2	11.6	18.6	7.5	4.8	7.8	12.8	20.1	7.8	13.9	7.1	3.4	5.4
		Amsterdam Prov.	7.4	13.3	48.7	≥ 60	11.7	≥ 25	≥ 25	8.8	15.1	21.4	31.0	10.0	11.7	18.8	9.7	16.2	14.1	21.8	9.1	7.0	11.1	10.4	17.1	10.2	16.8	8.5	4.9	7.9	11.1	18.0	6.9	12.8	7.9	3.5	5.6
		Brussels Prov.	7.7	13.7	≥ 60	≥ 60	11.4	≥ 25	≥ 25	9.1	15.5	23.5	33.6	9.8	12.8	20.4	10.0	16.5	14.3	22.0	8.9	6.9	11.0	10.2	16.8	9.8	16.3	8.6	4.8	7.7	10.7	17.4	7.0	12.9	8.2	3.7	5.9
		Luxembourg Prov.	7.9	13.9	47.4	≥ 60	11.2	≥ 25	≥ 25	9.2	15.6	21.8	31.5	9.7	11.6	18.6	10.0	16.6	14.5	22.3	8.9	7.0	11.2	10.7	17.4	10.5	17.2	8.4	4.9	7.9	11.4	18.3	7.1	13.1	7.8	3.5	5.7
		Paris Prov.	9.2	15.6	45.1	≥ 60	9.9	≥ 25	≥ 25	10.5	17.2	23.1	33.2	8.8	11.3	18.0	11.3	18.2	15.7	23.7	8.1	6.8	10.9	11.9	18.9	11.4	18.4	7.6	4.8	7.8	12.7	20.0	6.7	12.3	7.1	3.0	4.9

Legend

- Capacity fade above and equal 20%
- Capacity fade above or equal to 10% and below 20%;
- Capacity fade below 10%

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Capacity fade at 5 and 8 years and 100,000km and 160,000km

