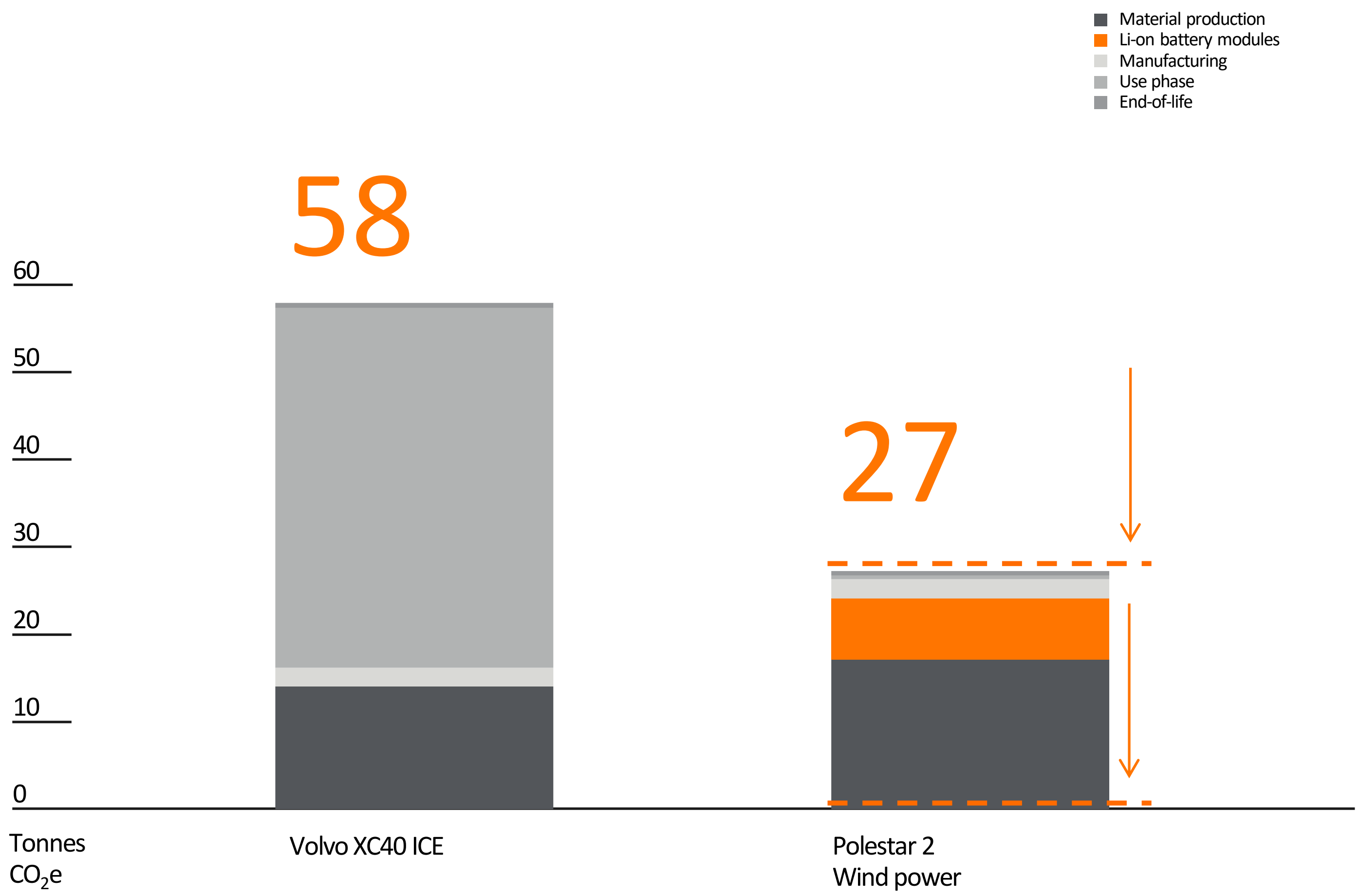

Polestar 0 Project
0 tCO_2e

→ The automotive industry is far off track to stay below the 1.5 degree limit, and will have spent its full CO_2e budget already by 2035.

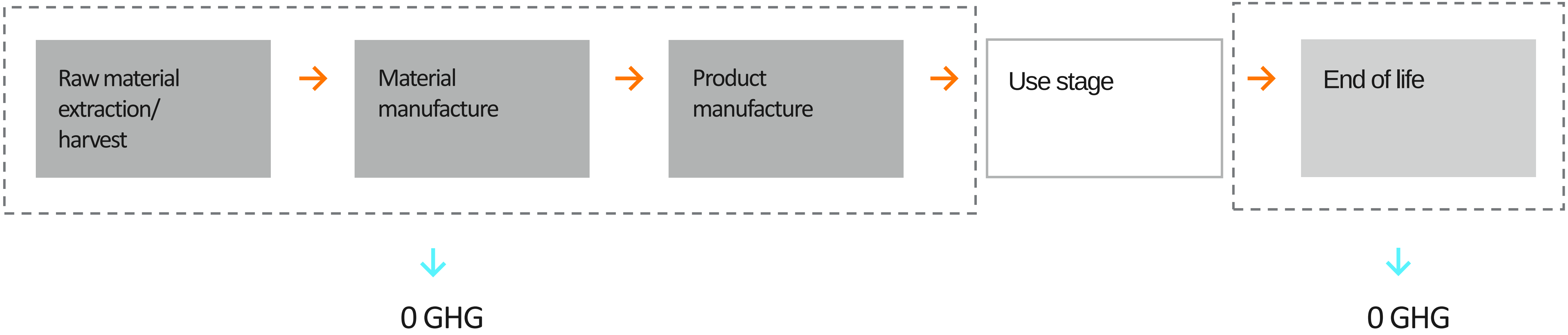
Polestar 0 Project

- Create a truly climate-neutral car by 2030
- Eliminate all GHG emissions, cradle to gate and end-of-life.



Carbon Footprint for Polestar 2 vs. a compact SUV ICE model
Tonnes CO_2-equivalents CO2-equivqlents per functional unit (200.000 km lifetime range).

