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Battery State of Health in Renault Zoe EV: An 11-Year Case Study of the Q210 Model

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Executive Summary

This study presents an analysis of battery State of Health (SOH) in Nickel Manganese Cobalt (NMC) technology, focusing on degradation in Renault Zoe electric vehicle over extended use. Utilizing data from a 2013 Q210 model, it is shown how the CAN-bus measured SOH stabilizes over the years but exhibits higher variability, ranging between 84% and 94% within the last year and after 10 years of utilization.

Through non-invasive CAN-bus measurements, this research captures critical SOH data, highlighting significant degradation variability influenced by driving patterns, charging frequency, and environmental factors. Results indicate that both usage patterns and calendar aging impact long-term battery health, with evidence of degradation stabilization in older Zoe models, suggesting potential stabilization mechanisms in NMC chemistry.

By evaluating the OEM's SOH algorithms, this study sheds light on algorithm strengths and limitations, advancing knowledge on battery health to support more accurate SOH estimation and sustainable electric mobility solutions.

Keywords: Electric Vehicles, Degradation, State of Health, Battery.

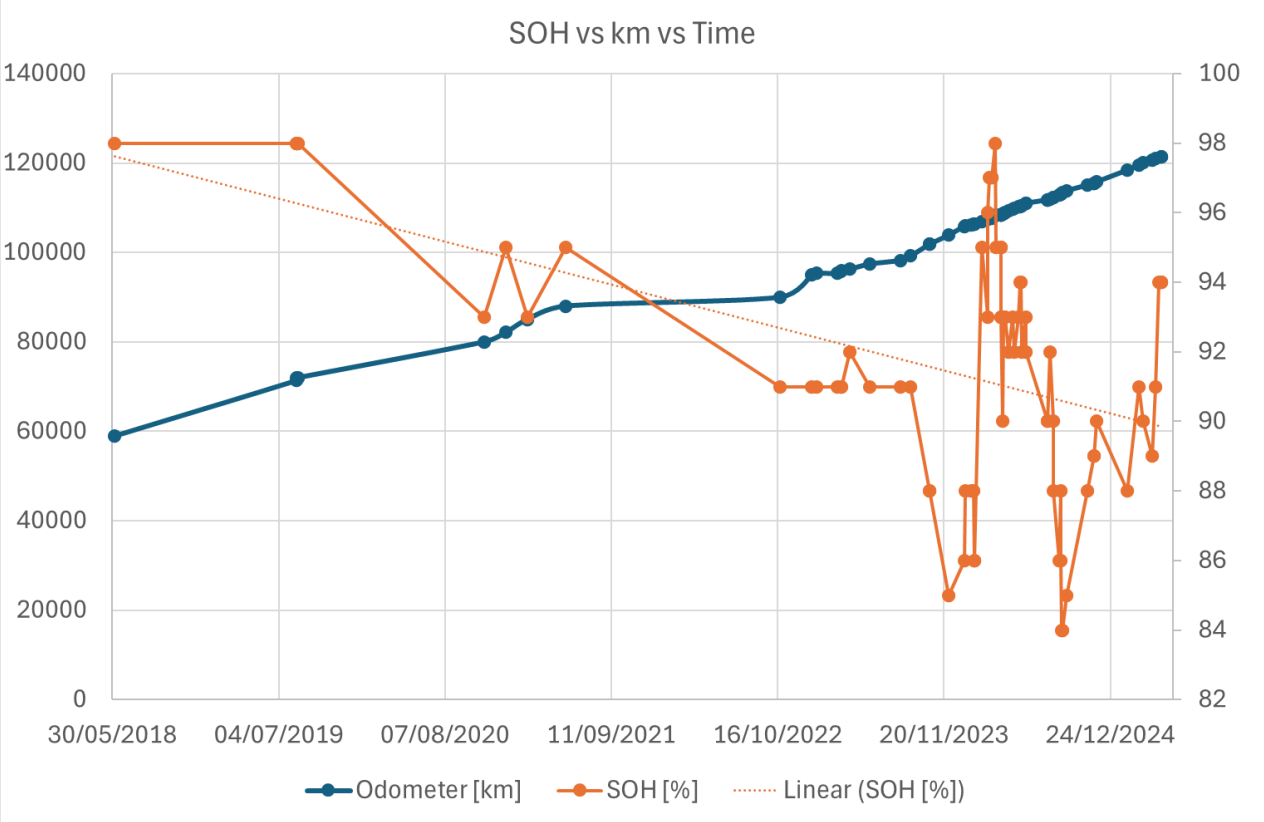
The adoption of electric mobility is closely linked to advancements in battery technology, with lithium-ion batteries currently dominating the electric vehicle (EV) market [1]. According to the authors of [2], one of the primary lithium-ion battery chemistries is Nickel Manganese Cobalt (NMC). The authors of [3] compare NMC with other chemistries, including Lithium Titanate Oxide (LTO) and Nickel Cobalt Aluminum (NCA), noting that NCA batteries, known for their high energy density, are particularly suited for applications where weight and space are critical. The incorporation of aluminum stabilizes NCA batteries while enhancing their lifespan and safety compared to other lithium-ion batteries with high nickel content. Although NCA batteries offer higher energy density than NMC batteries, they may also present stability and cost challenges due to their higher nickel and cobalt content [4].