Capacity fade in [%] at 5 years and 100,000km at 8 years and 160,000km Years Driving to Set Threshold Li-Ion NCM-LMO (2015)			0 - 500 km/month							500 – 1,000 km/month							1,000 -1,500 km/month							1,500 – 2,000 km/month							2,000+ km/month						
			5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #3	PHEV-1	Modena Prov.		4.8	42.1	≥ 60	18.3	≥ 25	≥ 25		2.6	9.2	18.1	21.5	12.3	19.8				3.9	30.2	7.7	12.3														
		Amsterdam Prov.		3.4	≥ 60	≥ 60	20.2	≥ 25	≥ 25																											
		Brussels Prov.		3.8	≥ 60	≥ 60	19.7	≥ 25	≥ 25		2.2	12.1	21.8	22.1	14.9	23.9																				
		Luxembourg Prov.		4.2	44.6	≥ 60	19.1	≥ 25	≥ 25																											
		Paris Prov.		5.6	45.7	≥ 60	17.4	≥ 25	≥ 25		4.3	13.2	23.2	19.0	13.6	21.8																				
	BEV-1	Modena Prov.	10.4	17.0	50.9	≥ 60	9.6	≥ 25	≥ 25	11.9	18.9	25.9	36.6	8.5	11.7	18.7	12.5	19.7	17.8	26.4	8.2	7.2	11.5	12.7	20.0	13.3	20.7	8.0	5.2	8.4							
		Amsterdam Prov.	8.5	14.7	53.6	≥ 60	11.1	≥ 25	≥ 25	10.3	16.9	27.6	38.7	9.6	14.3	22.9																				
		Brussels Prov.	8.6	14.8	≥ 60	≥ 60	11.0	≥ 25	≥ 25	10.3	16.9	29.0	40.5	9.6	15.2	24.4																				
		Luxembourg Prov.	9.3	15.7	46.7	≥ 60	10.4	≥ 25	≥ 25	10.7	17.5	27.4	38.5	9.3	13.7	21.9																				
		Paris Prov.	10.5	17.3	48.0	≥ 60	9.4	≥ 25	≥ 25	11.8	18.9	29.6	41.2	8.6	13.9	22.2																				
	BEV-2	Modena Prov.	7.5	13.5	40.5	≥ 60	12.1	≥ 25	≥ 25	6.9	12.7	17.6	26.3	12.7	11.1	17.7	6.2	11.8	9.7	16.2	13.7	6.8	10.9	5.4	10.8	5.2	10.6	14.8	4.9	7.9	4.6	9.8	2.5	7.2	16.0	4.0	6.4
		Amsterdam Prov.	6.0	11.5	41.2	≥ 60	13.9	≥ 25	≥ 25	6.3	11.9	17.5	26.0	13.6	11.7	18.7	6.4	12.0	11.0	17.8	13.4	7.4	11.8														
		Brussels Prov.	6.5	12.2	40.1	≥ 60	13.2	≥ 25	≥ 25	6.7	12.4	22.1	31.8	13.0	14.6	23.4																				
		Luxembourg Prov.	6.4	12.1	37.2	≥ 60	13.4	≥ 25	≥ 25	6.6	12.3	17.7	26.4	13.1	11.5	18.4	6.7	12.4	10.8	17.5	13.1	7.1	11.3														
		Paris Prov.	7.6	13.6	38.1	≥ 60	12.0	≥ 25	≥ 25	7.8	13.8	19.0	28.0	11.8	11.1	17.8	7.9	13.9	12.8	20.2	11.7	7.4	11.8	6.7	12.4	6.8	12.5	13.0	5.0	8.1							
	BEV-3	Modena Prov.	8.0	14.1	41.7	≥ 60	11.9	≥ 25	≥ 25	8.2	14.3	19.5	28.6	12.3	11.0	17.7	8.2	14.3	12.0	19.1	12.8	6.8	10.8	8.2	14.3	7.9	13.9	13.6	4.9	7.8	8.1	14.2	4.8	10.1	14.6	3.7	5.9
		Amsterdam Prov.	6.2	11.9	41.8	≥ 60	13.8	≥ 25	≥ 25	6.7	12.4	18.1	26.8	13.4	11.7	18.7	6.9	12.7	10.8	17.6	13.2	6.9	11.1	7.0	12.9	7.9	13.9	13.2	5.4	8.6							
		Brussels Prov.	6.7	12.5	40.7	≥ 60	13.1	≥ 25	≥ 25	7.0	12.9	21.6	31.3	12.9	13.8	22.1	7.1	12.9	12.9	20.3	13.3	8.0	12.8														