Cradle to gate including all logistics and end of life (use stage excluded)



Method

Polestar 0 Project

Experimental

Complex

Easy

1 Level 1

Product development

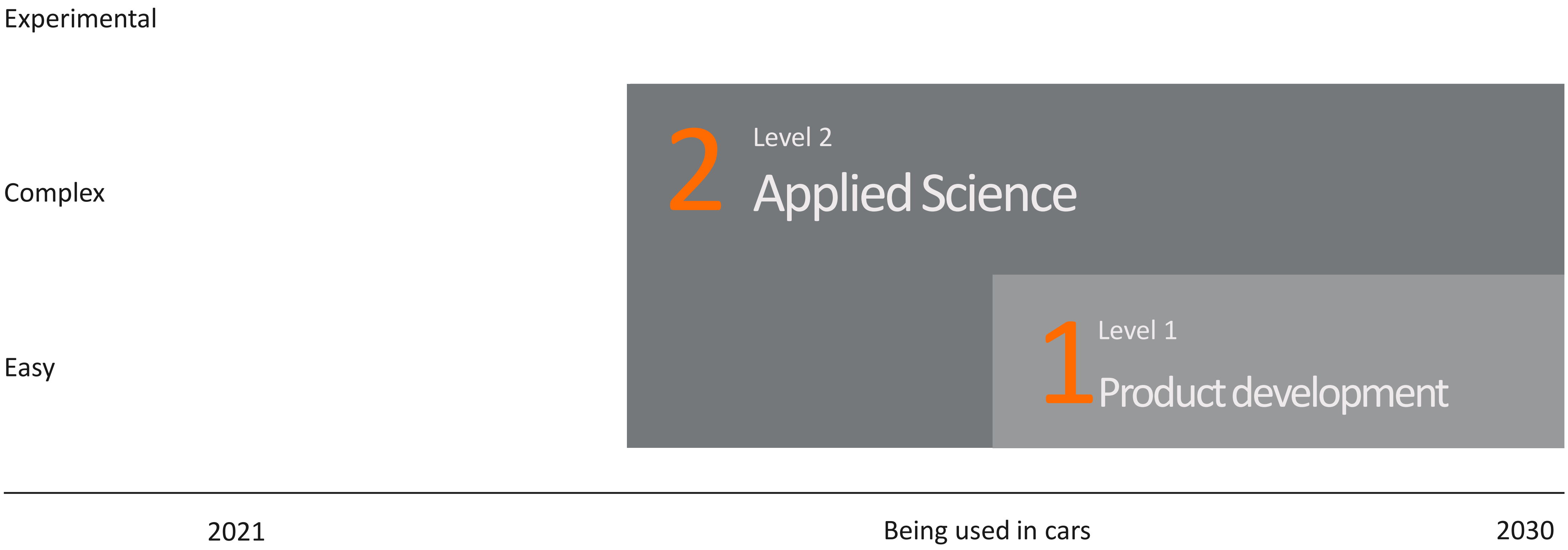
2021

Being used in cars

2030

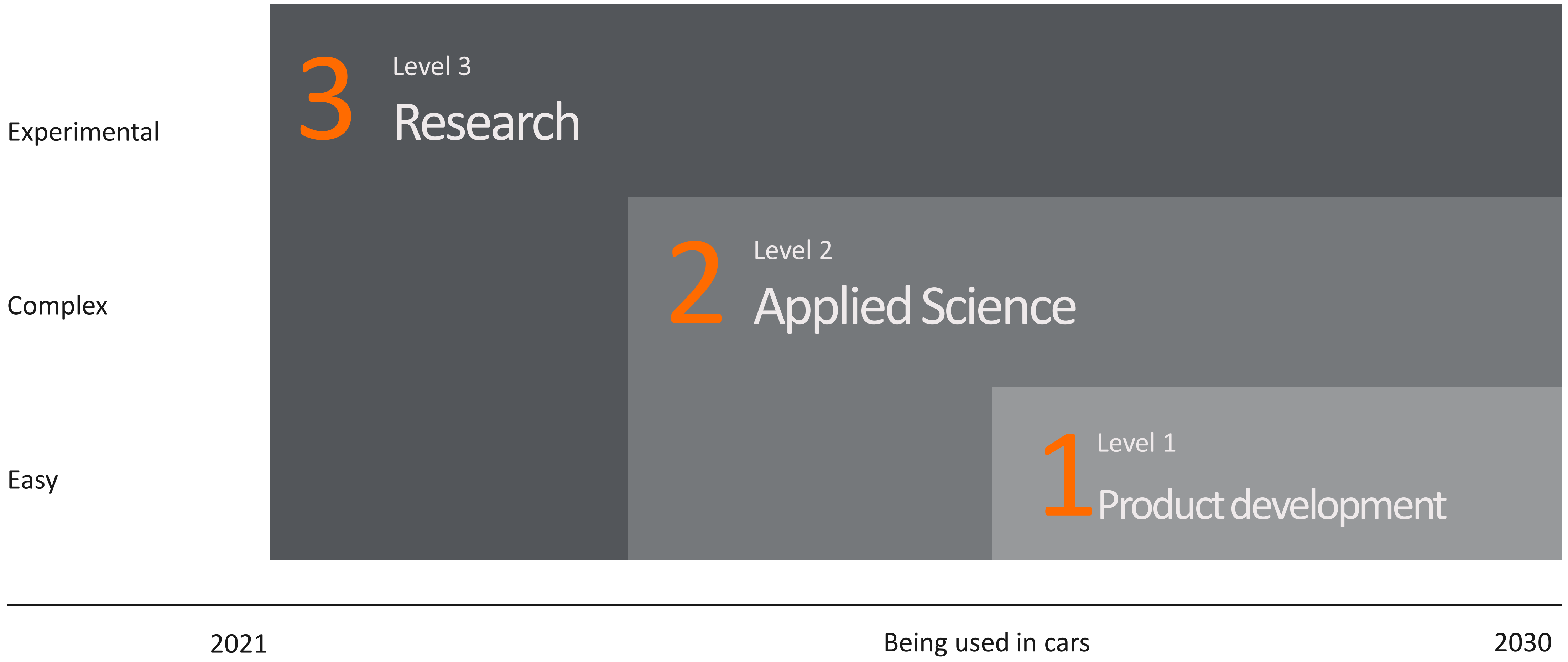
Method

Polestar 0 Project



Method

Polestar 0 Project



Timing

Polestar 0 Project

Research 2021 – 2025

- Build collaborations
- Discover sources for GHG emissions in present supply chain
- Start research on all identified level 3 sources

