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#RTR2026

SCAPE

Switching-Cell-Array-Based Power Electronics Conversion For Future Electric Vehicles

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IREC

Shaping Energy for a Sustainable Future

SCAPE
POWERING E-MOBILITY

2ZERO ERTRAC CCAM European Commission

With the support of BATT4EU Batteries European Partnership

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Overall project presentation

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SCAPE's Team

9 partners based in France, Italy, Spain, Turkey and Germany

- ✓ e-mobility industry experts and OEMs
- ✓ researchers in power converters
- ✓ specialists in modelling and control systems
- ✓ experts in environmental lifecycle assessment

Type of action: **RIA**

Duration: **48 months** (July '22 – June '26)

Budget: **5.999.750 €**

Member of the
E-VOLVE cluster

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SCAPE Objectives

- Standardize the EV power-converter design methodology.
- Reduce engineering and manufacturing costs.
- Increase the powertrain performance and perform health management.
- Increase EV acceptance and contribute to EU transport industry

Main KPIs	Reference commercial metrics	Targeted metrics
Efficiency	Inverter: 96 % OBC: 94%	> 97,5% (loss reduction > 35%)
Power density	Inverter: 20 kW/litre OBC: 3,5 kW/litre	> 100 kW/litre
Specific power	Inverter: 15 kW/kg OBC: 3 kW/kg	> 30 kW/kg
Cost	Inverter: 4 €/kW OBC: 40 €/kW	< 2,5 €/kW
Life expectancy	8.000 h, 300.000 km	> 16.000 h, 600.000 km

By means of:

- Modular and scalable system architecture using multilevel converters
- Integrated Inverter-Charger
- Chip-embedding technology
- Digital Twin of the powertrain and advanced controls
- Ecodesign and LCA
- Experimental validation with powertrain test bench

Considered Use Cases

400 V
50 kW
2L CLs

800 V
100 kW
3L CLs

1200 V
300 kW
4L CLs

Under implementation

Results presentation

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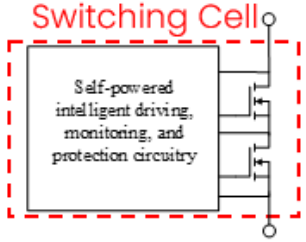
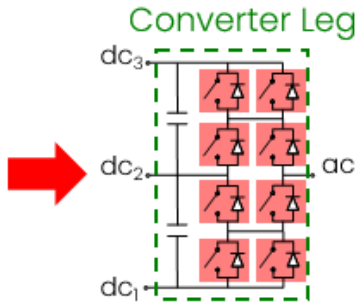
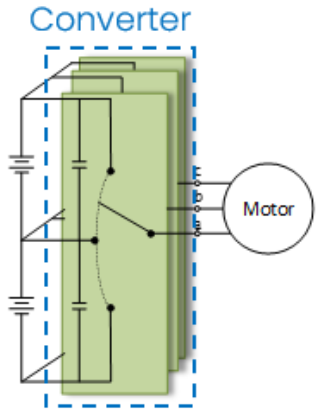
Power converter design approach

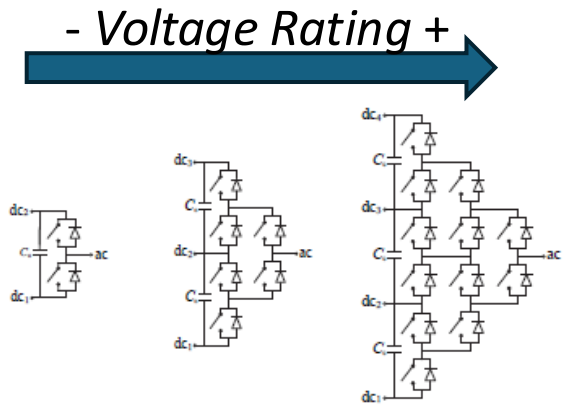
- Basic building block: **Switching cell**.
- Power conversion system built in a **modular** fashion.
- **Easily scalable** to achieve different converter voltage and current ratings.
- **Cost reduction** thanks to **scale economies** and low engineering design effort.