		Luxembourg Prov.	6.7	12.5	37.8	≥ 60	13.2	≥ 25	≥ 25	7.0	12.8	18.4	27.2	13.0	11.5	18.4	7.2	13.1	10.8	17.5	12.9	6.7	10.7	7.4	13.3	8.1	14.1	12.8	5.3	8.5							
		Paris Prov.	7.9	14.0	38.8	≥ 60	11.9	≥ 25	≥ 25	8.2	14.4	19.6	28.8	11.7	11.1	17.8	8.4	14.6	12.5	19.8	11.5	6.9	11.1	8.4	14.5	8.4	14.6	12.1	5.0	8.0	8.1	14.2	5.5	0.0	12.7	4.0	6.4
	BEV-4	Modena Prov.	9.3	15.7	44.8	≥ 60	10.2	≥ 25	≥ 25	10.3	17.0	22.6	32.5	9.7	11.1	17.7	10.9	17.7	15.2	23.1	9.6	6.8	10.9	11.2	18.1	11.2	18.1	9.8	5.0	8.0	11.5	18.5	8.9	15.4	9.9	4.1	6.6
		Amsterdam Prov.	7.4	13.4	44.9	≥ 60	11.7	≥ 25	≥ 25	8.8	15.0	21.2	30.7	10.2	11.7	18.7	9.5	15.9	14.7	22.6	9.5	7.4	11.8														
		Brussels Prov.	8.0	14.1	43.8	≥ 60	11.1	≥ 25	≥ 25	8.9	15.2	25.8	36.5	10.1	14.6	23.4																				
		Luxembourg Prov.	8.0	14.1	41.0	≥ 60	11.1	≥ 25	≥ 25	9.1	15.5	21.5	31.1	9.9	11.5	18.4	9.8	16.4	14.6	22.4	9.2	7.1	11.4														
		Paris Prov.	9.3	15.7	41.9	≥ 60	10.0	≥ 25	≥ 25	10.4	17.1	22.8	32.7	9.0	11.1	17.8	11.0	17.8	16.6	24.9	8.4	7.4	11.9	11.1	18.0	11.5	18.4	8.7	5.1	8.2							
Recharge Strategy #5	PHEV-1	Modena Prov.		6.6	41.5	≥ 60	16.3	≥ 25	≥ 25		8.3	15.0	25.5	13.3	11.5	18.5		9.0	6.7	15.0	14.1	7.0	11.1	2.1	9.2	1.9	9.0	13.9	4.9	7.9	2.1	9.2		5.2	13.9	3.9	6.2
		Amsterdam Prov.		4.1	56.3	≥ 60	19.2	≥ 25	≥ 25		6.2	15.0	25.4	15.6	13.2	21.1		7.1	5.8	13.9	15.8	7.4	11.8		7.4	1.9	8.9	15.6	5.5	8.8							
		Brussels Prov.		4.2	≥ 60	≥ 60	19.0	≥ 25	≥ 25		6.5	16.1	26.8	15.1	13.6	21.8		7.4	7.1	15.6	15.6	7.9	12.6														
		Luxembourg Prov.		4.9	44.3	≥ 60	18.2	≥ 25	≥ 25		6.7	14.0	24.2	14.9	12.1	19.4		7.5	6.1	14.2	15.5	7.3	11.7		7.7	0.7	7.4	15.3	4.9	7.8							
		Paris Prov.		6.6	42.8	≥ 60	16.3	≥ 25	≥ 25		8.1	15.6	26.2	13.6	12.0	19.2		8.8	7.4	15.8	14.3	7.3	11.7	2.0	9.1	2.3	9.5	14.1	5.1	8.2							
	BEV-1	Modena Prov.	10.7	17.5	50.3	≥ 60	9.3	≥ 25	≥ 25	12.9	20.2	26.7	37.6	7.9	11.3	18.0	14.2	21.8	19.2	28.1	7.2	6.9	11.0	15.2	23.1	15.0	22.8	6.8	4.9	7.9	16.2	24.4	11.6	18.7	6.3	3.6	5.8
		Amsterdam Prov.	8.6	14.9	53.7	≥ 60	11.0	≥ 25	≥ 25	10.8	17.6	26.3	37.1	9.2	12.9	20.6	12.3	19.5	17.8	26.4	8.3	7.2	11.6	13.5	20.9	13.5	21.0	7.6	5.0	8.0							
		Brussels Prov.	8.6	14.8	≥ 60	≥ 60	11.0	≥ 25	≥ 25	11.2	18.1	27.3	38.3	9.0	13.1	20.9	12.7	19.9	18.6	27.4	8.0	7.4	11.8														
		Luxembourg Prov.	9.2	15.5	52.4	≥ 60	10.5	≥ 25	≥ 25	11.4	18.3	25.5	36.1	8.8	11.8	19.0	12.7	20.0	18.0	26.6	8.0	7.1	11.4	13.7	21.2	14.0	21.5	7.5	5.1	8.1							
		Paris Prov.	10.6	17.4	49.7	≥ 60	9.4	≥ 25	≥ 25	12.6	19.8	27.2	38.2	8.1	11.8	18.8	13.9	21.5	19.2	28.1	7.4	7.0	11.2	14.9	22.7	14.9	22.8	6.9	5.0	8.0	15.8	23.8	12.0	19.2	6.5	3.9	6.2
	BEV-2	Modena Prov.	7.9	14.0	41.7	≥ 60	11.7	≥ 25	≥ 25	8.0	14.1	19.1	28.1	11.6	11.0	17.6	8.0	14.0	11.7	18.7	11.6	6.8	10.8	7.9	13.9	7.5	13.4	11.7	4.8	7.7	7.6	13.6	3.2	8.1	12.0	3.3	5.2
