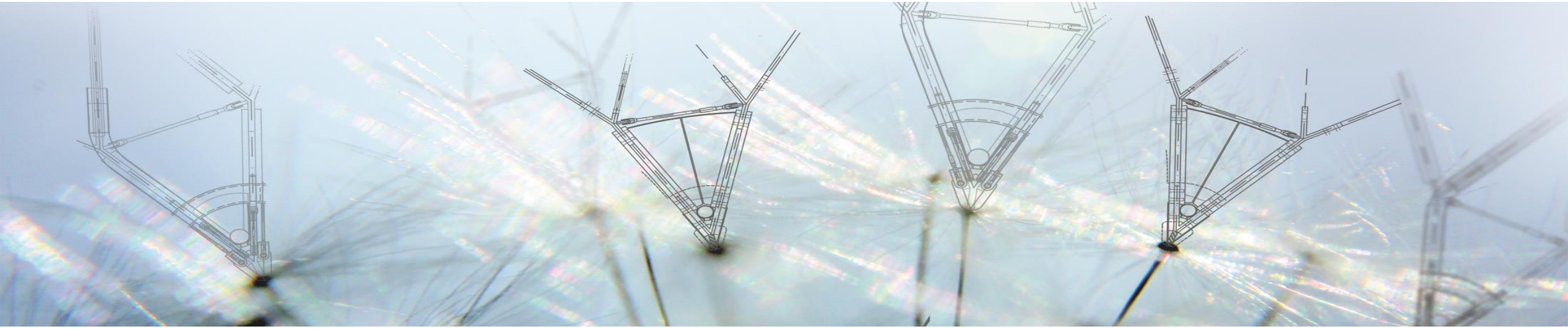
TGM LIGHTWEIGHT SOLUTIONS

NMIS National Manufacturing Institute Scotland

The TGM & NMIS collaboration - Our approach to lightweight solutions

A show-case study with lithium starter battery concept

in cooperation with Liteblox & Koller: Concept design phase



We combine expertise in the field of lightweight design & design for manufacture.

TGM Lightweight Solutions offers holistic lightweight consultancy and mass properties management for systems and structures of vehicles in the automotive, rail and aero/space industry.

The **National Manufacturing Institute Scotland** is a group of industry-led manufacturing research and development facilities where research, industry and the public sector work together to transform skills, productivity and innovation to attract investment and make Scotland a global leader in advanced manufacturing.

Our approach is illustrated in the following case study. (Lightweight lithium starter battery)

In a hypothetical scenario we screened the vehicle for weight saving opportunities and derived a qualified solution concept. Focus was to estimate the cost for manufacturing and forecast the primary lightweight cost.

Weight saving opportunity identified

+

Holistic weight analysis & ideation of potentials

+

Process for evaluation of effects on weight and cost

=

Show-case of our approach

In collaboration with our partners:

LITE BLOX high performance lightweight batteries

Manufacturer of Lithium iron phosphate batteries in professional motorsports:
Website Liteblox

KOLLER

Automotive TIER 1 supplier for tools & plastic components:

Website Koller Group

We present a patented LiFePO4 starter battery concept to replace existing Pb solutions. For the chosen scenario, the X5 Hybrid (F15), weight reduction based on manufacturing costs is approximately:

33.5 kg at 16 - 23 €/kg *

** However, our approach is not limited to starter batteries and we are more than happy to analyse any other component.*

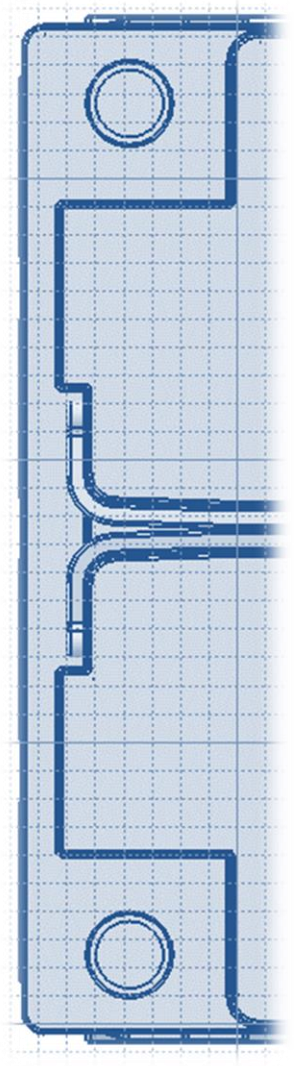
Our process

I. **Introduction assumptions & reference car**

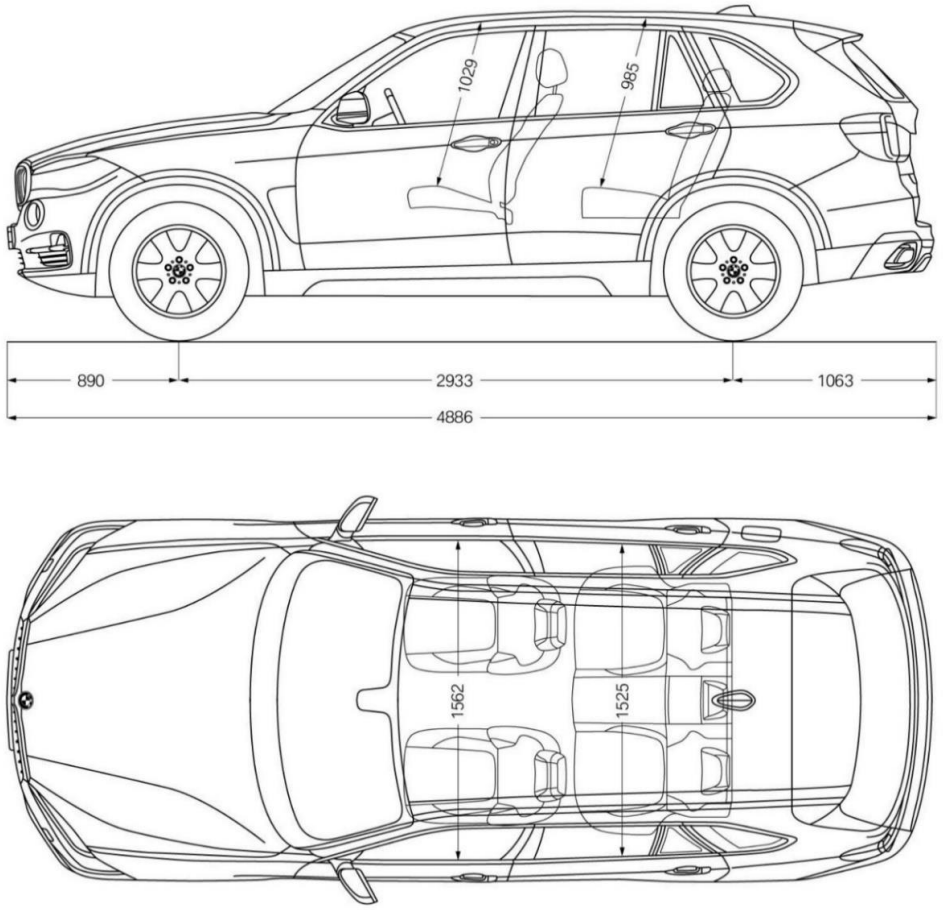
II. Lightweight potential starter battery

III. Manufacturing processes & estimation of cost

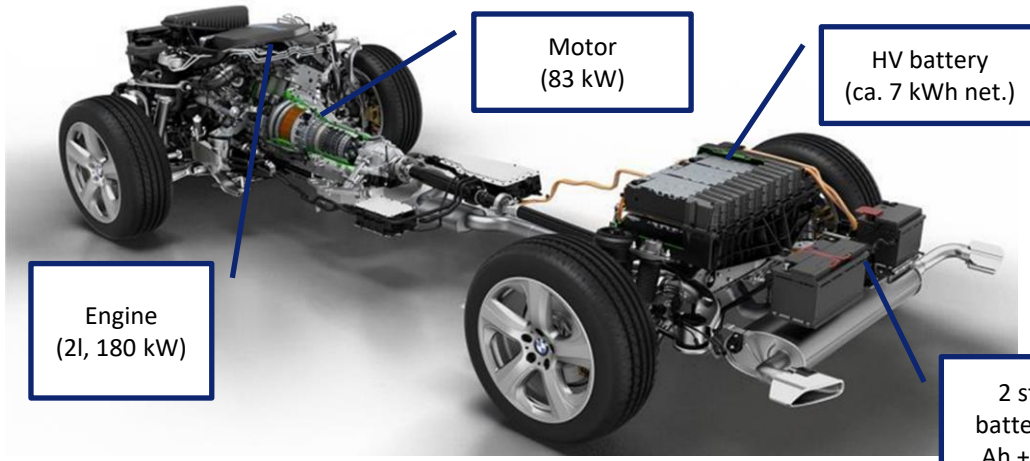
IV. Management summary & next steps



Reference is the BMW F15 40e hybrid which weighs 240 kg more than the 35i derivative with internal combustion engine, offering less trunk capacity and no extras like a third seat row.



[BMW15]



[KAB14]

We have chosen the F15 40e as it is the first series hybrid from BMW´s core brand. All referenced information is available in the public domain - published predominantly by BMW or A2MAC1 (a benchmarking tool). No confidential or private data has been used.

Together with our industry partners we assumed a framework of conditions for the BMW F15 based on publicly available data to develop our demonstrator project.

General requirements*

- Design for modularity
- Electrical
  - ➢Voltage
  - ➢Capacity
  - ➢Energy
  - ➢Electro-magnetic interferences
- Mechanical
  - ➢Crash loads
  - ➢Vibrations / resonance
- Thermal
- Geometries & interfaces
  - ➢Mounting
  - ➢Envelope space

Economical aspects*

- Manufacturing cost includes:

➢Verified price level for electrical components
➢Manufacturing equipment
➢Manufacturing tooling
➢Labour costs for manufacturing overheads
➢Costs calculated for production in Germany
➢Reliable costing, with 100k production rate validated by supply chain partners

- *Overall cost includes:*

➢*Overhead and engineering cost according to VDMA study at 30 to 70 % of manufacturing cost plus margin (changing over the volume)*

Manufacturing aspects*

- Material
- Part form complexity
- Manufacturing process rate
- Design and manufacture for assembly
- Recycling

Technology change*

- Lithium iron phosphate
  - ➢Lead equivalent
  - ➢Operating temperature
  - ➢Risk evaluation
- Battery management system
  - ➢Dimensions
  - ➢Positioning in the upper area of the battery due to heat dissipation

** Examples shown. We do have a 11 pages strong document defining the project scope and the basic specification of the starter battery.*

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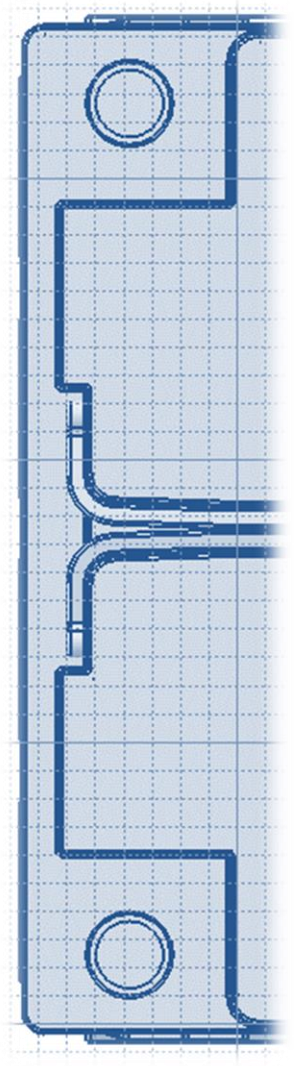


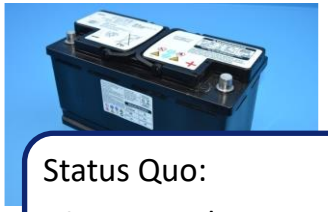
Scope of our demonstrator project is to substitute Pb by LiFePO4 and optimise the battery case in order to reduce weight and cost for an economical adaption.