Applied science 2025 – 2027

- Build and run pilot lines for new materials and processes
- Validate all concepts for material, function and supply chain
- Start vehicle architecture – Global commercial Polestar 0 car

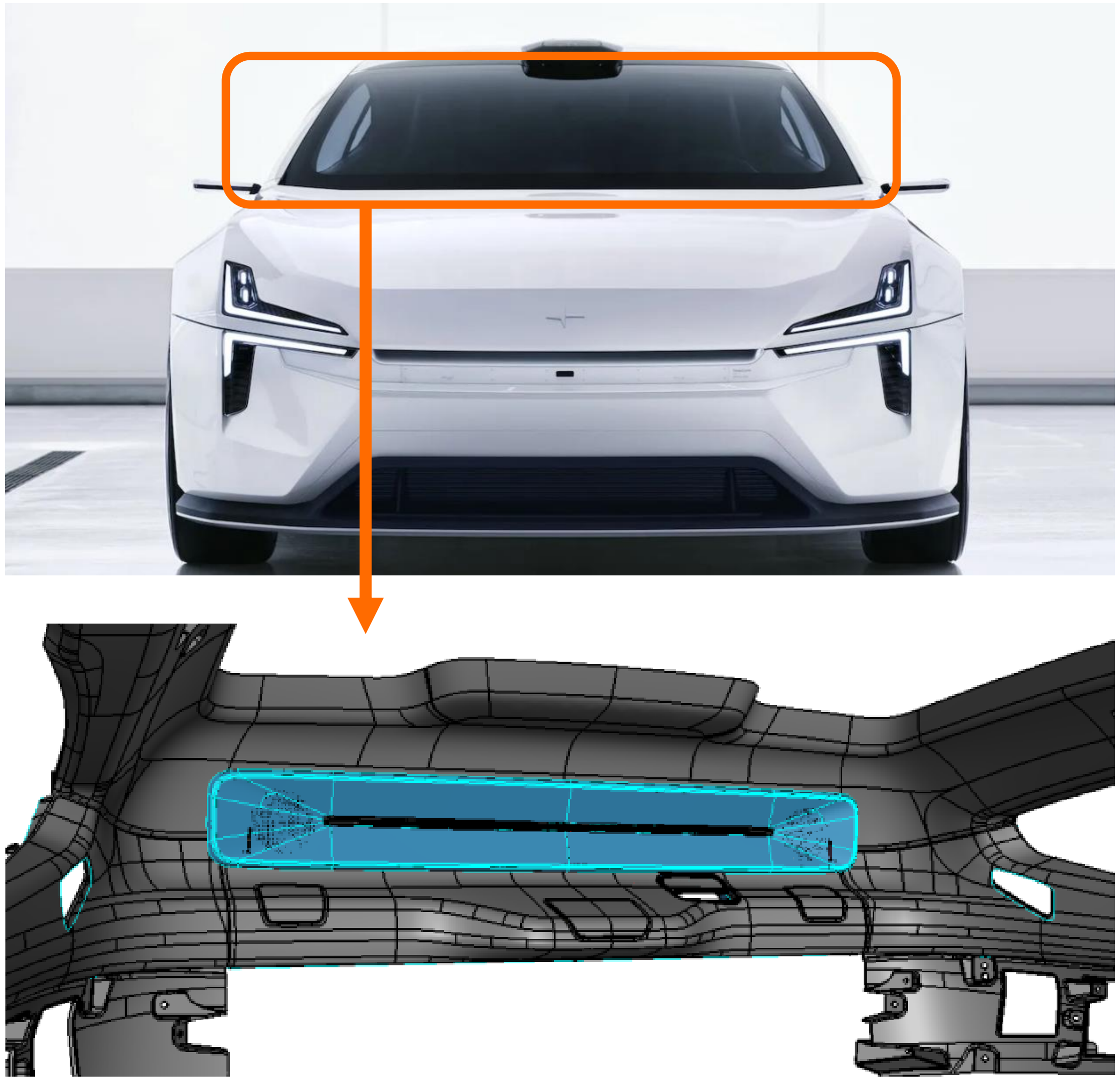
Product development 2027 – 2030

- Build all production sites for material, function and vehicle
- Finalize complete supply chain for high volume production including transport
- Vehicle development – SOP 2030


Polestar

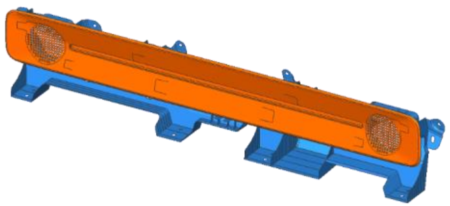
0 Wing Project

- Against this background, the 0 Wing project was initiated to explore the challenges of zero CO2e product development
- An exemplar interior component would be used to provide back-to-back comparison data
- GRM were approached to provide structural analysis which would enable material comparisons in a Life Cycle Assessment context
- GRM deployed their advanced optimisation methods to ensure design efficiency with minimum material usage.
- This approach ensured the best LCA performance would be extracted from each candidate material



0 Wing Analysis Approach

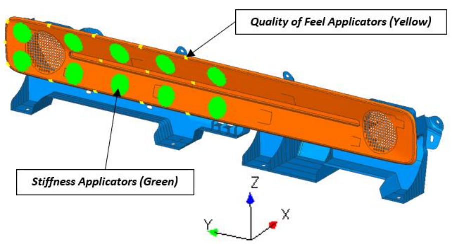
GRM worked with Polestar to deliver multiple 0 Wing designs that utilised the least amount of material across a number of material types. The following work-flow was defined to achieve this:



Baseline Original Design

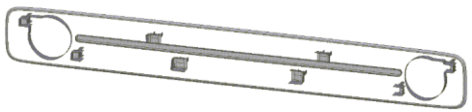
Selection of Materials to Study

Material
Generic Plastic
Steel
Aluminium
Magnesium
Polycarbonate
Bio Polycarbonate
Acrylic
Natural Fibre # 1
Natural Fibre # 2
Natural Fibre # 3



Benchmarking Studies

Optimisation Methods

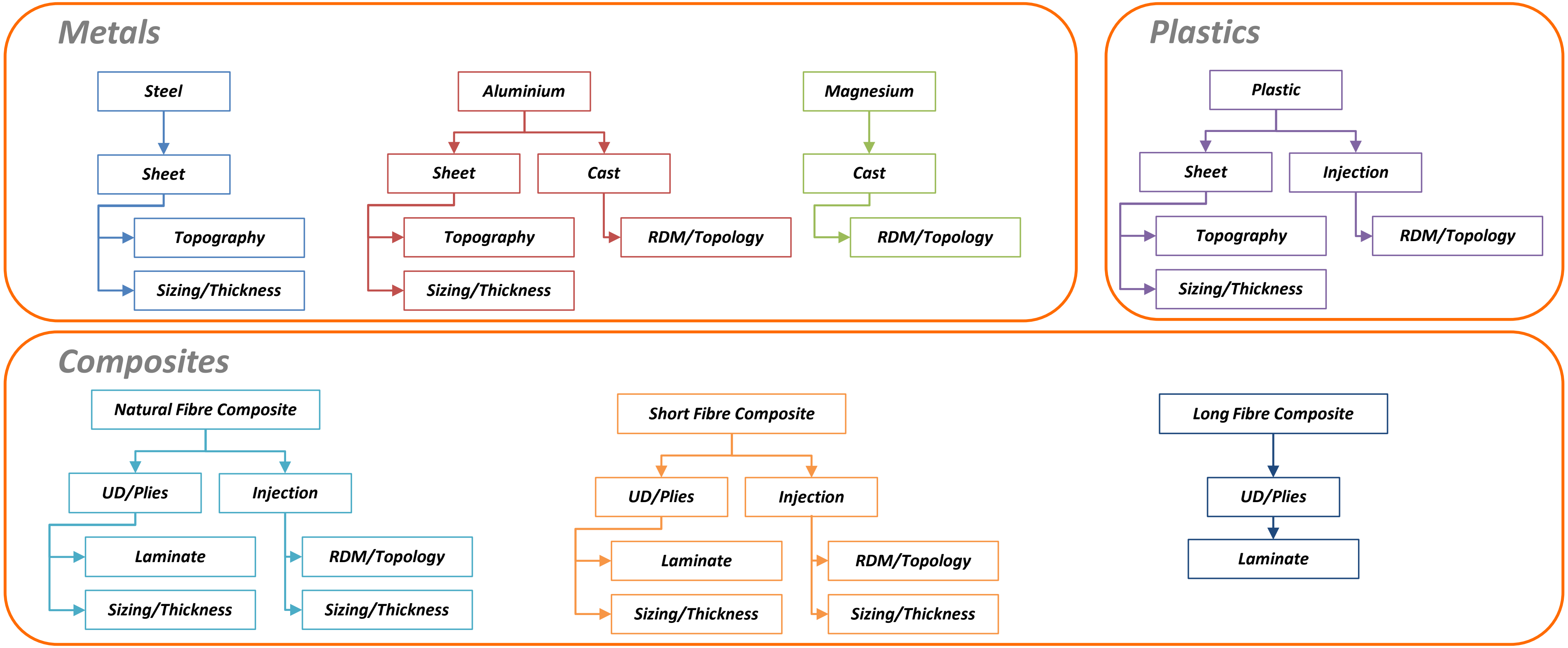


Material
Generic Plastic
Steel
Aluminium
Magnesium
Polycarbonate
Bio Polycarbonate
Acrylic
Natural Fibre # 1
Natural Fibre # 2
Natural Fibre # 3

Material Downselection

0 Wing Material Scoping

- Metals, plastics and composite materials were all explored as potential alternatives for the **0** Wing, each lending themselves to different optimisation techniques across sheet and cast manufacturing processes (*NB: designs can include an assembly of sheet and casted components*).