		Amsterdam Prov.	6.1	11.7	43.8	≥ 60	13.8	≥ 25	≥ 25	6.4	12.1	17.8	26.5	13.4	11.8	18.8	6.5	12.2	10.3	17.0	13.3	6.9	11.1	6.5	12.2	6.3	11.9	13.3	4.9	7.9	6.4	12.1	2.9	7.7	13.4	3.5	5.6
		Brussels Prov.	6.5	12.2	≥ 60	≥ 60	13.3	≥ 25	≥ 25	6.8	12.5	19.7	28.8	13.0	12.7	20.4	6.7	12.4	10.6	17.3	13.1	7.0	11.1	6.2	11.7	5.8	11.3	13.7	4.8	7.8	6.0	11.6	3.3	8.2	13.9	3.8	6.1
		Luxembourg Prov.	6.5	12.2	44.7	≥ 60	13.2	≥ 25	≥ 25	6.7	12.5	18.1	26.9	13.0	11.6	18.6	6.7	12.5	10.7	17.5	13.0	7.0	11.2	6.6	12.4	6.6	12.3	13.1	5.0	7.9	6.5	12.2	2.6	7.4	13.3	3.4	5.4
		Paris Prov.	7.8	13.8	41.5	≥ 60	11.8	≥ 25	≥ 25	7.9	14.0	19.5	28.6	11.7	11.3	18.0	8.0	14.0	11.8	18.9	11.6	6.8	10.9	7.9	13.9	7.5	13.5	11.7	4.8	7.8	7.6	13.6	3.2	8.0	12.0	3.2	5.2
	BEV-3	Modena Prov.	8.1	14.2	42.1	≥ 60	11.6	≥ 25	≥ 25	8.4	14.6	19.7	28.9	11.4	11.0	17.6	8.6	14.8	12.4	19.7	11.4	6.8	10.8	8.7	15.0	8.3	14.5	11.4	4.8	7.7	8.8	15.1	4.1	9.2	11.5	3.2	5.1
		Amsterdam Prov.	6.3	11.9	44.2	≥ 60	13.7	≥ 25	≥ 25	6.7	12.5	18.3	27.1	13.2	11.8	18.8	7.0	12.8	10.9	17.7	13.0	6.9	11.1	7.2	13.0	7.0	12.8	13.0	4.9	7.8	7.4	13.3	3.6	8.6	12.9	3.5	5.5
		Brussels Prov.	6.6	12.4	≥ 60	≥ 60	13.2	≥ 25	≥ 25	7.1	13.0	20.3	29.5	12.8	12.7	20.3	7.3	13.1	11.2	18.1	12.8	6.9	11.1	6.9	12.7	6.6	12.3	13.4	4.8	7.7	7.0	12.8	4.0	9.1	13.5	3.7	6.0
		Luxembourg Prov.	6.7	12.4	45.2	≥ 60	13.2	≥ 25	≥ 25	7.1	12.9	18.7	27.6	12.8	11.6	18.6	7.3	13.2	11.3	18.2	12.7	7.0	11.1	7.4	13.3	7.3	13.2	12.7	4.9	7.9	7.5	13.5	3.5	8.5	12.8	3.4	5.4
		Paris Prov.	7.9	14.0	42.0	≥ 60	11.7	≥ 25	≥ 25	8.3	14.5	20.0	29.2	11.5	11.3	18.0	8.5	14.7	12.4	19.6	11.4	6.8	10.9	8.6	14.9	8.2	14.4	11.4	4.8	7.7	8.7	15.0	3.8	8.8	11.6	3.2	5.0
	BEV-4	Modena Prov.	9.4	15.8	45.2	≥ 60	9.9	≥ 25	≥ 25	10.6	17.3	22.9	32.9	8.8	11.0	17.6	11.3	18.3	15.6	23.6	8.3	6.8	10.8	11.9	19.0	11.5	18.5	7.9	4.8	7.7	12.7	19.9	7.3	13.3	7.5	3.3	5.2
		Amsterdam Prov.	7.4	13.3	47.3	≥ 60	11.7	≥ 25	≥ 25	8.8	15.1	21.4	31.0	10.1	11.8	18.8	9.7	16.1	14.0	21.6	9.3	6.9	11.1	10.3	17.0	10.1	16.7	8.8	4.9	7.9	11.0	17.9	6.8	12.6	8.3	3.5	5.6
		Brussels Prov.	7.6	13.6	≥ 60	≥ 60	11.5	≥ 25	≥ 25	9.1	15.5	23.4	33.5	9.9	12.7	20.3	9.9	16.5	14.4	22.1	9.2	7.0	11.1	10.1	16.7	9.8	16.3	9.0	4.9	7.8	10.5	17.2	7.2	13.2	8.7	3.8	6.1
		Luxembourg Prov.	7.9	13.9	48.3	≥ 60	11.2	≥ 25	≥ 25	9.2	15.5	21.8	31.5	9.8	11.6	18.6	10.0	16.5	14.5	22.2	9.1	7.0	11.2	10.6	17.3	10.4	17.1	8.7	5.0	7.9	11.3	18.2	6.6	12.4	8.2	3.4	5.4
		Paris Prov.	9.2	15.6	45.1	≥ 60	10.0	≥ 25	≥ 25	10.4	17.1	23.1	33.2	8.9	11.3	18.0	11.2	18.1	15.6	23.6	8.3	6.8	10.9	11.8	18.8	11.4	18.3	7.9	4.8	7.8	12.5	19.8	7.2	13.1	7.5	3.2	5.2

