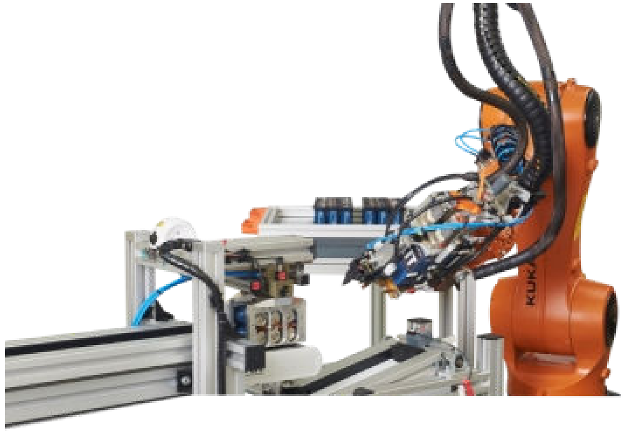
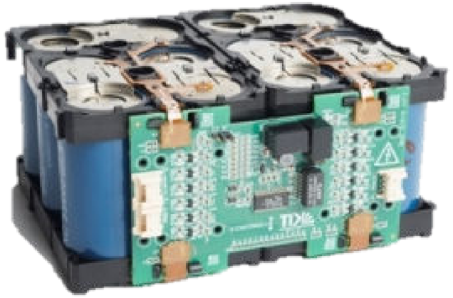
Comparative Concept Study of Passive Hybrid Energy Storage Systems in 48V Mild Hybrid Vehicles





Varying
Lithium-ion Battery and Supercapacitor Technologies

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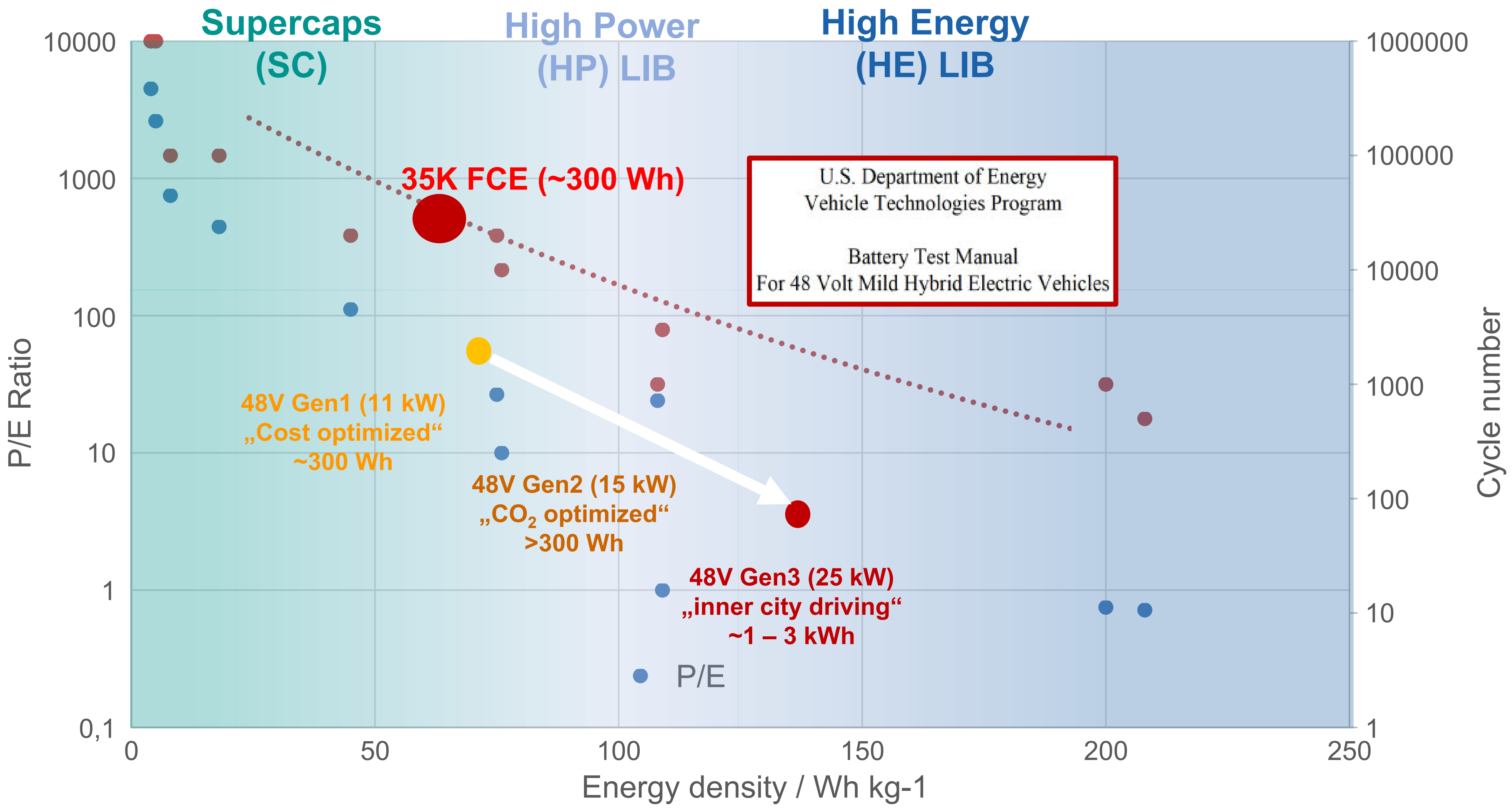
Agenda