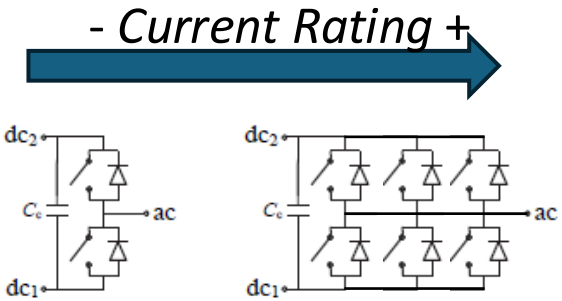




Multilevel NPC Topology







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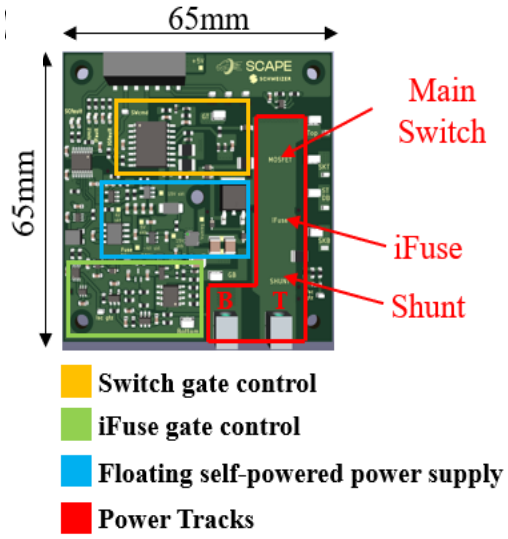
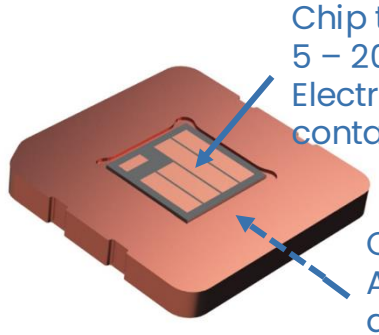
HV Switching Cell (HVSC) prototype

- **Chip Embedded** HVSC prototypes featuring:
  - Health management system
  - 3D printed cooling system
- Design aided by multiphysics simulations
- Chip embedding by Schweizer Electronic AG

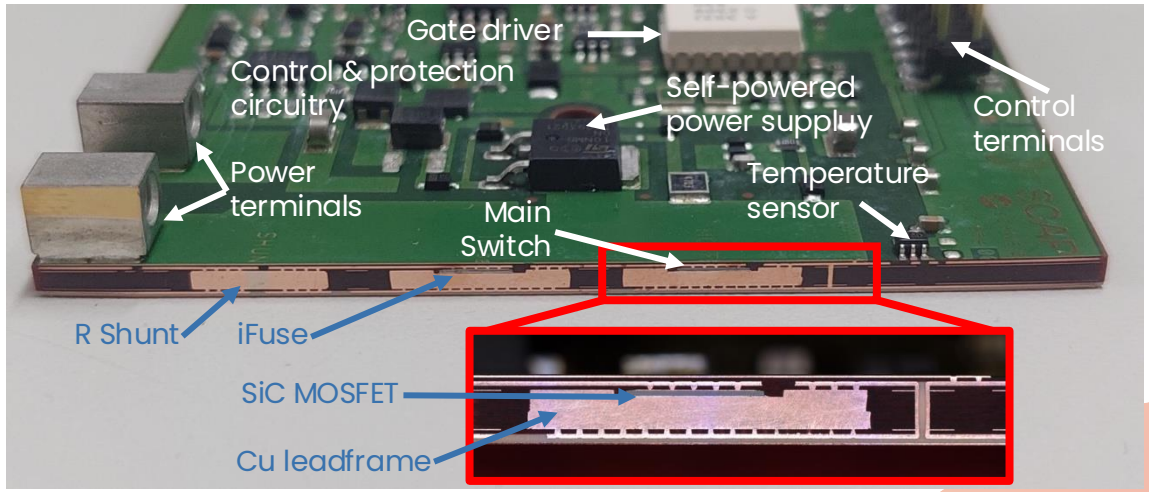
- Very promising results from experimental results:
  - $R_{th,j\text{-}backside}$ = 0,45 K/W ➡ **60% reduction***
  - L_{stray} = 2 nH ➡ **83% reduction***
- Large potential for power density & efficiency increase in the converters!

*Compared to a SC implemented with 2x MOSFETs model C3M0015065K and thermal pad SIL-PAD-400. $R_{th,j\text{-}h}$ = 1,15 K/W, L_{stray} = 20 nH.