Legend

- Capacity fade above and equal 20%
- Capacity fade above or equal to 10% and below 20%;
- Capacity fade below 10%

European Commission

PHEV Capacity fade at 5 and 8 years and 100,000km and 160,000km

Capacity fade in [%] at 5 years and 100,000km at 8 years and 160,000km Years Driving to Set Threshold Li-Ion NCM-LMO (2015)			0 - 500 km/month							500 – 1,000 km/month							1,000 -1,500 km/month							1,500 – 2,000 km/month							2,000+ km/month						
			5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km	5 years %	8 years %	100,000 km %	160,000 km %	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #1	PHEV-1	Modena Prov.		4.9	≥ 60	≥ 60	18.2	≥ 25	≥ 25		3.2	12.5	22.3	20.6	14.2	22.8																				
		Florence prov.		5.1	≥ 60	≥ 60	17.9	≥ 25	≥ 25		3.4	13.2	23.3	20.2	14.5	23.2																				
		Amsterdam Prov.		3.5	≥ 60	≥ 60	20.1	≥ 25	≥ 25		2.9	12.1	21.8	21.1	14.2	22.7																				
		Brussels Prov.		3.6	≥ 60	≥ 60	19.8	≥ 25	≥ 25		2.6	12.7	22.6	21.4	15.0	23.9																				
		Luxembourg Prov.		4.0	≥ 60	≥ 60	19.3	≥ 25	≥ 25		2.8	10.6	19.9	21.2	13.2	21.1																				
		Paris Prov.		5.6	≥ 60	≥ 60	17.4	≥ 25	≥ 25		4.2	12.8	22.7	19.2	13.5	21.6				6.6	26.1	7.966	12.7													
	PHEV-2	Modena Prov.		6.2	≥ 60	≥ 60	16.7	≥ 25	≥ 25		8.5	18.8	30.2	14.5	13.7	21.9																				
		Florence prov.		6.3	≥ 60	≥ 60	16.5	≥ 25	≥ 25		8.7	22.5	35.0	14.3	15.9	25.5																				
		Amsterdam Prov.		4.3	≥ 60	≥ 60	18.9	≥ 25	≥ 25		6.7	19.1	30.7	16.3	15.6	24.9																				
	PHEV-3	Modena Prov.		8.0	≥ 60	≥ 60	14.9	≥ 25	≥ 25	4.7	12.5	23.6	36.2	11.6	13.5	21.6																				
		Florence prov.		8.0	≥ 60	≥ 60	14.9	≥ 25	≥ 25	4.7	12.5	25.9	39.2	11.6	14.8	23.7																				
		Amsterdam Prov.		6.0	≥ 60	≥ 60	16.9	≥ 25	≥ 25	3.0	10.3	23.0	35.5	13.1	14.9	23.8																				
Recharge Strategy #3	PHEV-1	Modena Prov.		4.8	≥ 60	≥ 60	18.3	≥ 25	≥ 25		2.6	9.2	18.1	21.5	12.3	19.8				3.9	30.2	7.7	12.3													
		Florence prov.		5.1	≥ 60	≥ 60	18.0	≥ 25	≥ 25		2.7	9.5	18.5	21.4	12.5	19.9				5.2	29.0	8.1	12.9													
		Amsterdam Prov.		3.4	≥ 60	≥ 60	20.2	≥ 25	≥ 25																										
		Brussels Prov.		3.8	≥ 60	≥ 60	19.7	≥ 25	≥ 25																										
		Luxembourg Prov.		4.2	≥ 60	≥ 60	19.1	≥ 25	≥ 25																										
		Paris Prov.		5.6	≥ 60	≥ 60	17.4	≥ 25	≥ 25		4.3	13.2	23.2	19.0	13.6	21.8																				
	PHEV-2	Modena Prov.		6.7	≥ 60	≥ 60	16.2	≥ 25	≥ 25		8.5	19.3	30.9	14.5	14.0	22.4																				
		Florence prov.		6.8	≥ 60	≥ 60	16.1	≥ 25	≥ 25		8.7	19.2	30.7	14.3	13.8	22.1																				
		Amsterdam Prov.		4.3	≥ 60	≥ 60	18.9	≥ 25	≥ 25																										
	PHEV-3	Modena Prov.		8.8	≥ 60	≥ 60	14.3	≥ 25	≥ 25	4.8	12.5	23.6	36.2	11.6	13.5	21.6																				
		Florence prov.		8.8	≥ 60	≥ 60	14.3	≥ 25	≥ 25	4.9	12.7	23.7	36.4	11.4	13.4	21.5																				