Facts&Figures

- EU Targets 2020/21 CO_2 emission → 25% reduction compared to 2015

48V Benefits

- 15-20% CO_2 reduction
- 30% (HV)-FHEV costs



Source(s):
A. Burke, "Ultracapacitor technologies and application in hybrid and electric vehicles," Int. J. energy Res., vol. 34, pp. 133–151, 2010.
The Idaho National Laboratory, "U.S. Department of Energy Vehicle Technologies Program Battery Test Manual For 48 Volt Mild Hybrid Electric Vehicles," 2017. [Online]. Available: https://inldigitallibrary.inl.gov/sites/sti/sti/7364006.pdf
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A. I. Stan, et al., "Lithium ion battery chemistries from renewable energy storage to automotive and back-up power applications - An overview," 2014 Int. Conf. Optim. Electr. Electron. Equipment, OPTIM 2014, no. May, pp. 713–720, 2014.

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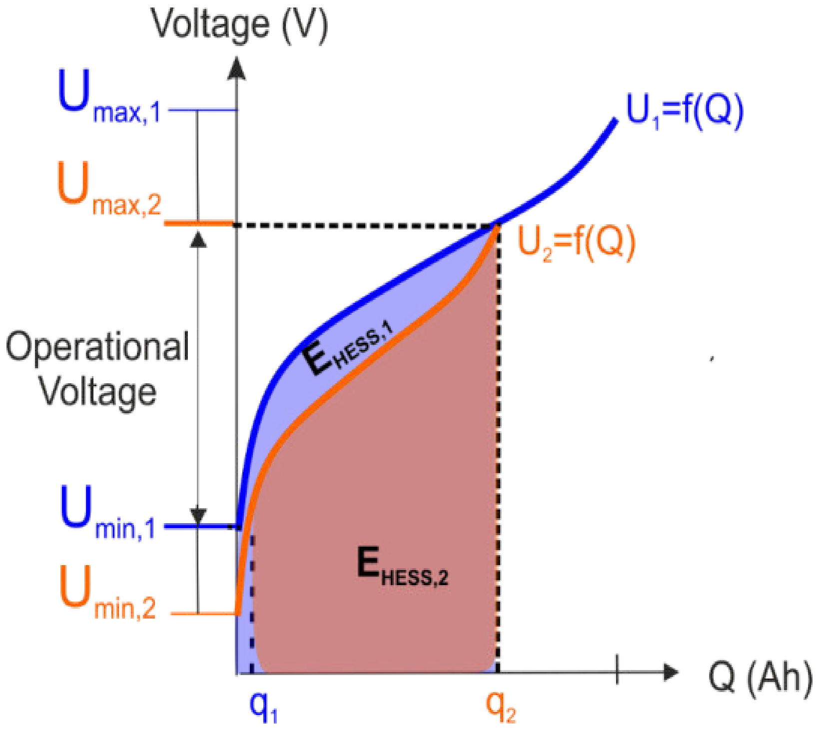
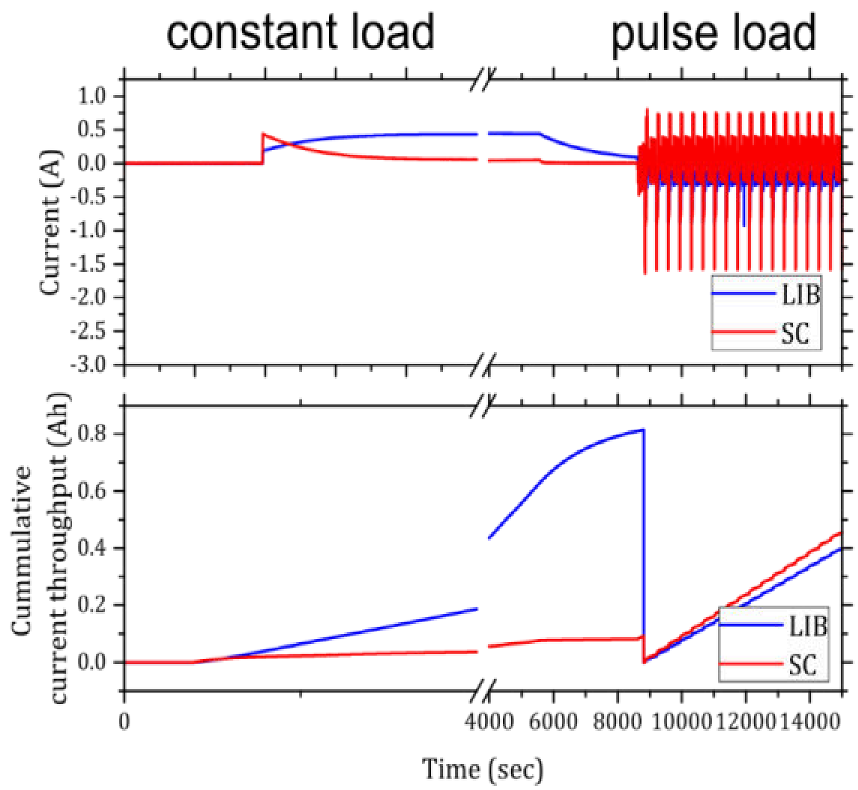
1. Voltage match