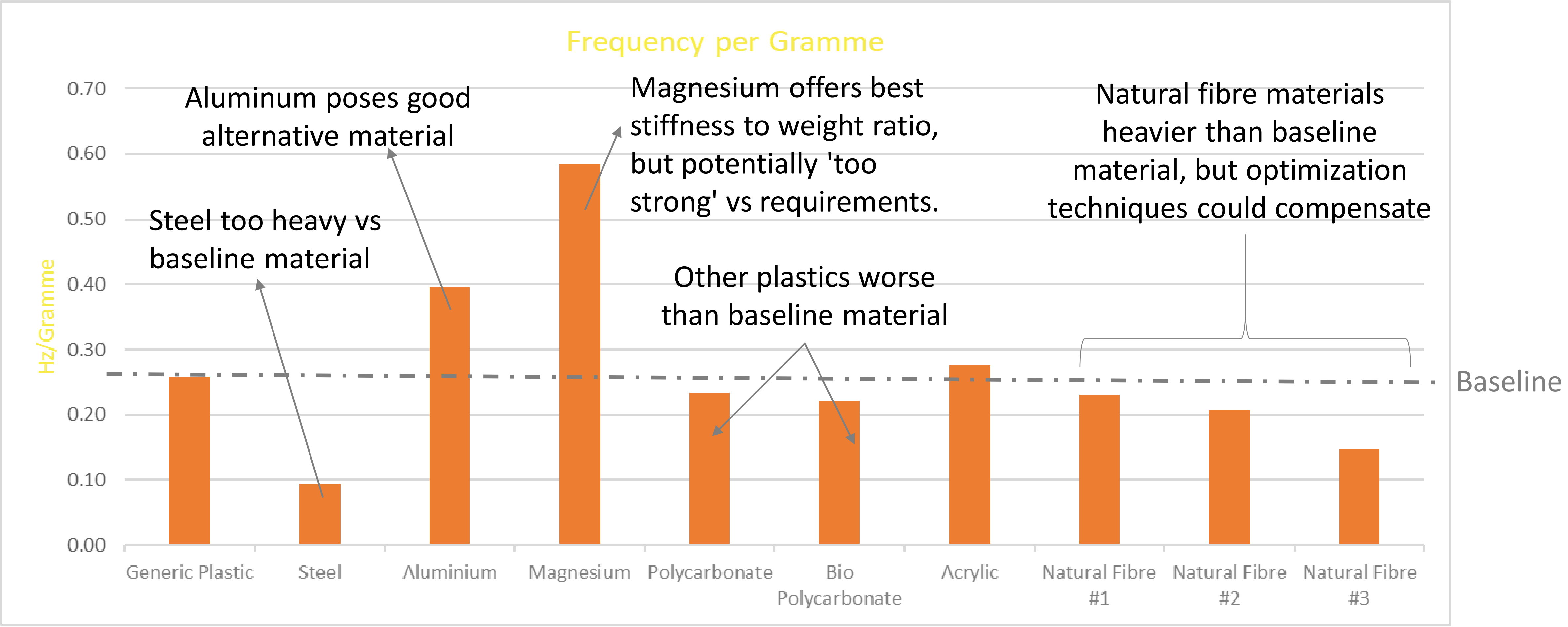
0 Wing Material Selection

- The table below shows the materials selected for each category based upon manufacturing methods, availability and their impact on sustainability:

Material Selected	Comment
Steel	Mild Steel is commonly used in automotive applications and is easy to recycle
Aluminium	Grade selected commonly used and already significantly used in the construction of the Polestar vehicles.
Magnesium	Grade chosen typically used in sheet and casting processes, high performing and fully recyclable.
Generic Plastic	Base material used as a benchmark
Polycarbonate	Polycarbonate forming the basis of a Mono-Material design
Bio Polycarbonate	Bio based alternative to virgin PC material.
Acrylic	Alternative polymer for the Mono-Material design structure
Natural Fibre #1	Bio based resin with embedded short natural fibres. Suitable for injection moulding.
Natural Fibre #2	Press moulded material made from bio-degradable sources. Manufacturing process requires a constant thickness.
Natural Fibre #3	Sustainable material made from flax and hemp. Moulded and fabricated as a typical laminate.

0 Wing Benchmarking Results

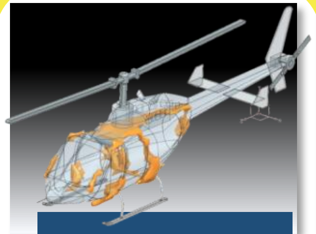
- Benchmarking the result sets on a “frequency vs mass” basis allowed each of the selected materials to be interrogated using a stiffness to weight ratio comparator.



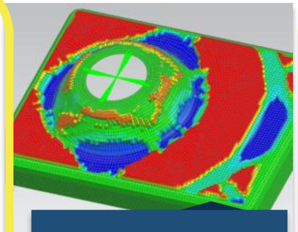
Optimisation Material Selection

The following materials were then selected for the **0** Wing Topology (RDM) and sizing optimisations:

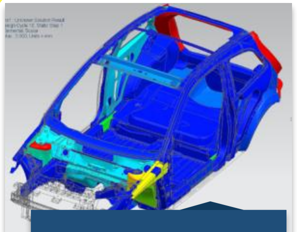
- **Aluminium** – Low mass and recyclable, a skeletal design concept that requires a fabric cover.
- **Acrylic** – Lightest plastic design, mono-material meaning one continuous component and simplified assembly.
- **Natural Fibre #2** – Lightest natural fibre, limited to constant thickness requires additional parts for mounting.



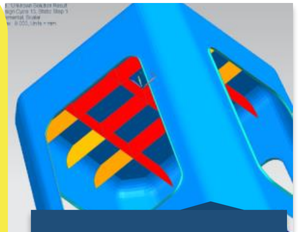
RDM®



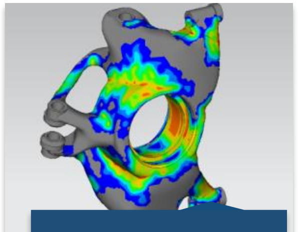
Topography



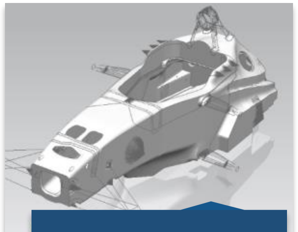
Gauge / Sizing



Topometry



Free-Shape



Composites

RDM®
The Reinforcement Derivation Method (RDM®) provides workflows to leverage Topology to guide engineers in meeting structural targets.

Topography Optimisation
Develop reinforcing patterns in thin shell structures
Suitable to:
Maximise stiffness, frequency
Minimise stress

Thickness Optimisation
Develop optimal thickness of thin shell structural assemblies
Suitable to:
Maximise stiffness or frequency.
Minimise stress

Free-Thickness Optimisation
Develop thickness distribution of thin shell structures
Suitable for:
Castings, mouldings and thin shell machined parts

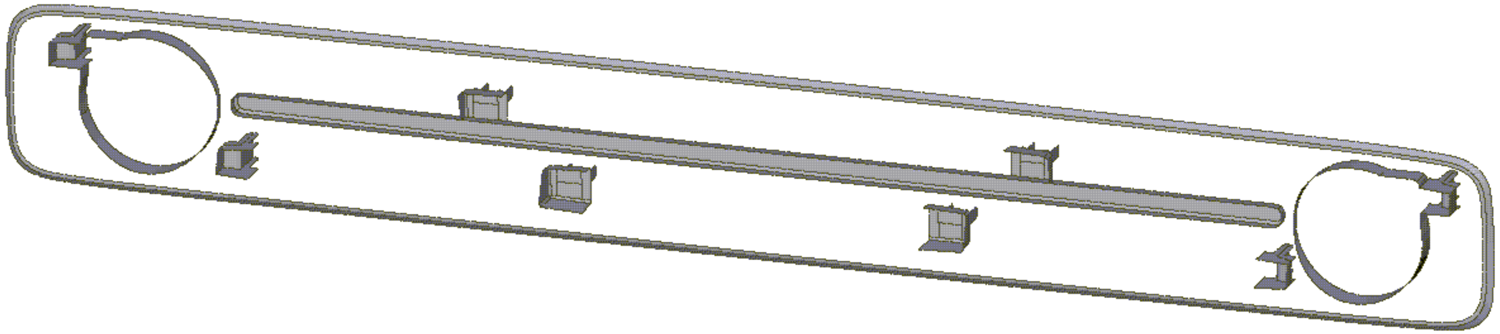
Shape Optimisation
Refinement of design's performance through nodal position changes
Suitable for:
Resolving local stress issues