		Amsterdam Prov.		6.0	≥ 60	≥ 60	16.9	≥ 25	≥ 25																										
Recharge Strategy #4	PHEV-1	Modena Prov.		4.8	≥ 60	≥ 60	18.3	≥ 25	≥ 25		2.9	10.5	19.7	21.0	13.0	20.8																				
		Florence prov.		5.1	≥ 60	≥ 60	18.0	≥ 25	≥ 25		3.0	10.7	20.1	20.9	13.1	20.9																				
		Amsterdam Prov.		3.5	≥ 60	≥ 60	20.0	≥ 25	≥ 25																										
		Brussels Prov.		3.8	≥ 60	≥ 60	19.6	≥ 25	≥ 25		2.2	12.1	21.8	22.1	14.9	23.9																				
		Luxembourg Prov.		4.3	≥ 60	≥ 60	18.9	≥ 25	≥ 25																										
		Paris Prov.		5.9	≥ 60	≥ 60	17.1	≥ 25	≥ 25		4.0	13.5	23.6	19.4	14.1	22.6																				
	PHEV-2	Modena Prov.		6.7	≥ 60	≥ 60	16.2	≥ 25	≥ 25		8.6	18.9	30.4	14.5	13.7	22																				
		Florence prov.		6.8	≥ 60	≥ 60	16.1	≥ 25	≥ 25		8.7	19.2	30.7	14.3	13.8	22.1																				
		Amsterdam Prov.		4.1	≥ 60	≥ 60	19.2	≥ 25	≥ 25																										
	PHEV-3	Modena Prov.		8.8	≥ 60	≥ 60	14.3	≥ 25	≥ 25	4.8	12.5	23.6	36.3	11.6	13.5	21.6																				
		Florence prov.		8.8	≥ 60	≥ 60	14.3	≥ 25	≥ 25	4.9	12.7	23.9	36.6	11.4	13.5	21.6																				
		Amsterdam Prov.		5.6	≥ 60	≥ 60	17.4	≥ 25	≥ 25																										
Recharge Strategy #5	PHEV-1	Modena Prov.		6.6	≥ 60	≥ 60	16.3	≥ 25	≥ 25		8.3	15.0	25.5	14.7	11.5	18.5		9.0	6.7	15.0	14.1	7.0	11.1	2.1	9.2	1.9	9.0	13.9	4.9	7.9	2.1	9.2		5.2	13.9	3.9	6.2
		Florence prov.		6.7	≥ 60	≥ 60	16.2	≥ 25	≥ 25		8.4	15.4	26.0	14.6	11.7	18.7		9.0	7.1	15.6	14.1	7.1	11.4	2.2	9.3	2.2	9.3	13.8	5.0	8.0	2.2	9.2		5.3	13.9	3.9	6.2
		Amsterdam Prov.		4.1	≥ 60	≥ 60	19.2	≥ 25	≥ 25		6.2	15.0	25.4	16.8	13.2	21.1		7.1	5.8	13.9	15.8	7.4	11.8		7.4	1.9	8.9	15.6	5.5	8.8							
		Brussels Prov.		4.2	≥ 60	≥ 60	19.0	≥ 25	≥ 25		6.5	16.1	26.8	16.4	13.6	21.8		7.4	7.1	15.6	15.6	7.9	12.6													
		Luxembourg Prov.		4.9	≥ 60	≥ 60	18.2	≥ 25	≥ 25		6.7	14.0	24.2	16.2	12.1	19.4		7.5	6.1	14.2	15.5	7.3	11.7		7.7	0.7	7.4	15.3	4.9	7.8							
		Paris Prov.		6.6	≥ 60	≥ 60	16.3	≥ 25	≥ 25		8.1	15.6	26.2	14.8	12.0	19.2		8.8	7.4	15.8	14.3	7.3	11.7	2.0	9.1	2.3	9.5	14.1	5.1	8.2							
	PHEV-2	Modena Prov.		7.7	≥ 60	≥ 60	15.2	≥ 25	≥ 25	3.5	11.0	18.9	30.4	12.5	11.9	19.1	5.0	12.9	10.8	20.1	11.3	7.1	11.4	6.1	14.2	6.4	14.6	10.6	5.1	8.2							
		Florence prov.		7.7	≥ 60	≥ 60	15.2	≥ 25	≥ 25	3.5	11.0	19.8	31.5	12.5	12.4	19.9	5.0	12.8	11.5	21.0	11.4	7.4	11.9	5.9	14.0	5.9	14.0	10.7	5.0	8.0							
		Amsterdam Prov.		4.6	≥ 60	≥ 60	18.6	≥ 25	≥ 25		8.3	18.8	30.2	14.7	13.9	22.2	3.1	10.4	10.1	19.3	13.0	7.9	12.6													
	PHEV-3	Modena Prov.		9.7	≥ 60	≥ 60	13.5	≥ 25	≥ 25	6.4	14.6	22.9	35.4	10.4	11.8	18.8	8.7	17.5	14.8	25.2	9.0	7.0	11.2	10.5	19.8	10.5	19.7	8.1	5.0	8.0							
		Florence prov.		9.6	≥ 60	≥ 60	13.6	≥ 25	≥ 25	6.4	14.6	23.6	36.3	10.4	12.1	19.4	8.6	17.4	15.5	26.1	9.0	7.3	11.7	10.6	19.9	10.4	19.7	8.0	5.0	7.9							
		Amsterdam Prov.		6.3	≥ 60	≥ 60	16.6	≥ 25	≥ 25	3.9	11.5	22.8	35.2	12.2	13.8	22.0	6.5	14.6	14.1	24.3	10.3	7.8	12.4													