[BMW15a]

Reference:

BMW X5 40e

- Simulate a consulting project
- Set requirements for our concept
- Enable flexibility



[A2MAC1]

Status Quo:

12V starter battery system

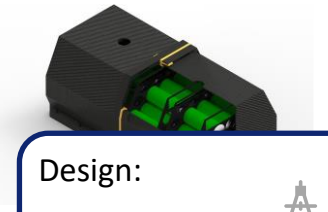
- Analyse lightweight potentials of existing, conventional lead batteries

[A123]

Technology:

Li-Ion Battery

- Disrupt current configuration by replacing dual Pb battery setup
- Using a single, modular LiFePO4 battery



Design:

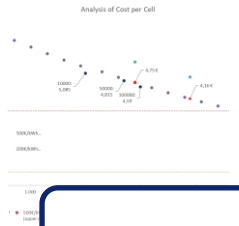
Battery case

- Consider optimal structure
- Simplify assembly
- Consider optimal material

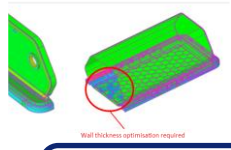
Gather requirements and barriers

Generate light weight opportunities & design concepts

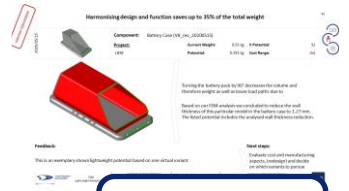
Generate sketches and draft models based on concepts



Cost model and review concept solutions

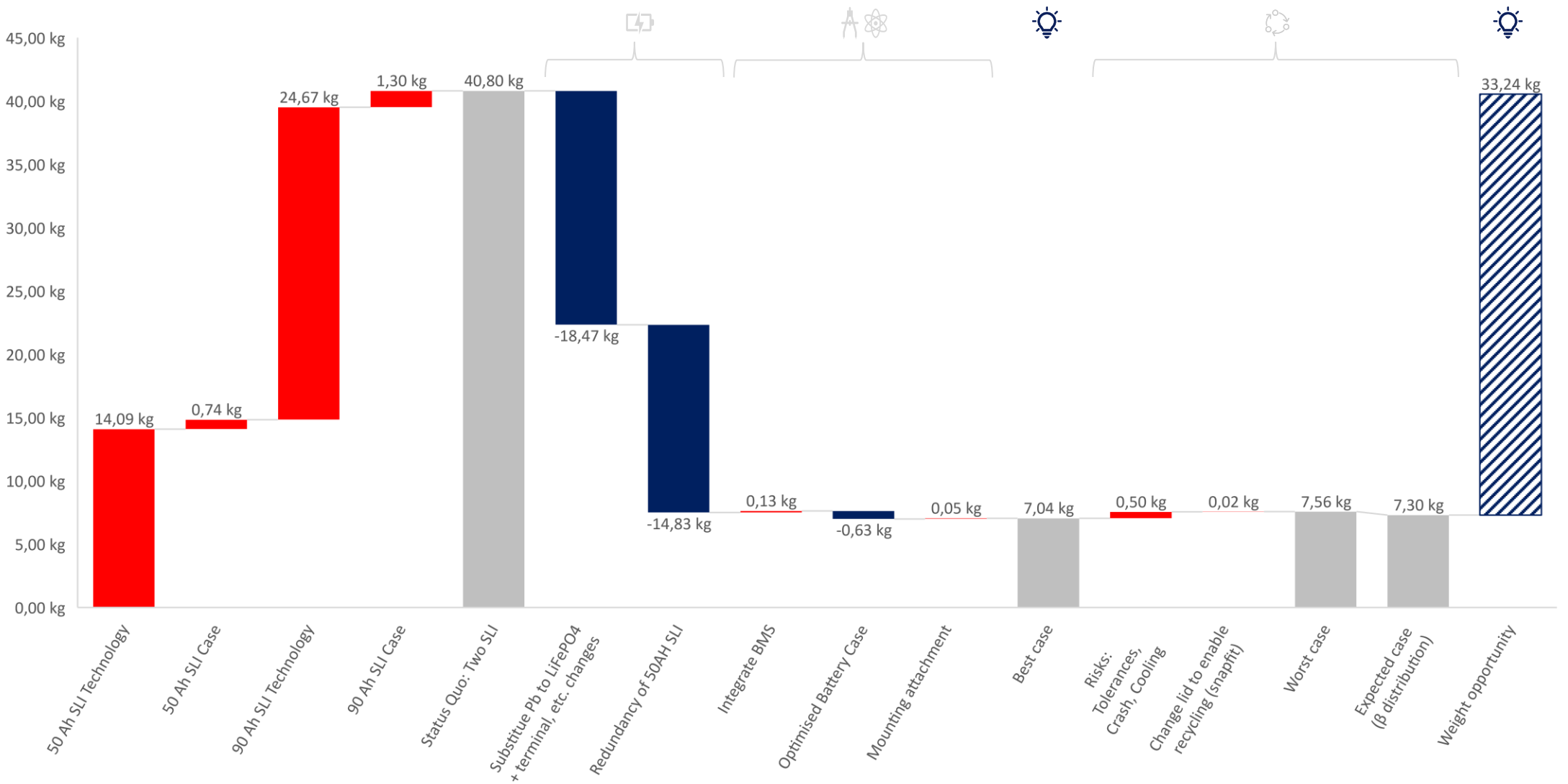


Optimise design for cost and manufacture



Create one-pagers for lightweight potentials

A technology change to LiFePo4 in an optimized case offers a lightweight potential of 33 kg.