(Source: Schweizer Electronic AG)



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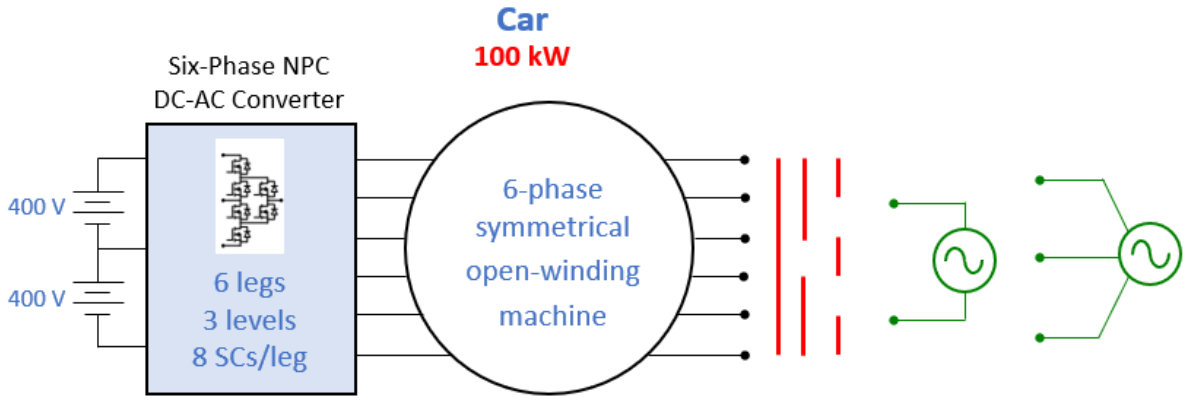
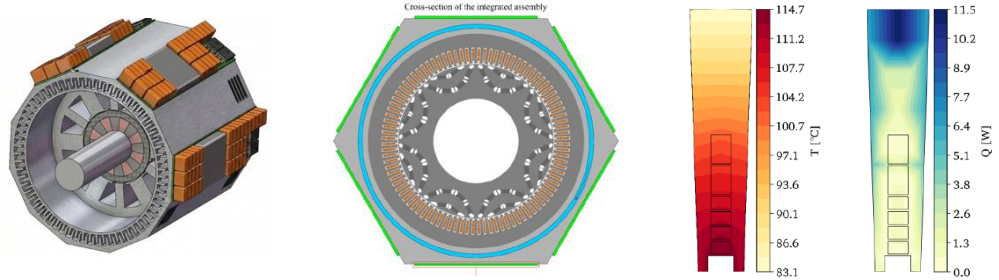
Integration of hardware and functions

Integrated Inverter-Charger

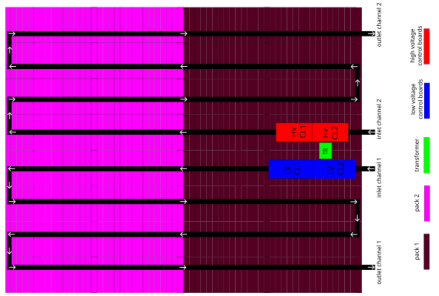


- **2-in-1** converter
- **Power-losses balancing**
- **Fault tolerant**
- **Low common-mode voltage** during charging to meet safety standards
- **Lossless SOC balancing** between battery modules
- ↑ **Power Density**
- ↑ **Fault Tolerance**
- ↑ **Reliability**

Integration of converter into motor and battery



- Enabled by **Modular Design** and **Chip Embedding**
- Converters can **adapt to multiple shapes**
- Losses spreading allows **shared cooling system**
- *Integrated designs verified through simulations*

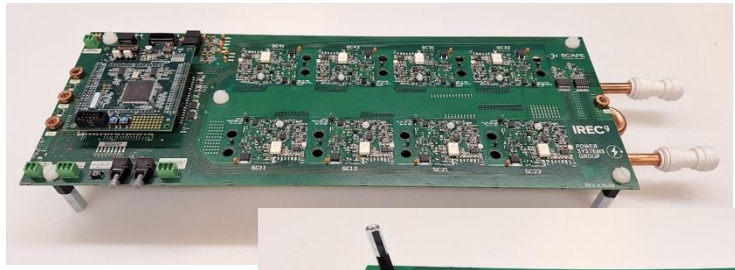


Integrated Inverter-Charger Prototype

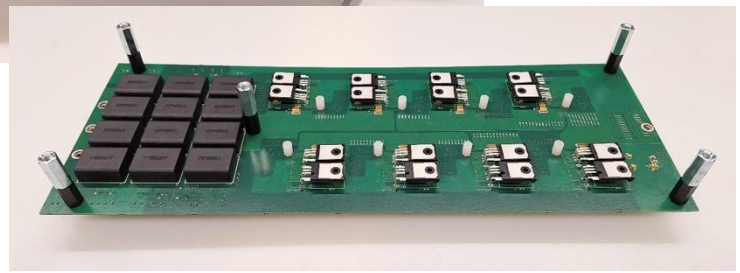
1st prototype using conventional power devices packaging (TO-247)

- For initial hardware and controls verifications
- As base case for chip-embedding

1x converter leg (top view)