Legend

- Capacity fade above and equal 20%
- Capacity fade above or equal to 10% and below 20%;
- Capacity fade below 10%

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Years to EoL, 100,000km and 160,000km

EoL @ 80% capacity Li-Ion NCM-LMO (2015) **Years Driving to Set Threshold**				0 - 500 km/month			500 – 1,000 km/month			1,000 -1,500 km/month			1,500 – 2,000 km/month			2,000+ km/month		
				Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km	Years to EoL	Years to 100,000 km	Years to 160,000 km
Recharge Strategy #1	BEV-1	Modena Prov.	NCM-LMO (2015)	9.7	≥ 20	≥ 20	8.6	12.8	≥ 20	8.2	7.9	12.6						
		Amsterdam Prov.		11.1	≥ 20	≥ 20	9.7	13.9	≥ 20	9.0	7.5	12.0						
		Brussels Prov.		11.1	≥ 20	≥ 20	9.5	14.3	≥ 20									
		Luxembourg Prov.		10.6	≥ 20	≥ 20	9.4	13.2	≥ 20	8.8	7.4	11.9						
		Paris Prov.		9.5	≥ 20	≥ 20	8.6	12.9	≥ 20	8.1	7.5	12.0	8.1	5.2	8.3			
	BEV-2	Modena Prov.		12.1	≥ 20	≥ 20	12.7	11.2	17.9	13.6	6.9	11.0	14.7	5	8.1	16.1	3.9	6.3
		Amsterdam Prov.		13.9	≥ 20	≥ 20	13.7	11.6	18.6	13.7	7.2	11.5	14.3	5.2	8.3	15.7	4.0	6.4
		Brussels Prov.		13.4	≥ 20	≥ 20	13.4	13.2	≥ 20	14.1	7.5	12.0						
		Luxembourg Prov.		13.4	≥ 20	≥ 20	13.4	11.6	18.5	13.6	7.1	11.4	14.2	5.1	8.2	14.7	4.1	6.6
		Paris Prov.		12.0	≥ 20	≥ 20	12.0	11.2	17.9	12.1	7.0	11.3	12.8	5.1	8.1	14.1	3.8	6.1
	BEV-3	Modena Prov.		11.9	≥ 20	≥ 20	12.3	11.1	17.8	12.8	6.8	10.9	13.5	4.9	7.9	14.4	3.8	6.1
		Amsterdam Prov.		13.8	≥ 20	≥ 20	13.5	11.6	18.6	13.4	6.9	11.1	13.7	5.0	8.1	14.4	3.8	6.1
		Brussels Prov.		13.3	≥ 20	≥ 20	13.2	12.9	≥ 20	13.6	7.4	11.8	14.3	5.3	8.4			
		Luxembourg Prov.		13.3	≥ 20	≥ 20	13.2	11.6	18.5	13.2	7.0	11.2	13.5	5.0	8.0	13.8	3.9	6.3
		Paris Prov.		11.9	≥ 20	≥ 20	11.8	11.2	17.9	11.8	6.8	10.9	12.1	5.0	8.0	12.8	3.8	6.1
	BEV-4	Modena Prov.		10.2	≥ 20	≥ 20	9.7	11.2	17.9	9.6	6.9	11.1	9.8	5.1	8.2	10.0	3.9	6.3
		Amsterdam Prov.		11.7	≥ 20	≥ 20	10.3	11.6	18.6	9.6	7.2	11.5	9.5	5.2	8.3	9.5	4.0	6.4
		Brussels Prov.		11.5	≥ 20	≥ 20	10.3	13.3	≥ 20	10.0	7.6	12.1						
		Luxembourg Prov.		11.3	≥ 20	≥ 20	10.1	11.6	18.5	9.5	7.2	11.5	9.3	5.1	8.2			
		Paris Prov.		10.1	≥ 20	≥ 20	9.1	11.2	17.9	8.6	7.1	11.3	8.6	5.1	8.1	8.8	3.9	6.2
Recharge Strategy #2	BEV-1	Modena Prov.	NCM-LMO (2015)	9.3	≥ 20	≥ 20	7.9	11.7	18.7	7.1	7.1	11.4	6.6	5.1	8.1	6.2	3.7	6
		Amsterdam Prov.		11.0	≥ 20	≥ 20	9.2	13.3	≥ 20	8.1	7.4	11.8	7.5	5.2	8.3	7.0	4.0	6.5
		Brussels Prov.		11.0	≥ 20	≥ 20	8.9	13.2	≥ 20	7.9	7.1	11.4	7.4	5.1	8.2			
		Luxembourg Prov.		10.5	≥ 20	≥ 20	8.8	12.2	19.5	7.8	6.9	11.1	7.2	4.9	7.8	6.6	3.5	5.6
		Paris Prov.		9.3	≥ 20	≥ 20	8.0	12.0	19.2	7.2	7.0	11.2	6.7	4.9	7.9	6.3	3.7	5.9
	BEV-2	Modena Prov.		11.6	≥ 20	≥ 20	11.4	11	17.7	11.3	6.8	10.8	11.2	4.8	7.7	11.2	3.4	5.4
		Amsterdam Prov.		13.7	≥ 20	≥ 20	13.2	11.7	18.8	13.0	7.0	11.2	12.8	4.9	7.9	12.7	3.5	5.7
		Brussels Prov.		13.2	≥ 20	≥ 20	12.8	12.8	≥ 20	12.7	6.9	11.0	13.1	4.8	7.7	13.2	3.7	5.9
		Luxembourg Prov.		13.2	≥ 20	≥ 20	12.8	11.7	18.6	12.6	7.0	11.2	12.5	4.9	7.9	12.5	3.4	5.5
		Paris Prov.		11.8	≥ 20	≥ 20	11.5	11.3	18.0	11.4	6.8	10.9	11.3	4.8	7.7	11.4	3.0	4.8
	BEV-3	Modena Prov.		11.5	≥ 20	≥ 20	11.3	11.0	17.6	11.1	6.8	10.8	11.0	4.8	7.7	10.9	3.3	5.3
		Amsterdam Prov.		13.7	≥ 20	≥ 20	13.1	11.7	18.7	12.8	6.9	11.1	12.6	4.9	7.9	12.4	3.5	5.6
		Brussels Prov.		13.1	≥ 20	≥ 20	12.6	12.7	≥ 20	12.5	6.9	11.0	12.9	4.8	7.7	13.0	3.7	5.9
		Luxembourg Prov.		13.1	≥ 20	≥ 20	12.7	11.6	18.6	12.5	7.0	11.1	12.4	5.0	7.9	12.3	3.5	5.6
		Paris Prov.		11.7	≥ 20	≥ 20	11.4	11.2	18.0	11.2	6.8	10.9	11.1	4.8	7.7	11.2	3.0	4.7
	BEV-4	Modena Prov.		9.8	≥ 20	≥ 20	8.6	11.0	17.7	8.0	6.8	10.8	7.5	4.8	7.8	7.1	3.4	5.4
		Amsterdam Prov.		11.7	≥ 20	≥ 20	10.0	11.7	18.8	9.1	7.0	11.1	8.5	4.9	7.9	7.9	3.5	5.6
		Brussels Prov.		11.4	≥ 20	≥ 20	9.8	12.8	≥ 20	8.9	6.9	11.0	8.6	4.8	7.7	8.2	3.7	5.9
		Luxembourg Prov.		11.2	≥ 20	≥ 20	9.7	11.6	18.6	8.9	7.0	11.2	8.4	4.9	7.9	7.8	3.5	5.7
		Paris Prov.		9.9	≥ 20	≥ 20	8.8	11.3	18.0	8.1	6.8	10.9	7.6	4.8	7.8	7.1	3.0	4.9