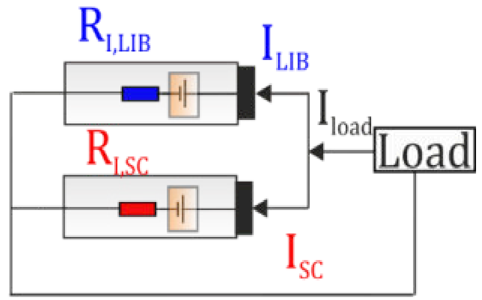


$$E_{HESS} = \int_{q_1}^{q_2} U_1(Q)\,dQ + \int_{q_1}^{q_2} U_2(Q)\,dQ$$

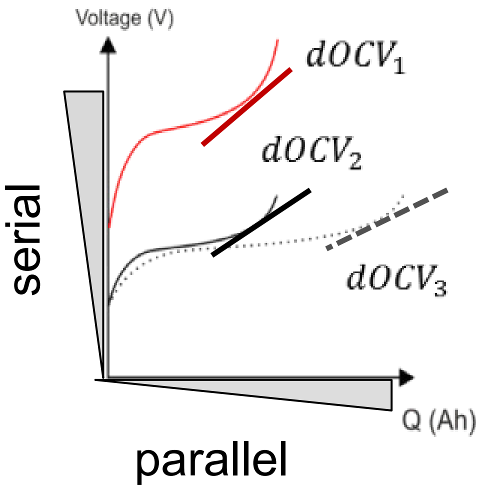
2. Load profile



3. Cell and system dynamics



dOCV



$dOCV_1 > dOCV_2 > dOCV_3$

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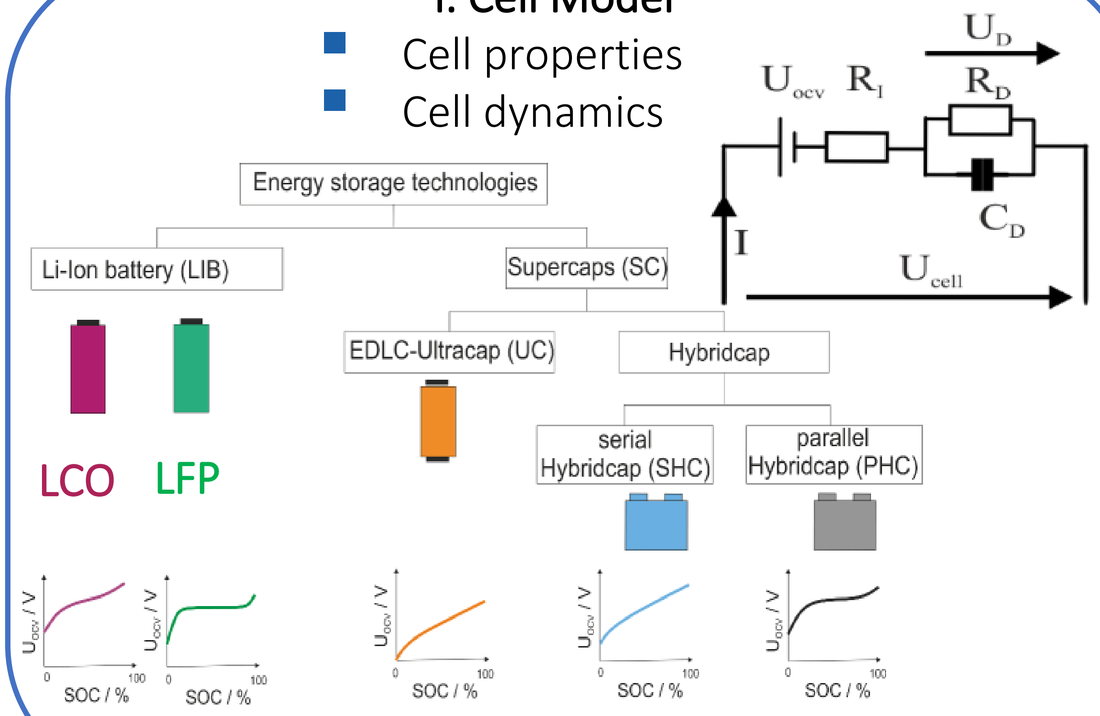
- 1 Model / 4 Technologies
- Equal parameter campaign with slightly changes
- Model error: $\overline{I}_{NRMSE}$ ~7% (16 errors) – $\overline{U}_{NRMSE}$ ~3% (22 errors)