Technological advancements in battery design are progressing rapidly, with new technologies emerging in the mobility sector. However, current battery life often falls short of meeting long-term user demands [5], necessitating a deeper understanding of degradation mechanisms to extend vehicle lifespan. The authors of [6] categorize the key issues of lithium-ion battery degradation into four areas: 1) "influence factors" (design, production, and application); 2) "side reactions" (e.g., electrode particle cracking);

3) "degradation modes" (loss of active material, resistance increment); and 4) "battery experiences," characterized by capacity or power fade. This investigation primarily focuses on how application types influence battery capacity, given that design and production are largely outside end-user control.

The study in [6] investigates the influence of operational conditions on battery degradation rates, highlighting three main factors: (i) temperature extremes, (ii) extreme states of charge (SOC), and (iii) variable charge/discharge rates. Field validation techniques and degradation modeling approaches have been proposed for various chemistries, including LFP, NMC, and LMO. A simplified model based on field data for NMC batteries is presented in [7], where degradation mechanisms are classified into calendar aging and cycle aging. This modeling approach is also employed in [8] and adopted in this paper. Additionally, [8] reports that among 50 analyzed EV models, 76% utilize NMC technology, followed by 18% with LFP and 6% with NCA batteries.

In this context, the present study shows battery SOH in an early Renault ZOE model to further investigate the battery degradation variability after many years of utilization. This variability is also hinted at in the table in the appendix from the CanZE project [9], offering a comprehensive perspective on current technology. To further analyze the degradation of a 10+ year NMC battery, we investigate an 11-year-old Renault Zoe Q210 model. The figure below shows a clear linear reduction in the SOH of the battery in the car analyzed, while also showing increased variability in the measured SOH from the battery management system (BMS) as the battery ages.



Considering that the measured SOH from the BMS is the same as the one utilized by the OEM to assess the warranty of the battery in the vehicle, it is not fully understood how the value of this SOH is calculated. A further assessment of the different SOH values, considering the SOC when the battery is fully empty and/or fully charged and balanced, could provide more information on the actual degradation of the battery in combination with the voltage values of the single cells and their temperature.

In conclusion, the SOH of the 2013 Renault Zoe taken under investigation exhibits a consistent and above 84% SOH, pointing out that even a relatively small battery with a gross capacity of 25.92 kWh and an available capacity of 22 kWh (for a SOH of 100%) and the capability of being charged at almost 2C (43 kW AC charger) still maintains great performance after more than 120,000 km driven. This totals a battery usage above 25,000 kWh with 1,615 full charges and 3,437 partial charges in its active history. This promising result might be the outcome of a good combination of BMS, the mild Danish climate, and the air cooling of the battery itself. The second part of this decade will reveal if such a configuration will be able to keep the battery at a good level for the use of an electric vehicle.

Acknowledgments

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References

[1] F. Jung, M. Schroder, and M. Timme, “Exponential adoption of battery electric cars,” PLoS one, vol. 18, no. 12, p. e0295692, 2023.

[2] X. Chen, W. Shen, T. T. Vo, Z. Cao, and A. Kapoor, “An Overview of Lithium-ion Batteries for Electric Vehicles,” 2012 10th International Power & Energy Conference (IPEC), pp. 230–235, 2012.

[3] Y. Miao, P. Hynan, A. Von Jouanne, and A. Yokochi, “Current li-ion battery technologies in electric vehicles and opportunities for advancements,” Energies, vol. 12, no. 6, p. 1074, 2019.

[4] P. Van den Bossche et.al., *SUBAT, an assessment of sustainable battery technology*, Journal of Power sources, ISSN 0378-7753, 162(2006), 913-919.