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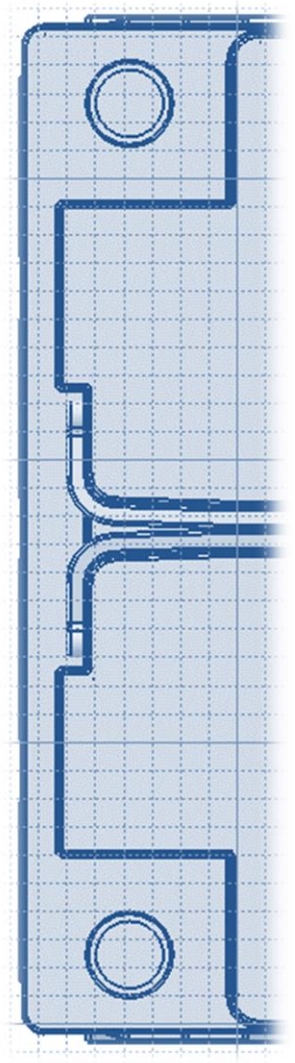
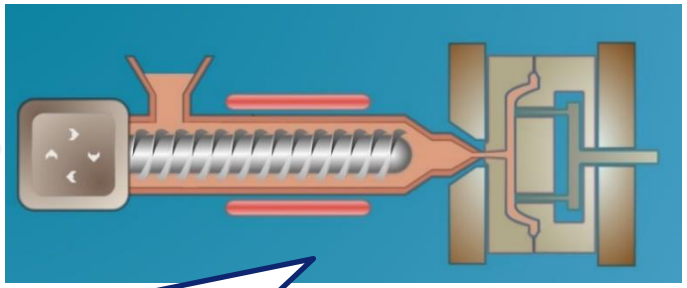


Injection moulding offers suitable capablities to produce the designed shape at relative low cost while enabling serial production runs.

Method of Manufacture Down-selection Process

Method of Manufacture	Optimal methods of manufacture were identified by considering the following:	Suitable methods of manufacture identified
Fused Depositon Modelling Stereolithography Injection Moulding Compression Moulding Injection Blow Moulding Machining Thermoforming Vacuum Forming Transfer Moulding Extrusion Structural Foam Injection Moulding Plastic deep drawing	Is this process suitable for volumes in excess of 100,000 parts?	**Optimal**: Injection Moulding (conventional)
	Can this process create the currently proposed geometry (with only final dressing / machining required)?	**Viable**: Injection Moulding (Gas)
	Does this process result in low material scrappage? (i.e. minimal excess material removal required; no viable reprocessing opportunities)	**Viable**: Injection Moulding (Foam)
	Can the process create the desired geometry without additional methods of manufacture processes?	**Opportunity**: Extrusion *(Applied to selected case design scenarios)*



(BPF 2020)

Conventional injection moulding:

Material is fed from a hopper into a reciprocal screw. The screw is heated, causing the material to melt. This material is then forced via sprues and gates into a mould cavity, where it sets and forms the part geometry.

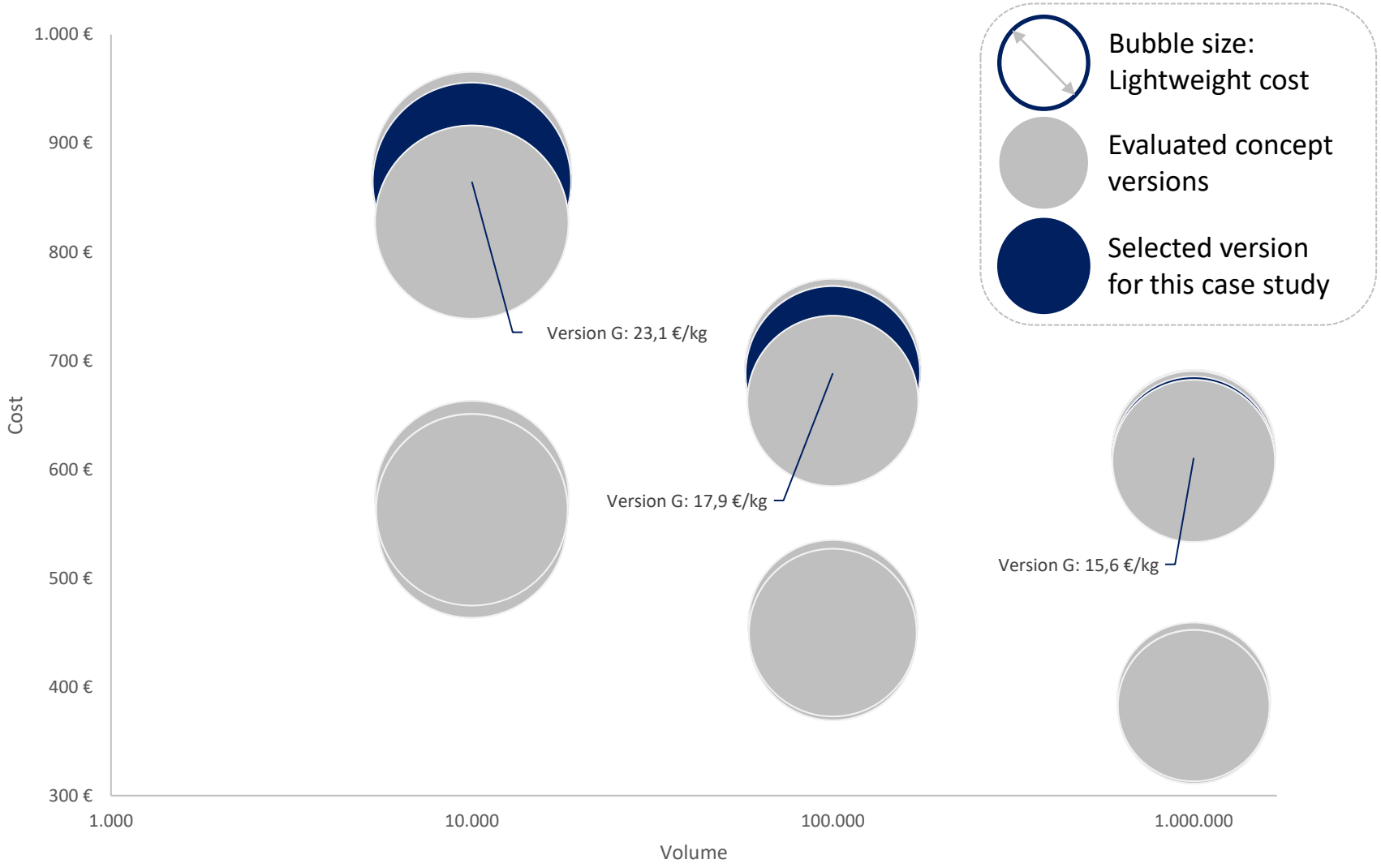
Mainly driven by electrical components and the complexity of the tool with the necessary assembly processes the expected cost are estimated.