I. Cell Model

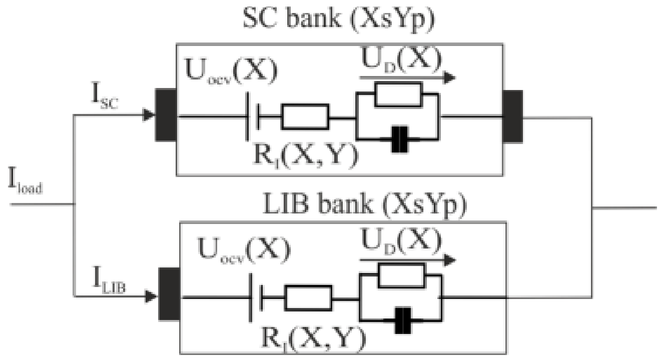
- Cell properties
- Cell dynamics



Li-Ion Capacitors (LIC)

II. System Model

- Cell-2-System transformation (XsYp)
- Module-to-Module-interaction



$$\begin{bmatrix} 1 & 1 \\ R_{I,LIB}(t) & -R_{I,SC}(t) \end{bmatrix} \begin{pmatrix} I_{LIB}(t) \\ I_{SC}(t) \end{pmatrix} = \begin{pmatrix} I_{load}(t) \\ -U_{OCV,LIB}(t) - U_{D,LIB}(t) + U_{OCV,SC}(t) + U_{D,SC}(t) \end{pmatrix}$$