[5] *A. Barr´e, B. Deguilhem, S. Grolleau, M. G´erard, F. Suard, and D. Riu,“A review on lithium-ion battery ageing mechanisms and estimations for automotive applications,” Journal of power sources, vol. 241, pp. 680–689, 2013.*

[6] X. Han, L. Lu, Y. Zheng, X. Feng, Z. Li, J. Li, and M. Ouyang, “A review on the key issues of the lithium ion battery degradation among the whole life cycle,” eTransportation, vol. 1, p. 100005, 2019.

[7] M. Marinelli, L. Calearo, J. Engelhardt, and G. Rohde, “Electrical thermal and degradation measurements of the leaf e-plus 62-kwh battery pack”, in 2022 International Conference on Renewable Energies and Smart Technologies (REST), vol. 1, pp. 1–5, IEEE, 2022.

[8] K. Sevdari, M. Marinelli and F. Pastorelli, "Overview of EV battery types and degradation measurement for renault ZOE NMC batteries", in Proceedings of 2024 International Conference on Renewable Energies and Smart Technologies (REST) IEEE. pp. 1-5, 2024. https://doi.org/10.1109/REST59987.2024.10645453

[9] The CanZE project https://canze.fisch.lu/battery-health-status/ retrieved 10-01-2025.

Appendix

As a reference a list of Renault Zoe vehicles across various model years and conditions is presented from CanZE project [9]. This list summarizes the SOH behavior in NMC battery capacities of 25.9 kWh, 44.1 kWh, and 54.7 kWh, providing insights into real-world battery aging. A critical parameter in the SOH measurement is given by the optional battery BMS update that has been rolled over by Renault within the first years in the market of the Zoes.

User	Purchased	Battery	Charges	Charging	Charging	Km (x1000)	Car
		Health %	per week	power (kW)	place		
Fesch	2013.05.00	102	02/Mar	3,7	closed garage	28	Zoé
Fesch	2013.05.00	102	05/Jul	03.07	closed garage	60	Zoé
Fesch	2013.05.00	98	05/Jul	03.07	closed garage	92	Zoé
Fesch	2013.05.00	90	05/Jul	03.07	closed garage	102	Zoé
Fesch	2013.05.00	88	05/Jul	03.07	closed garage	103	Zoé
Daniel	2013.08.00	89	02/Apr	43	open carport	21	Zoé
Jeroen	2013.11.00	91	7	3,7	open	30	Zoé
Jesper	2011.11.00	97	02/Mar	3,7	open		Zoé
Rémy	2011.12.00	84	02/Apr	3,7	open	39	Fluence
Andy	2013.10.00	94	01/Feb	7	open	19	Zoé
Berndte	2013.03.00	102	05/Jul	22-43	open	47	Zoé
Tor	2015.04.00	100	05/Jul	11	open	12	Zoé (Q210)
Ole	2015.06.00	100	Jul/15	3,7 & 22	open carport	22	Zoé
Sandy	2014.06.00	98	1.5-2	7 & 43	open	13	Zoé
Sandy	2014.06.00	90	1.5-2	7 & 43	open	17	Zoé
Sandy	2014.06.00	88	1.5-2	7 & 43	open	26	Zoé
Sandy	2014.06.00	85	1.5-2	7 & 43	open	27	Zoé
Sandy	2014.06.00	98	1.5-2	7 & 43	open	28	Zoé (BMS updated)
Sandy	2014.06.00	96	1.5-2	7 & 43	open	35	Zoé
Sandy	2014.06.00	95	1.5-2	7 & 43	open	40	Zoé
Sandy	2014.06.00	94	1.5-2	7 & 43	open	41	Zoé
Sandy	2014.06.00	93	1.5-2	7 & 43	open	41	Zoé
Sandy	2014.06.00	93	1.5-2	7 & 43	open	48	Zoé
Fer	2015.05.00	87	06/Jul	09.00	closed garage	12	Zoé (Q210)
Fer	2015.02.00	91	06/Jul	04.06	closed garage	18	Zoé (Q210)
Tho	2013.06.00	93	07/Oct	Nov/43	open	25	Zoé
Ritxi	2012.02.00	78	05/Jul	03.03	closed garage	66	Fluence
Henrik	2014.05.00	105	02/Apr	02.04	open	18	Fluence
Fivari	2013.12.00	101	2	06.05	closed garage	28	Zoé
Schouf26	2013.03.00	102	7	22	open garage	74	Zoé
Jimbo	2014.11.00	99	03/Apr	03.06	carport	10	Zoé
mmezo	2014.06.00	102	01/Feb	3	closed garage	4	Zoé
mmezo	2014.06.00	102	2	3	closed garage	6	Zoé
Sten	2013.06.00	92	01/Feb	7 & 22	open carport	21	Zoé