Cost model for all eight variants is split in two parts

Precise cost calculation includes cost for:

1. **Material**
2. **Tooling**
3. **Assembly**
4. **Cells & cell management**
5. **Other manufacturing related costs**

Estimated surcharges (based on VDMA statistics) for engineering, overhead and margin



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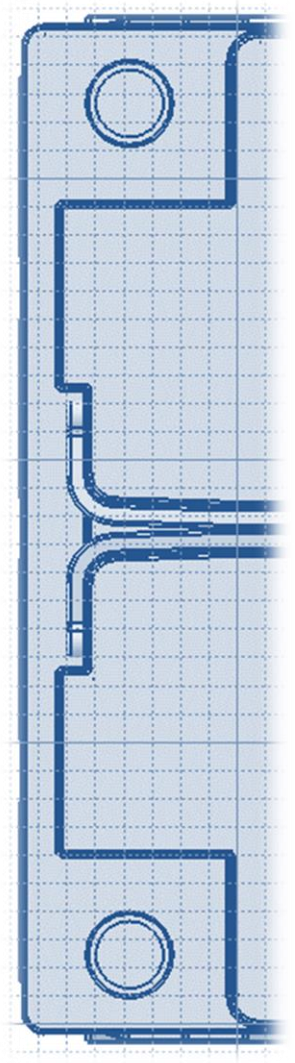


Our first concept evaluation offers approximately a 33 kg weight saving at 18 €/kg as well as 10 L less packaging, tripling the operational life expectancy.

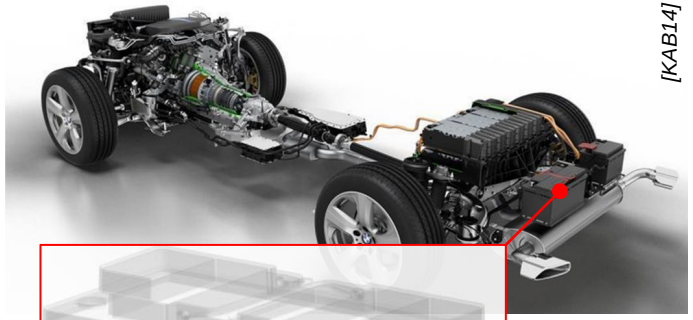
Component: 90 Ah + 60 Ah Starter Battery BMW F15 **# Potential:** 1 **Status:**

Weight savings [kg]

0 33

Cost change [€]

0 200 400 600 800 1000



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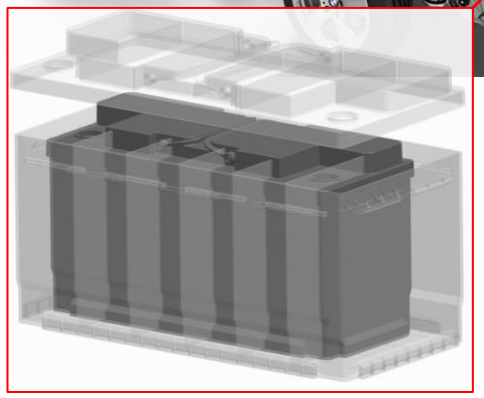
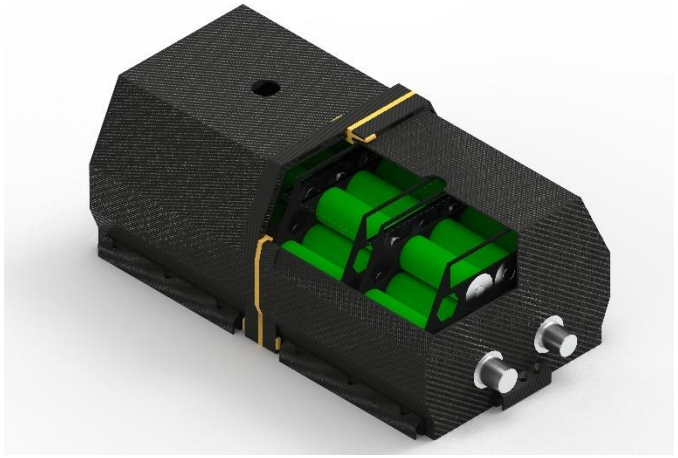


- Consolidate both batteries into one
- Substitute Pb with LiFePO4
- Use cylindrical cells instead of pouch cells to increase discharging currents
- Minimise envelope space to place the battery at a different position or use space to optimise functionality (e.g. crash resistance)
- Minimise lever arms and increase the case´s moment of inertia to reduce wall thickness
- Optimise for manufacturing issues
- Integrate into vehicle to utilise better crash capabilities due to design



Notes:

Our modular design enables to supply BEV and sport cars as well as 48V applications with appropriate capacity. Final validation of electrical and mechanical properties as well as cost depends on OEM requirements and desired functionality. Other solutions possible.