- Updating time depending cell properties

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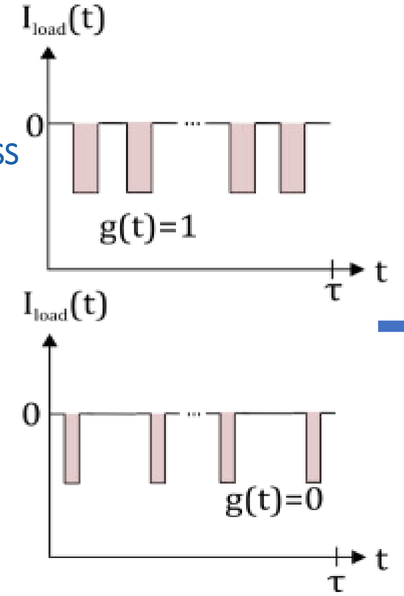
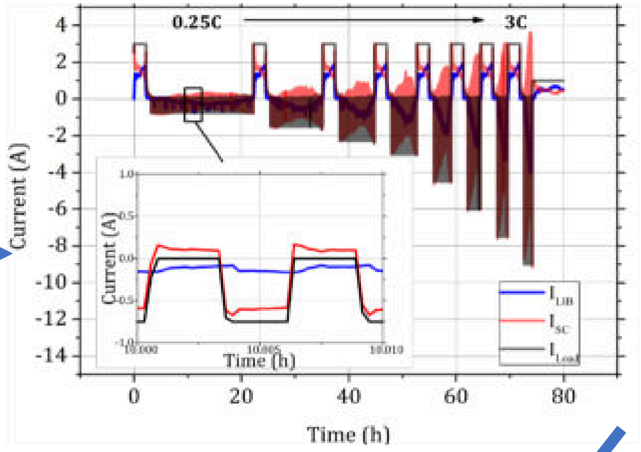
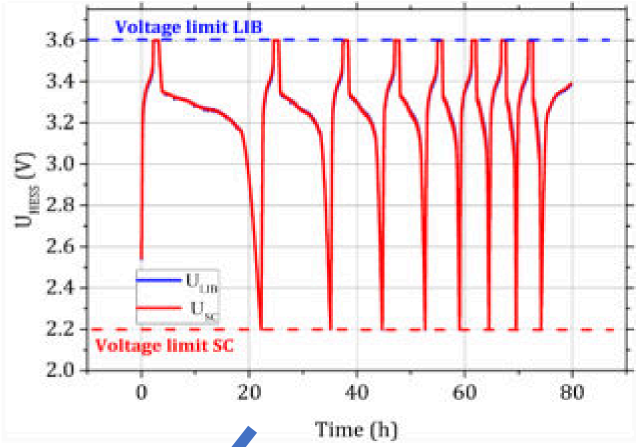
Energy density e_{HESS}

Power enhancement p_{HESS}

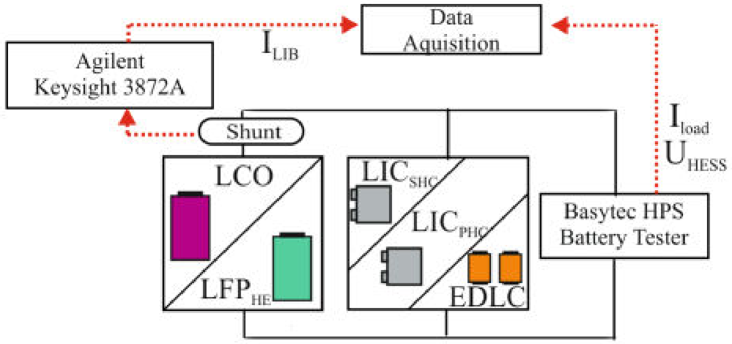


Stop if I_{LIB}> C-Rate max in CHG direction

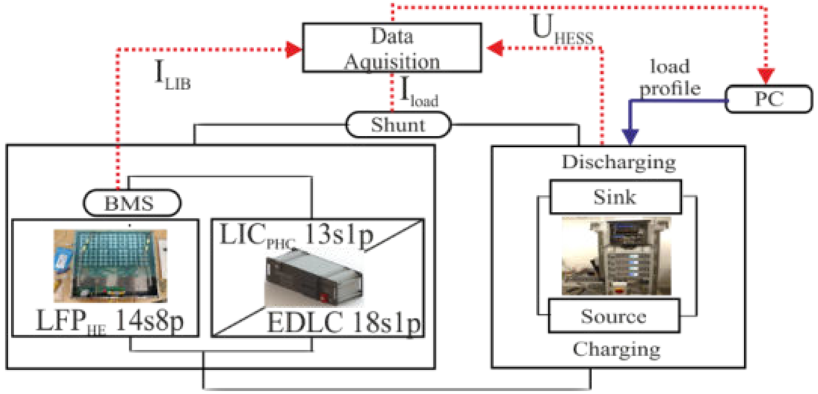




Cell 2 Cell (C2C)