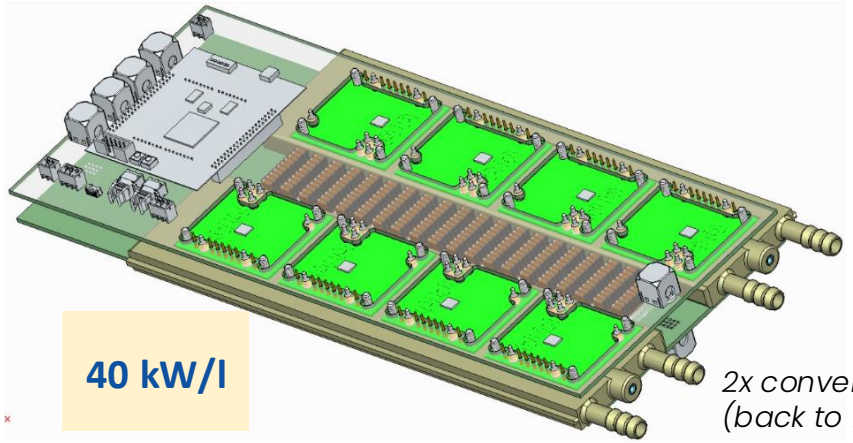
10 kW/l



1x converter leg (bottom view, coldplate removed)

2nd prototype with chip embedding (under development)

- **Easy reparability** and **recyclability** (separated SC boards).
- Expected 100 kW/l KPI reachable with:
  - Integration of subcircuits
  - CL and SCs into a single board
  - Stripping of non-essential functionalities
- **Space saving** in the vehicle: **9 – 10 litres!***



40 kW/l

2x converter legs (back to back)

*Compared to the space occupied by a conventional 100 kW, 20 kW/l inverter and a 22 kW, 3.5 kW/l OBC.

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Cost Reduction from Modularity & Integration

- Full advantage of scale economies → Same module (HVSC) used in all converter types
- Integration into motor or battery → Shared cooling system (no coldplate)

→ Only cost of electronic components and PCBs accounted

Vehicle type	#Vehicle per type	Total vehicle power	Converter #Levels	SCs per CL	dc Voltage	€/kW*
Motorbike 1	100,000	25	2	2	400	**3.3 – 7.6**
Motorbike 2	100,000	50	2	4	400	**2.2 – 5.0**
Motorbike 3	100,000	100	2	8	400	**1.6 – 3.7**
Car 1 (Entry-level)	100,000	50	2	4	400	**2.2 – 5.0**
Car 2 (Mainstream)	100,000	100	3	8	800	**1.6 – 3.7**
Car 3 (AWD)	100,000	200	3	16	800	**1.3 – 3.1**
Truck 1 (Light-duty)	100,000	150	3	8	800	**1.1 – 2.5**
Truck 2 (Medium-duty)	100,000	300	4	16	1200	**0.9 – 2.0**
Truck 3 (Heavy-duty)	100,000	600	4	32	1200	**0.8 – 1.9**

☑ Target = 2,5 €/kW

Commercial inverter = 4 €/kW

Up to 60% cost reduction!

Cost follow Wright's Law:

$$C(Q) = C_0 \times Q^{-b}$$

Total number of SCs: ~60 M

Individual SC module cost*: 1.57 € - 3.83 €

* Prices deflated to 2021.

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Mid to long term expected impacts of the project

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SCAPE Impacts

Technological Impacts

- **Cost reduction:** 40% cost reduction in power converters considering wide adoption of the proposed modular & scalable design approach.
- **Improved EV driving range:** 9% to 18% increase (from motorbikes to trucks), thanks to:
  - Increase in conversion efficiency
  - Increase of power density (more space for batteries)
  - Active inter-module SoC balancing
  - Reuse of heat losses for cabin heating
- **Improve powertrain reliability**, thanks to:
  - Fault-tolerant powertrain architecture
  - Health management strategies with Digital Twins
  - Predictive Maintenance

SCAPE Impacts

Environmental Impacts

- **CO_{2e} emission reduction:** 30 kTonnes/year.
  - Considering 10% adoption of SCAPE technologies in the new EVs (5 million sold by year), 2400 kWh/year average consumption per EV, and the projected EU energy mix by 2030.

Societal Impacts

- **Accelerate uptake of EVs:** The increased driving range and higher reliability can promote the user acceptance of e-mobility.

Economical Impacts

- **Improve EU Industrial Leadership:** The higher performance of SCAPE powertrain and reduction of manufacturing costs, can boost the competitiveness of EU EV industry, and extend it to other sectors (Energy, Maritime and Airborne transport, Robotics)

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Connect with SCAPE

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