Current 12 V design: One module is sufficient for the Tesla Model X and two modules for the F15 Hybrid or V12 Lamborghini Aventador. Shown version G has snap fits to enable easy recycling (such as cell repair & replacement). Carbon look film for aesthetic purposes only.

Contact:

Hans-Peter Dahm
(TGM)

Our next steps would be based on the customers needs.

Review
- Check assumptions with the company's constraints / requirements
- Check weight books to understand the specific circumstances of the vehicle

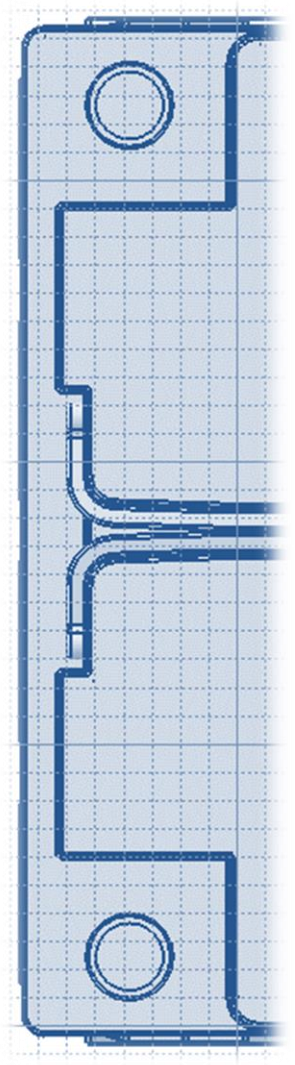
Follow-up
- Incorporate identified mass optimisation opportunities from the mass properties management process
- Functional and structural analysis of the battery in it´s design space
- Determine the optimal position within the vehicle

Analysis
- Evaluate potential functional integration of solution into surroundings (e.g. mating features, location envelope)
- Evaluate opportunities to combine functions and geometry to optimise geometry and mass
- Evaluate secondary effects (e.g. lighter holder, shorter wires, …)
- Conclude topology and topography optimisation

Development & Prototyping
- Optimise the battery management system and its software
- Optimise and mature the battery concept (e.g assembly process, sealing)
- Integrate further cost aspects (e.g. engineering, logistics, …) and challenge cost for global production
- Simulate, test and validate the battery as well as its production with our partners

(Serial) Production
- Identify needed partners and qualify supply chain
- Kick-start battery implementation

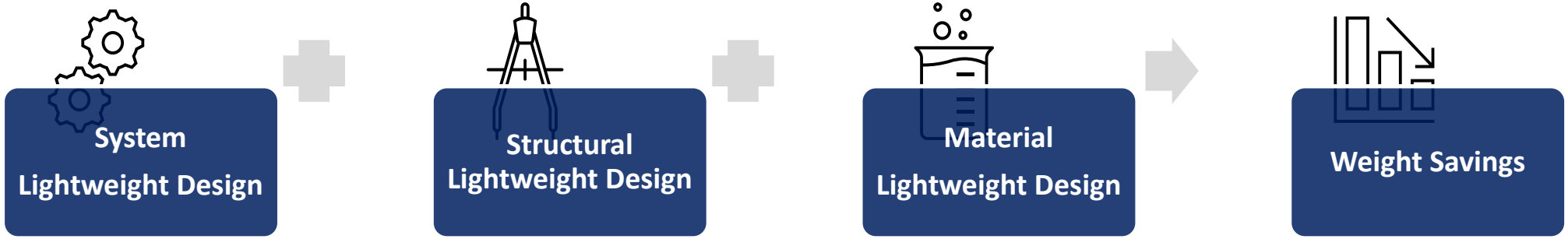
Detailed information on project partners & network



Our portfolio is split in five pillars which support our approach to reduce the weight of industrial products.

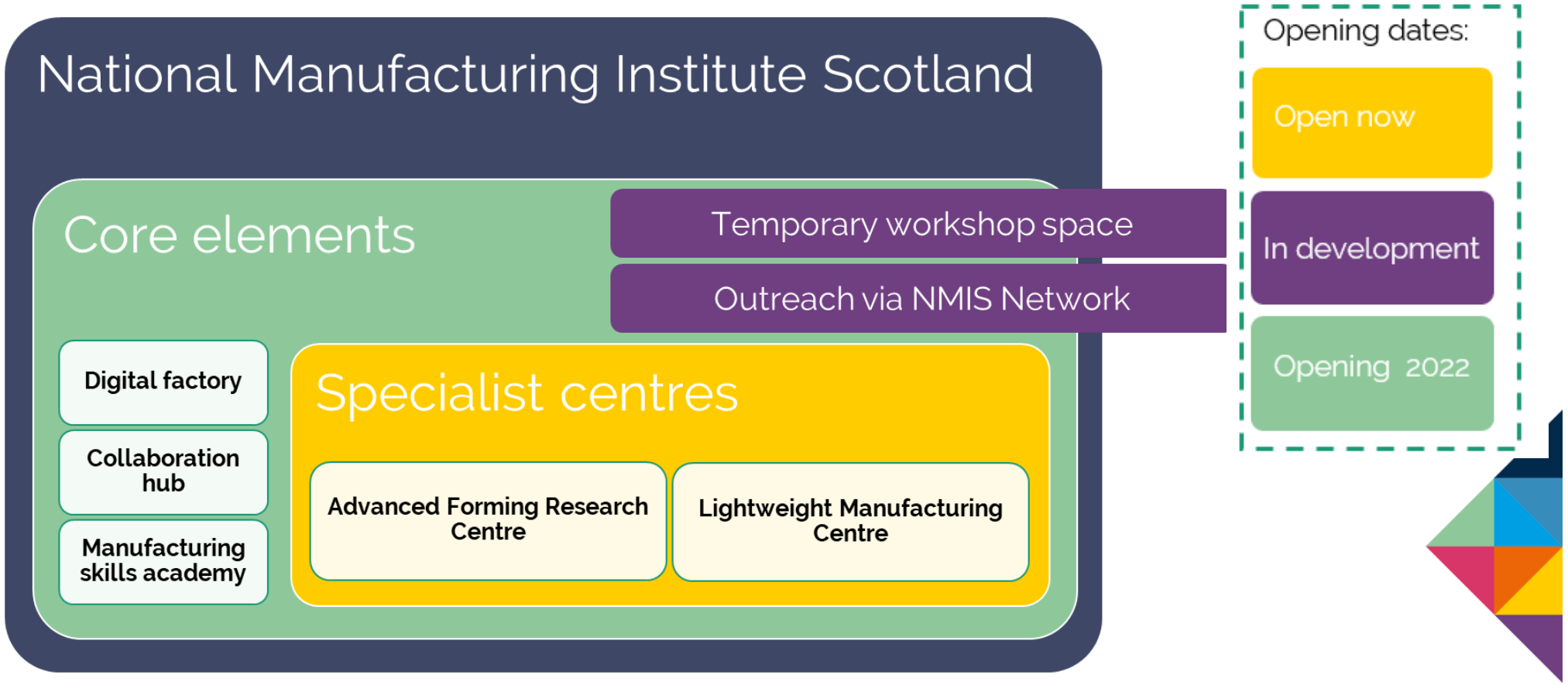
Consulting & Controlling	Optimisation of Systems & Structure	Concepts & Innovation	Software & Tools	Academy