ener73	2013.06.00	102	04/May	7.4 & 22	closed garage	62	Zoé
Arthur	2013.07.00	89	01/Mar	Nov/22	open carport	27	Zoé (Q210)
Crf	2015.12.00	105	7	2	open carport	2	Zoe (R240)
Crf	2015.12.00	84	7	2	open carport	39	Zoe (R240)
GertjanVB	2013.10.00	89	03/Jul	03.07	open	44	Zoé
JoDa	2014.06.00	92	6	11	closed garage	27	Zoé
cece74	2013.04.00	86	6	03.07	closed garage	51	Zoé
Claude	2013.05.00	86	02/Mar	11	closed garage	32	Zoé
Tim	2013.09.00	89	02/Mar	7 & 43	open	52	Zoé (Q210)
Tim	2015.09.00	100	02/Mar	3.7, 7 & 43	open	9	Zoé (Q210)
Grejazi	2014.06.00	109	Jul/21	2.3 & 3.7	closed garage / carport	19	Fluence
THellweg	2014.08.00	94	05/Jul	22	open	35	Zoe (Q210white)
THellweg	2015.12.00	96	05/Jul	22	open	11	Zoe (Q210black)
Alexc	2013.12.00	86	01/Feb	22	open	50	Zoe (R240grey)
lingley	2013.06.00	85	03/Jul	2.4-43	closed garage	42	Zoe (Q210)
Kai	2013.06.00	84	03/May	9, 22 & 43	open carport	45	Zoe (Q210)
Kai	2013.06.00	86	03/May	9, 22 & 43	open carport	54	Zoe (Q210)
beatus	2015.01.00	98	05/Jul	14-43		10	Zoe (Q210black)
most	2016.02.00	105	02/May	22	open	2	Zoé (R240)
JBS-EP Tender	2013.03.00	102	03/Apr	7	open (near Paris)	49	Zoe (Q210)
bene	2015.10.00	96	05/Jun	22	open	23	Zoe (R240)
Claude	2013.05.00	84	02/Mar	11	closed garage	40	Zoé
Bernd	2014.12.00	72	03/May	22	open carport	17	Zoé (Q210)
Claude	2013.05.00	82	02/Mar	11	closed garage	41	Zoé
Lorenzo	2014.10.00	81		22	open		Zoé
Fidelio	2013.03.00	102	03/Apr	22	open	72	Zoé (Q210)
Grejazi	2014.06.00	101	Jul/21	2.3 & 3.7	closed garage / carport	40	Fluence
FrancescZOE	2013.10.00	86	01/Feb	04.06	closed garage	38	Zoé (Q210)
FrancescZOE	2013.10.00	97	01/Feb	20	closed garage	82	Zoé (Q210)
evzone	2015.06.00	80	3	02.03	carport	18	Zoé
Bruce	2015.05.00	94	01/Feb	7	closed garage	5	Zoé (Q210)
schussi	2016.07.00	101	01/Feb	22	open	20	Zoé (R240)
schussi	2016.07.00	98	01/Feb	22	open	30	Zoé (R240)
schussi	2016.07.00	98	01/Feb	Feb/22	open & closed	49	Zoé (R240)
Jin Feng Goh	2017.02.00	105	02/Mar	Mar/22	open	0	Zoé (R240)
Jin Feng Goh	2017.02.00	103	02/Mar	Mar/22	open	12	Zoé (R240)
Jin Feng Goh	2017.02.00	101	02/Mar	Mar/22	open	24	Zoé (R240)
Jin Feng Goh	2017.02.00	100	02/Mar	Jun/22	open	36	Zoé (R240)
Jin Feng Goh	2017.02.00	98	03/Apr	Jun/22	open	60	Zoé (R240)