System 2 System (S2S)



$$e_{HESS} = \frac{1}{m_{HESS}} \int_0^{\tau} U_{HESS}(t) \cdot I_{load}(t) \cdot g(t) \mathrm{d}t$$

$$p_{HESS} = \frac{e_{HESS}}{\tau D}$$

D is the fraction of τ in which the current pulse is active

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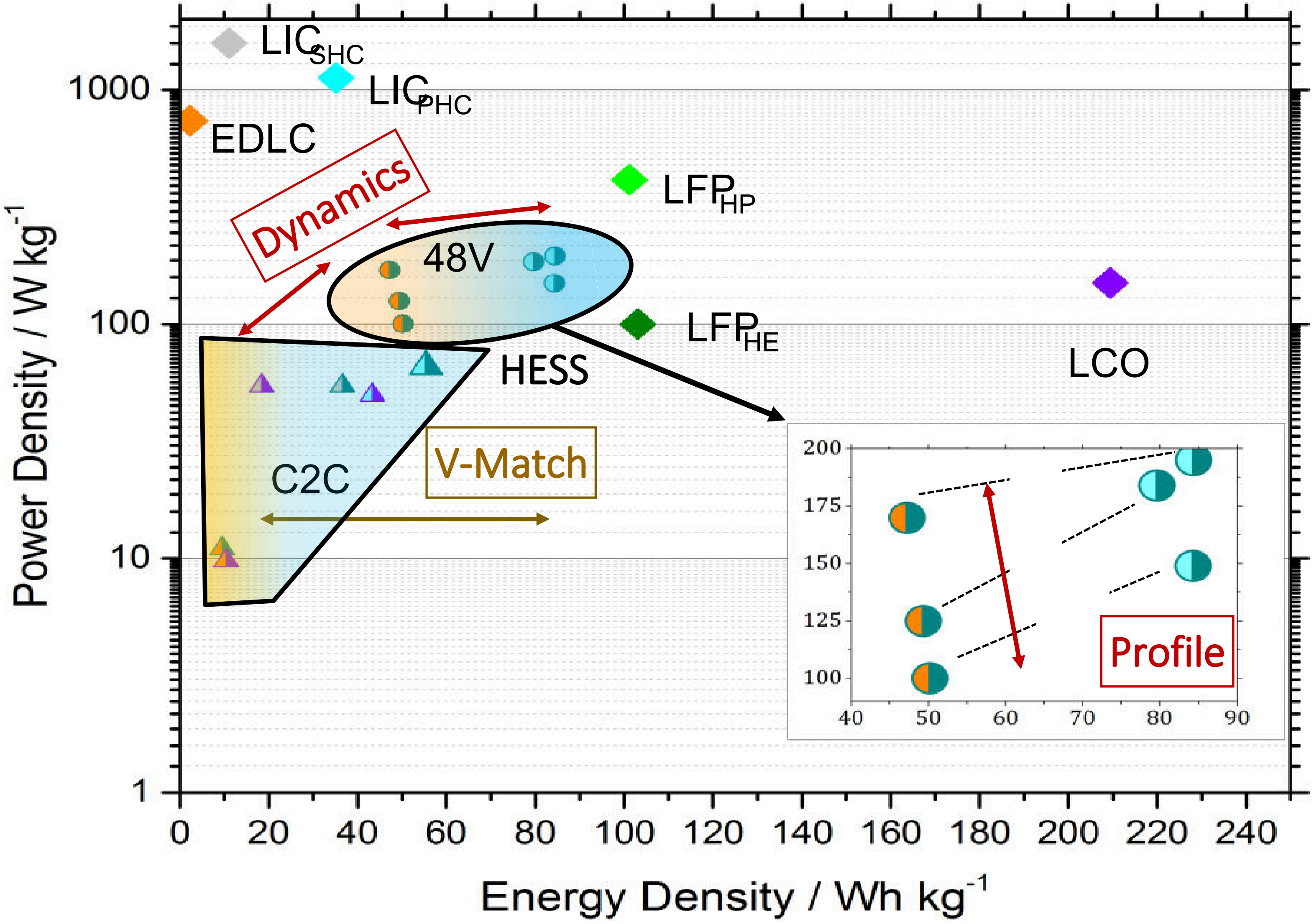
LICHESS
EDLCHESS



Highlights

- **V-Match** influences mainly energy density at same topology
- **System design / dynamics** influence energy and power density (C2C→S2S)
- **Short pulse profiles** enhance power density