• Methodological analysis, prediction and steering of mass properties
• Development & analysis of primary and secondary weight saving opportunities
• Definition of modules´ weight targets for mass properties
• Development of weight management processes
• Innovation workshops
• Estimation of light weight costs
	• Methodological optimisation of systems and structures
	• Evaluation of structures with FEA (incl. optimisation of topology and topography)
	• Analysis of life cycles, crash as well as simulation of elastomers and vault structures
	• Mass evaluation of weight saving opportunities & risks
		• Design of concept for light weight solutions
		• Patents (examples)
		  • Modular system for a lightweight equipment container (Patent # 10 2018 006 186)
		  • Modular battery system (Patent # 10 2020 007 150.3)
		  • Heat exchanger based on thermally conductive plastics (patent in filing)
			• Smart Act
			• WeightDataTool
			• Knowledge Base
				• Trainings on light weight topics for customers
				• Trainings for TGM software
				• Light weight conferences



The NMIS Group

A combination of core NMIS capability, specialist technology centres and an active network of partners in the manufacturing community.



Advanced Forming Research Centre

A globally-recognised centre of excellence in innovative manufacturing technologies, engineering research and development, and metal forming and forging research

Offering world-class expertise and cutting-edge technologies that help companies develop solutions that bring about real business benefits for companies of all sizes from across the UK and internationally

The only High Value Manufacturing Catapult centre in Scotland: more than 600 industrial projects delivered.

NMIS
National Manufacturing Institute Scotland

Lightweight Manufacturing Centre

Open now

The Lightweight Manufacturing Centre focuses on working with and developing novel lightweight solutions to help manufacturing businesses face and overcome the challenges of the modern-day world.

Through working with the Lightweight Manufacturing Centre companies can access world-class expertise and technologies. The team is highly-experienced in a breadth of processes and materials and recognises that flexibility is key.

NMIS
National Manufacturing Institute Scotland

LITE BLOX

high performance lightweight batteries

LIGHTWEIGHT DESIGN FROM GERMANY

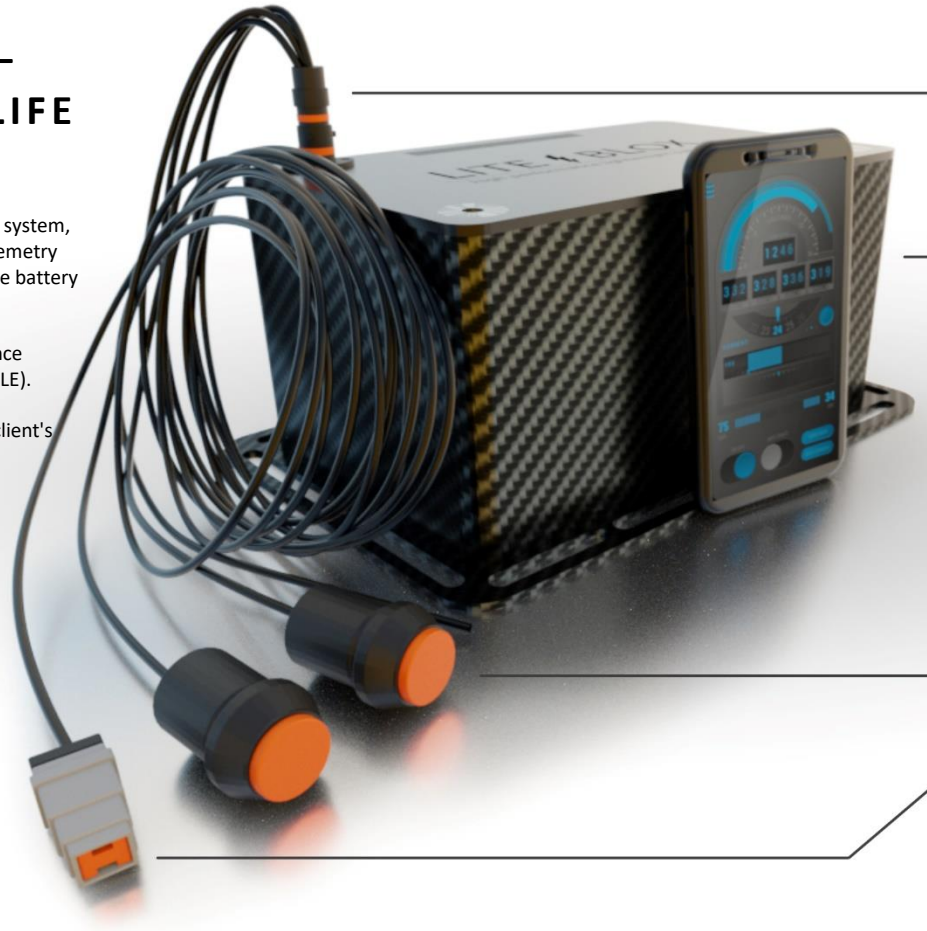
LITEWERKS is a young and highly motivated company, specialized in holistic lightweight engineering since 2011.
Based on our house brand LITE BLOX batteries, we are busy working on sophisticated projects for our ambitious customers in professional motorsports, OEM automotive and industry.