Laminate Optimisation
Develop optimal ply shapes and laminates
Suitable for:
Meeting stiffness, strength and vibration requirements

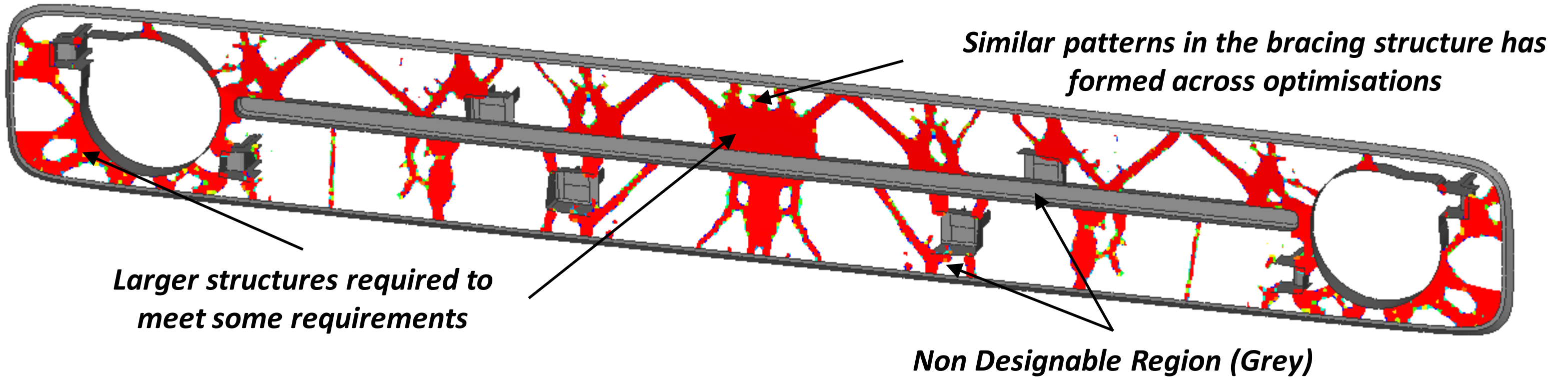
Aluminium – Topology Optimisation

- A 2D topology optimisation of the **0** Wing was conducted by GRM, assuming a 0.8mm thick Aluminium sheet material and achieved an optimized mass of 177 grams (**53% of baseline**).

Topology Optimisation

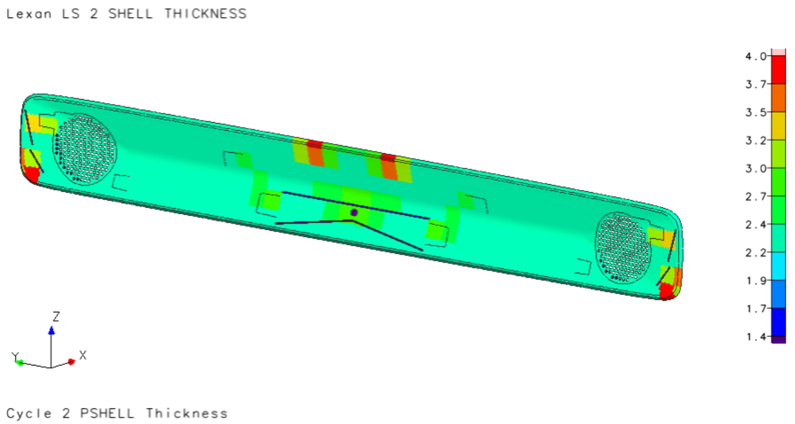


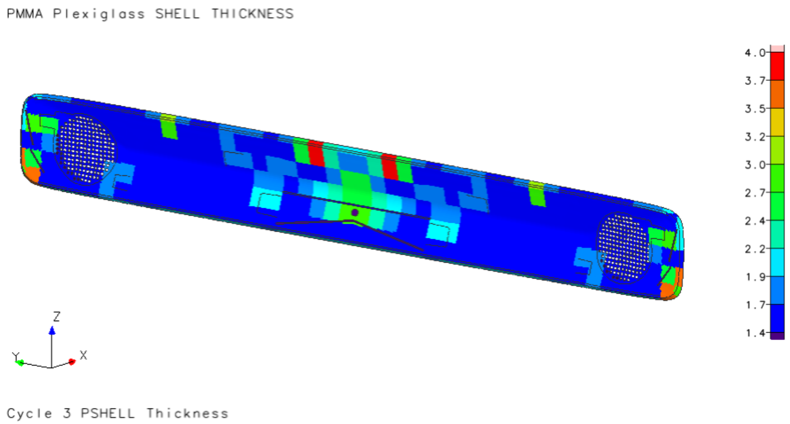
Optimisation Result



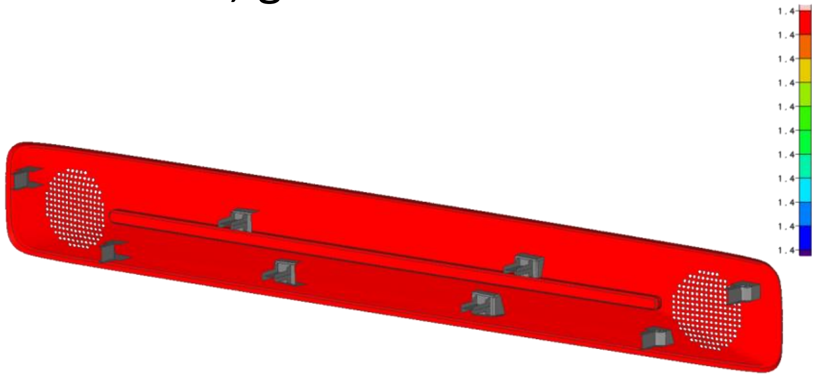
Plastic & Natural Fibre – Sizing Optimisations

- Local thickness optimisations were studied for a number of material options. However, the results showed very local and sharp increases in thickness that posed additional complexities in manufacture.