Jin Feng Goh	2017.02.00	98	02/Mar	Mar/22	open	101	Zoé (R240)
Jin Feng Goh	2017.02.00	98	03/Apr	Jun/22	open	72	Zoé (R240)
Jin Feng Goh	2017.02.00	98	02/Mar	Mar/22	open	96	Zoé (R240)
Jin Feng Goh	2017.02.00	99	03/Apr	Jun/22	open	48	Zoé (R240)
Jin Feng Goh	2017.02.00	98	03/Apr	Jun/22	open	84	Zoé (R240)
Jin Feng Goh	2021.03.00	99	01/Feb	Jun/22	open	0	Zoé (Z50 R110)
Jin Feng Goh	2021.03.00	98	01/Feb	Jun/43	open	12	Zoé (Z50 R110)
iwi	2013.06.00	76	02/Mar	Apr/22	open carport	19	Zoé
decalco	2013.03.00	102	06/Jul	6.4 & 22	open	56	Zoe (Q210)
decalco	2017.02.00	101	05/Jun	2.3 & 22	open	0	Zoé (Z40 R90)
decalco	2017.02.00	100	05/Jun	2.3 & 22	closed garage	15	Zoé (Z40 R90)
decalco	2017.02.00	99	05/Jun	2.3 & 22	closed garage	23	Zoé (Z40 R90)
decalco	2017.02.00	94	05/Jun	2.3 & 22	closed garage	50	Zoé (Z40 R90)
decalco	2019.03.00	102	05/Jun	2.3 & 22	closed garage	0	Zoé (Z40 R110)
decalco	2019.03.00	96	5	22	open	27	Zoé (Z40 R110)
decalco	2019.03.00	95	1	22	open	30	Zoé (Z40 R110)
decalco	2019.03.00	94	02/Mar	22	open	34	Zoé (Z40 R110)
decalco	2021.10.00	99	02/Mar	22	open	0	Zoé (Z50 R110)
Gyuri	2012.11.00	88	05/Jul	2.3-3.7	closed garage	48	Fluence
Gyuri	2012.11.00	79	05/Jul	2.3-3.7	closed garage	70	Fluence
Eros	2013.06.00	102	7	2.3 & 43	open & closed garage	113	Zoé (Q210)
Technieq	2016.01.00	114	21	2.3 & 3.7	open	10	Kangoo ZE 26kWh
mohikaner57	2012.06.00	80	01/Feb	3.3-4.1	open	65	Fluence
Pixie	2018.10.00	101	3	3	garage	0	Zoe (Z40 R90)
Pixie	2018.10.00	100	3	2+22	garage	4	Zoe (Z40 R90)
Pixie	2018.10.00	99	3	2+22	garage	9	Zoe (Z40 R90)
Pixie	2018.10.00	98	3	2+22	garage	14	Zoe (Z40 R90)
Pixie	2018.10.00	97	3	22	garage	26	Zoe (Z40 R90)
Pixie	2018.10.00	95	1	22	garage	33	Zoe (Z40 R90)
Bahrt	2018.08.00	83	05/Jun	22	open	8	Zoe (R240)
Zuhril	2017.09.00	98	05/Oct	2,3.7,22,43	open & closed	20	Zoe (Q210)

Peter	2015.11.00	73	01/Mar	3,7	open & closed	33	Zoe (R240)
Peter	2015.11.00	98	01/Mar	03.07	open & closed	34	Zoe (R240) BMS 0854
Luis Mendes	2017.09.00	95	7	2	garage	29	Zoe (Z40 R90)
Alex	2019.06.00	100	01/Feb	09/Nov	outdoor parking	6	Zoe (Z40 R110)
DompaEV	2017.02.00	97	01/Mar	3.7-22	open & closed	18	Zoe (Z40 R90)
warpi	2014.03.00	93	2	02.03	garage	91	Zoe
Limpan4all	2019.09.00	95	06/Jul	11	open	71	Zoé (Z40 R110)
Neno	12	87	01/Feb	Oct/22	open	115	Zoé (Z40 R90)
Adam	2013.10.00	94	02/Mar	Sep/22	open & garage	239	Zoe (Q210)
northcup	2022.10.00	98	02/Mar	Nov/22	garage	17	Zoe (R240)

Presenter Biography

Francesco Pastorelli holds a Ph.D. in Solar Energy and is a dedicated researcher specializing in solar energy applications. With a strong focus on sustainable technology, Francesco has contributed extensively to advancing novel photovoltaic technologies and their integration within electric mobility systems. His work also encompasses in-depth research on electric vehicle (EV) battery health, particularly exploring how EV batteries can be leveraged for grid services. Through empirical analyses of EV battery degradation and performance, Francesco's research supports the development of sustainable electric mobility and aims to enhance battery management systems for improved efficiency and longevity.