SMART ELECTRONICS – FOR ENHANCED CELL LIFE AND SAFETY.

We use our technology leading and fully adjustable BMS system, offering optional CAN/LIN bus integration, enhanced telemetry analysis (SOC / SOH status), plus the ability to operate the battery via an external harness (battery isolator).

Furthermore we provide an app for extended maintenance and remote operation via smartphone over Bluetooth (BLE).

This system can be completely customized to serve our client's requirements.



AUTOSPORT CONNECTOR
Ability to operate the system via an external harness (battery isolator)

ANDROID & IOS
App for extended maintenance and remote operation via smartphone over Bluetooth (BLE)

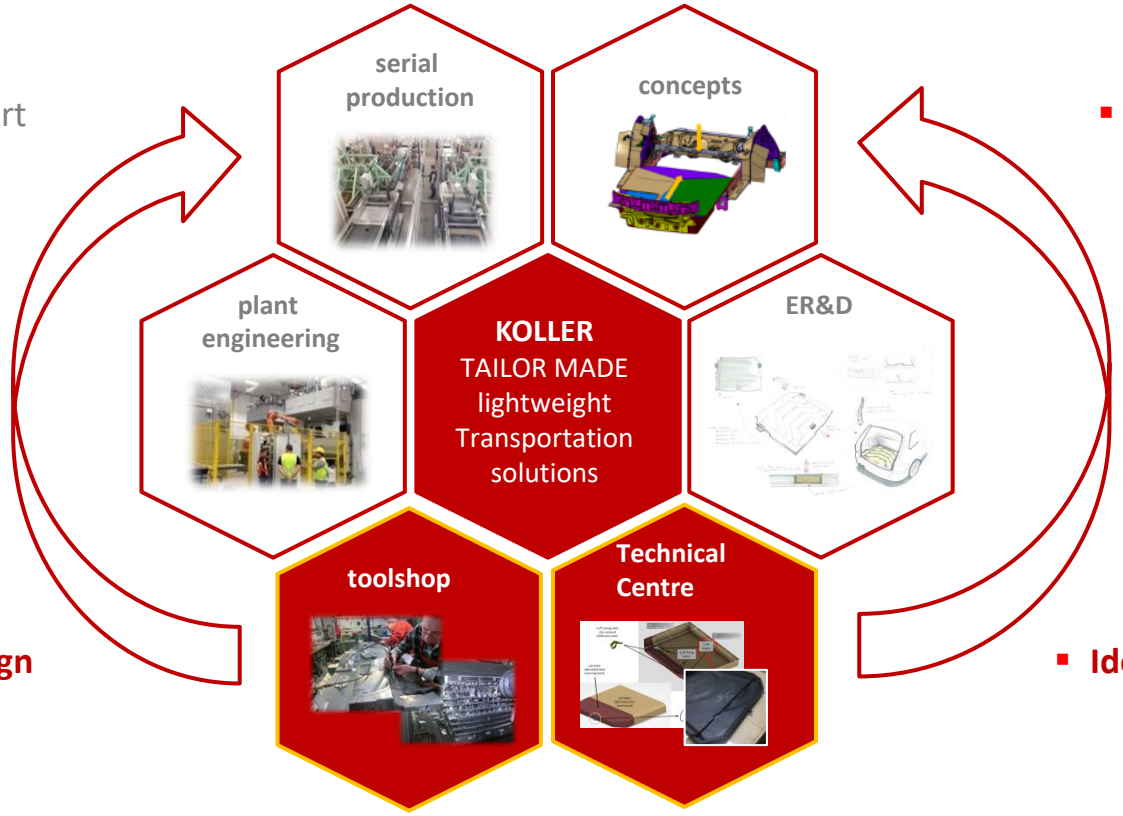
Download iOS APP
Download Android APP
Watch Video

FIA KILL-SWITCH

CAN-BUS
Optional CAN/LIN bus integration and enhanced telemetry analysis (SOC / SOH status)

Koller offers tailor made lightweight solutions …

- lifetime support
- best-in-class cycle times with own developed process-equipement
- **Koller-“smart“ tool design**



- Cooperation-Network for Lightweight Solutions focused in Lightweight Centre
- design to manufacturing and cost-targets
- **Ideas and Prototypes**

… as a full-service-supplier for automotive and transportation industries.

VISION

- Full-service-supplier for tailormade lightweight solutions, modules and systems for automotive and transportation industries.
- Solving problems, finding solutions, technical implementation and industrialization in one hand.
- From Bavarian roots to internationalization.

STRATEGIES

Owner management	→ sustain the company culture and brand equity.
Technology -competence and –development	→ extend core competences.
Inhouse-value-added	→ flexibility and know-how-protection.
Cooperation's	→ complementary services.
Enthusiastic employees	→ multiplicators.
Strong financial partners	→ financing further growth and localizations.

Publication bibliography

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plus weights and performance data from A2MAC1: https://portal.a2mac1.com/benchmarking-database/