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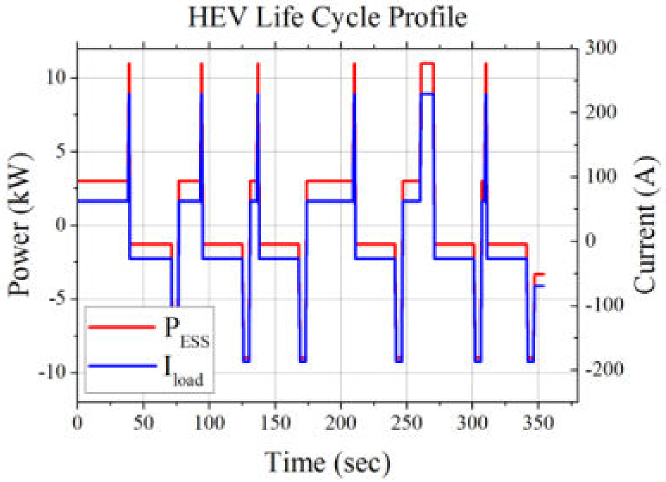
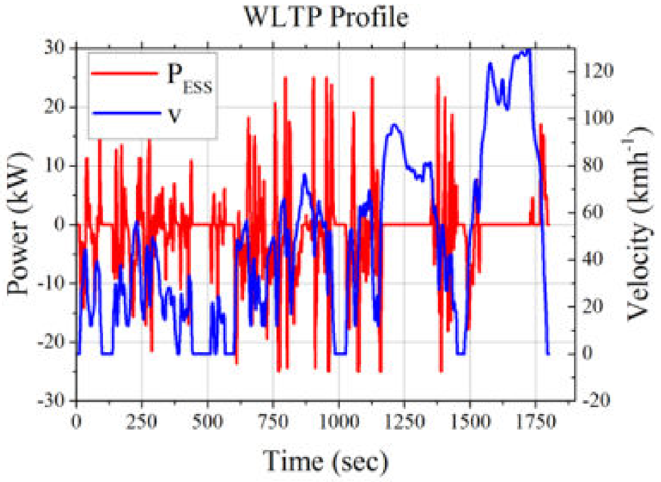
Generation 1 (11 kW) – cost optimized



- **USABC**
- Protocol for 48 V MHEV
- March 2017
- **Power oriented**

Generation 3 (25 kW) – pure electric inner city driving



- **WLTP**
- Emulating “real” driving behavior
- September 2017
- Simple EMS for emulating ESS load
- **Energy oriented**

Target(s)

- Improvement of ESS due to HESS add on
- HE-Hybrid competitive to HP-ESS
- Cross-generational solution

Study 1	HE-Hybrid vs. HP ESS	HESS same dimension as ESS	Gen1
Study 2	HE-Hybrid vs. HP ESS	Minimize HESS dimension	Gen1
Study 3	HE-Hybrid vs. HE ESS	Minimize HESS dimension	Gen3
Study 4	HP-Hybrid vs. HP ESS	Minimize HESS dimension	Gen3

HE/HP technology SC technology: LIC_{PHC}

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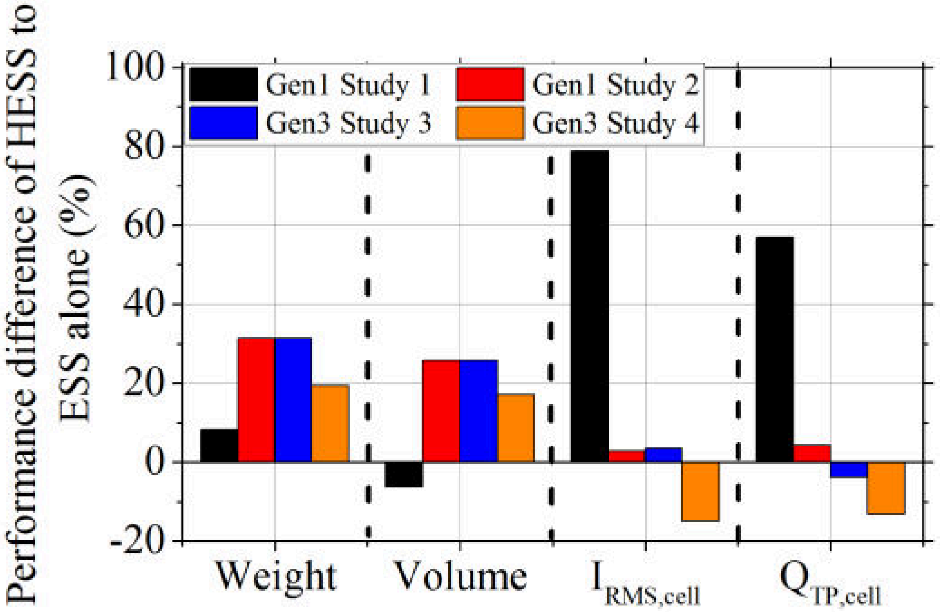