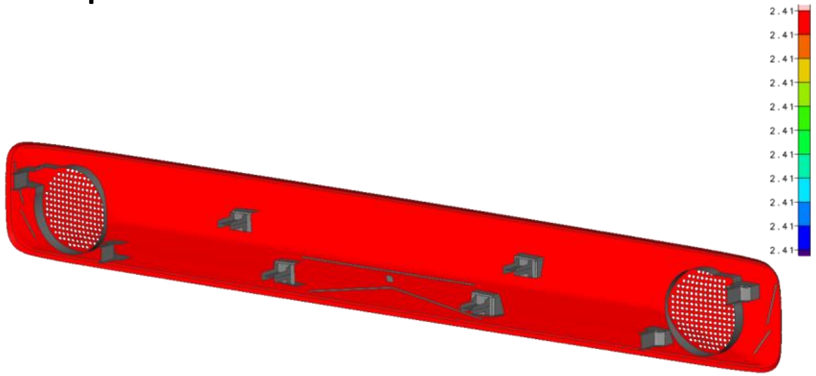




- Therefore, global thickness studies were performed for the plastic and natural fibre materials.



Optimised Natural Fibre #2 Mass = 227 grams

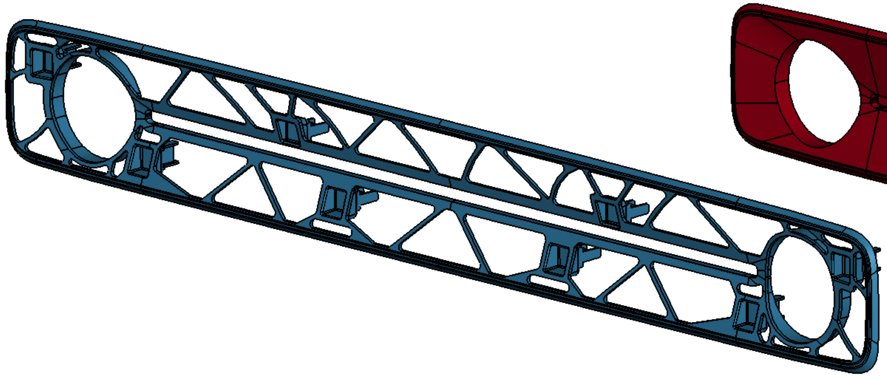


Optimised Acrylic Mass = 317 grams

0 Wing Design Interpretations

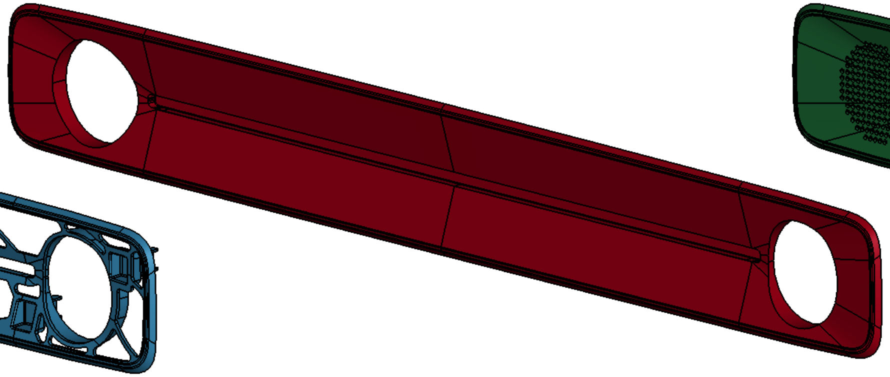
- The three down selected designs were interpreted and CAD geometry was created from the raw optimisation results:

Design 1 – Aluminium



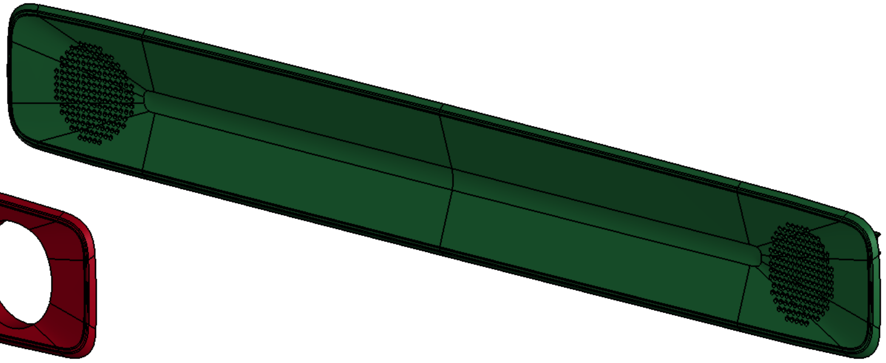
(0.8 mm thick skeletal structure)

Design 2 – Natural Fibre #2



(1.4 mm thickness)