Legend	
	EoL below 5.0 years;
	EoL above or equal to 5.0 and below 10.0 years;
	EoL above or equal to 10.0 years;

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Input/output of in-vehicle battery durability module of JRC TEMA platform

	Input to JRC TEMA
General parameters	• Age of the car since manufacture [yrs] • Run-in km • Vehicle technology (BEV, PHEV) • EoL threshold for capacity fade and power fade
Environmental parameters	• Ambient temperature max and min for each month of the year [°C]
Duty cycle parameters	• Average number of trips per month • Average driven distance [km] • Average driving time [h] • Average driving speed [km/h] • Average energy consumption [Wh/km] • Average resting time without charging [h] • Average parking time [sec]
Charging data	• Average recharging time [h] • Recharging power [kW] • Charging mode/level • Average number of recharge per month
Battery parameters	• Battery chemistry • Battery architecture (no. of modules, no. of cells, cell voltage, cell current, series/parallel connection i.e. 48S-2P-2S etc.) • Reference battery voltage [V] • Battery capacity [Wh] • Battery reserve [%] • Average weighted battery temperature [°C] • Battery temperature min and max (BMS) [°C] • Average battery SoC min driving [%] • Average battery Delta SoC during charging [%] • Average battery SoC parking no charging [%]

HV battery chemistry	Output from JRC TEMA			
	Capacity fade		Power fade	
	Calendar	Cycle	Calendar	Cycle
$LiFePO_4$	Sarasketa-Zabala et Al. (2013/14);	Wang et Al. (2011);	Sarasketa-Zabala et Al. (2013);	
		Sarasketa-Zabala et Al. (2013);		
		Sarasketa-Zabala et Al. (2015);		
NCM + Spinel Mn	Wang et Al. (2014);		-	-
NCM – LMO	-	Cordoba-Arenas et Al. (2014);	-	Cordoba-Arenas et Al. (2015);