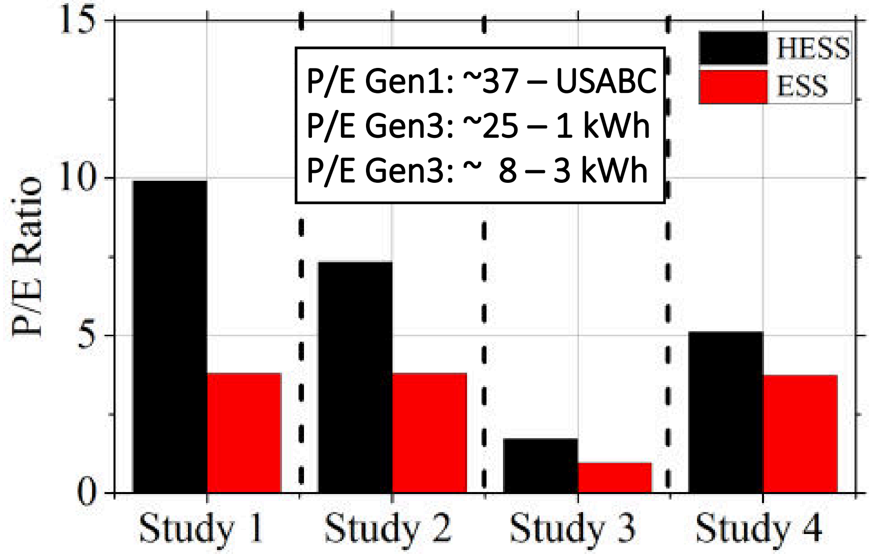

Study 1: Reduction of single cell stress ($I_{RMS,cell}$ **80%**; $Q_{TP,cell}$ **58%**) at approx. same dimensions
Study 1 – 2: HE-HESS module **compatitive** to HP-ESS module
Study 3 – 4: Improvements of ESS due to (H)ESS add-on module
Study 1 – 4: Cross-generational reduction of dimensions compared to ESS (**20 – 30%**) by an increasement of battery stress up to 14%
Study 1 – 4: Enhanced P/E Ratio up to a factor of 2-3

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Conclusion

- HESS are a highly adaptable approach for ESS solutions within high dynamic applications
- Characteristics are depending on V-match, system design and load profile
- For 48V MHEV applications, passive HESS are a cross-generational solution to design high performable ESS solutions

Outlook

- Ageing and thermal properties should be considered for further lifetime and efficiency estimation

Thank you for your Attention!

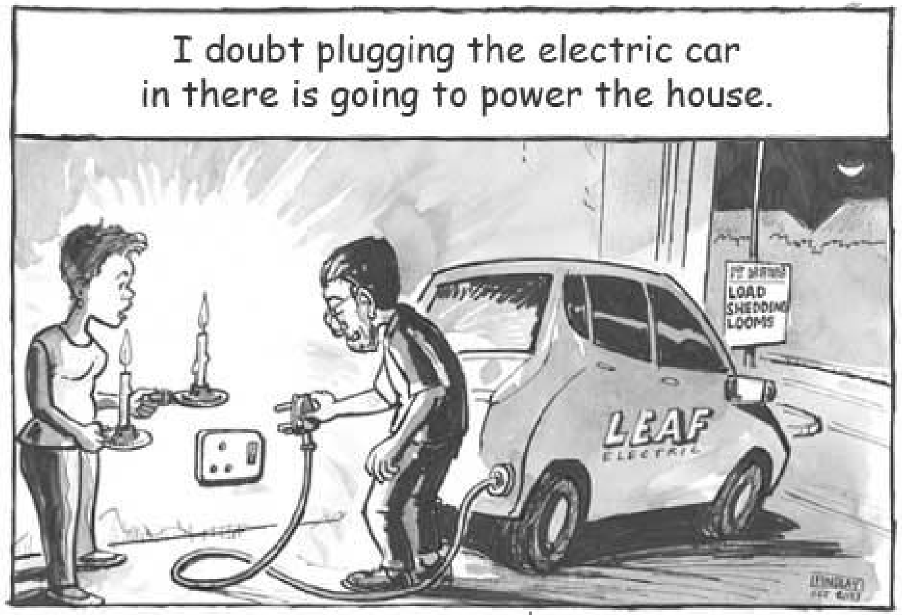

Image source: www.quora.com

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