Design 3 – Acrylic

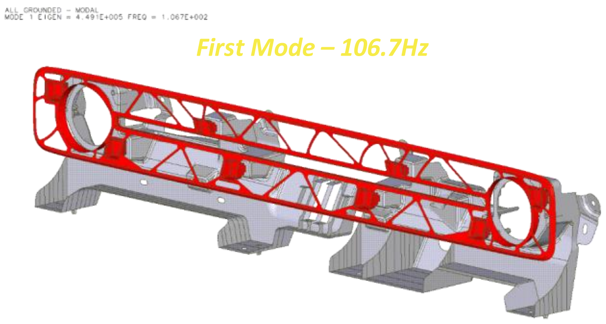


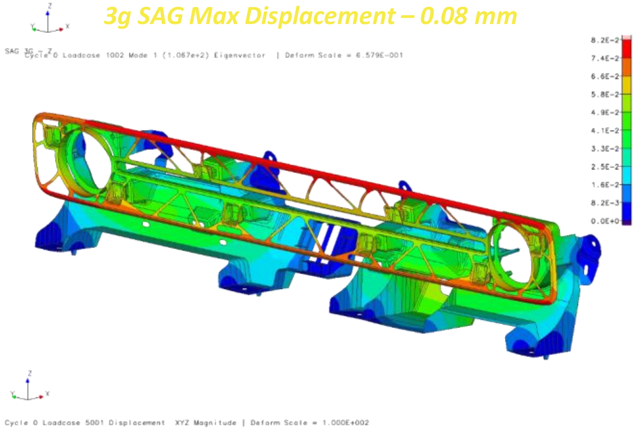
(2.4 mm Thickness Mono-Material)

0 Wing Design Validations

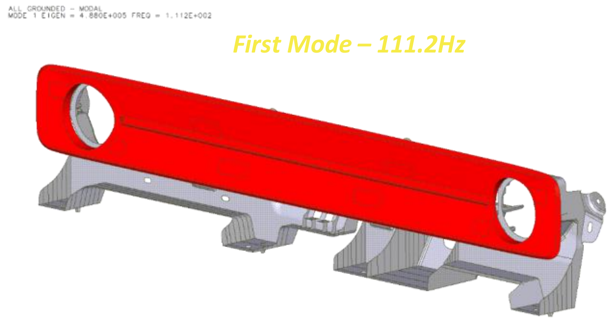
- Each of the three designs were then subjected to firmness feel, static stiffness and modal assessments to determine the best overall material for the 0 Wing design.

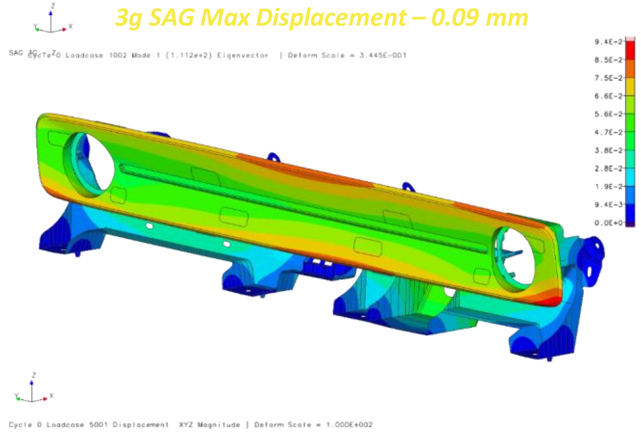
Design 1 – Aluminium



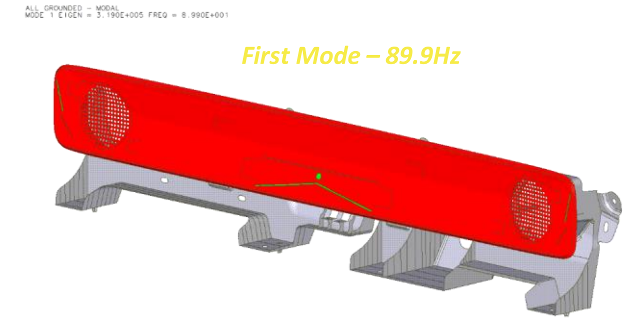


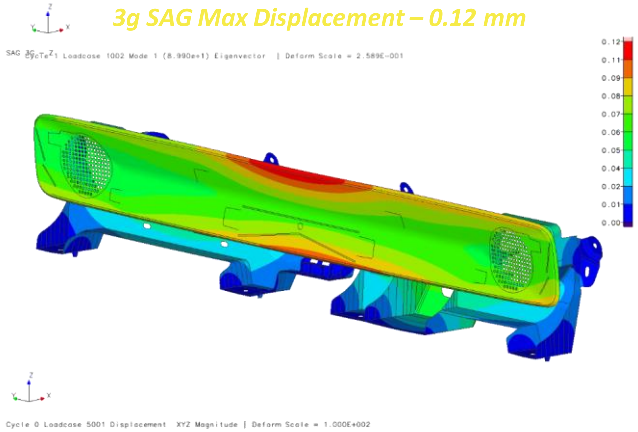
Design 2 – Natural Fibre #2





Design 3 – Acrylic





Performance Summary

Each of the 3 alternative **0** Wing designs that GRM delivered to Polestar for subsequent Life Cycle Analysis featured materials with their own respective merits:

- The Aluminium design has the highest mass, but also significant performance improvements over the baseline. It is also easily recyclable.
- The Acrylic design shows an improvement in both mass and performance over the baseline, as well as offering a mono-material solution.
- The Natural Fibre #2 design is the lightest and showed improved performance over the baseline Generic Plastic material design.

Category	Thickness (mm)	Mass (Grammes)
		Requirement / Target:
Generic Plastic Design	2.50	337
Aluminium Design	2.60	407
Acrylic Design	2.40	317
Natural Fibre #2 Design	1.40	296

0 Wing Outcome

- GRM worked with Polestar to deliver multiple **0** Wing designs that utilise the least amount of material across a number of material types.
- The information provided was utilised in Polestar's own Life Cycle Analysis (LCA) to assess the environmental impact and determine the most sustainable design along side performance and design requirements.
- The learnings achieved from this project provided Polestar additional insight into the process and design considerations in producing sustainable components.

LCA Results

- By using scenario analysis, Polestar were able to interrogate and apply a weighting to different design approaches for future reference
- Predictions were also made based on the likely outcomes of ongoing low CO2e material studies
- GRM's optimisation studies were used to achieve a best predicted CO2e reduction of 72% when compared to the baseline assembly
- This study highlighted the interplay between material, structure and assembly complexity which must all be carefully balanced to achieve the best result

The Future?

- Polestar continue to develop their products through the dual strategies of continuous improvement and the exploration of advanced material research as defined by Polestar 0
- We aim to create our first climate neutral car by 2030
- We aim to become a climate neutral company by 2040