SPEAKER WICTOR DOTTER

COMPANY ZEBEYOND

TOPIC

EMBEDDING SUSTAINABILITY INTO EARLY STAGE R&D

Engineering Beyond Net ZERO

Embedding Sustainability Into Early-Stage R&D

21.06.23

ZeBeyond

Agenda

1. About us & Context industry uncertanty
2. ePOP Optimization Philosophy
3. How it works
4. Use cases
5. How to engage and collaborate

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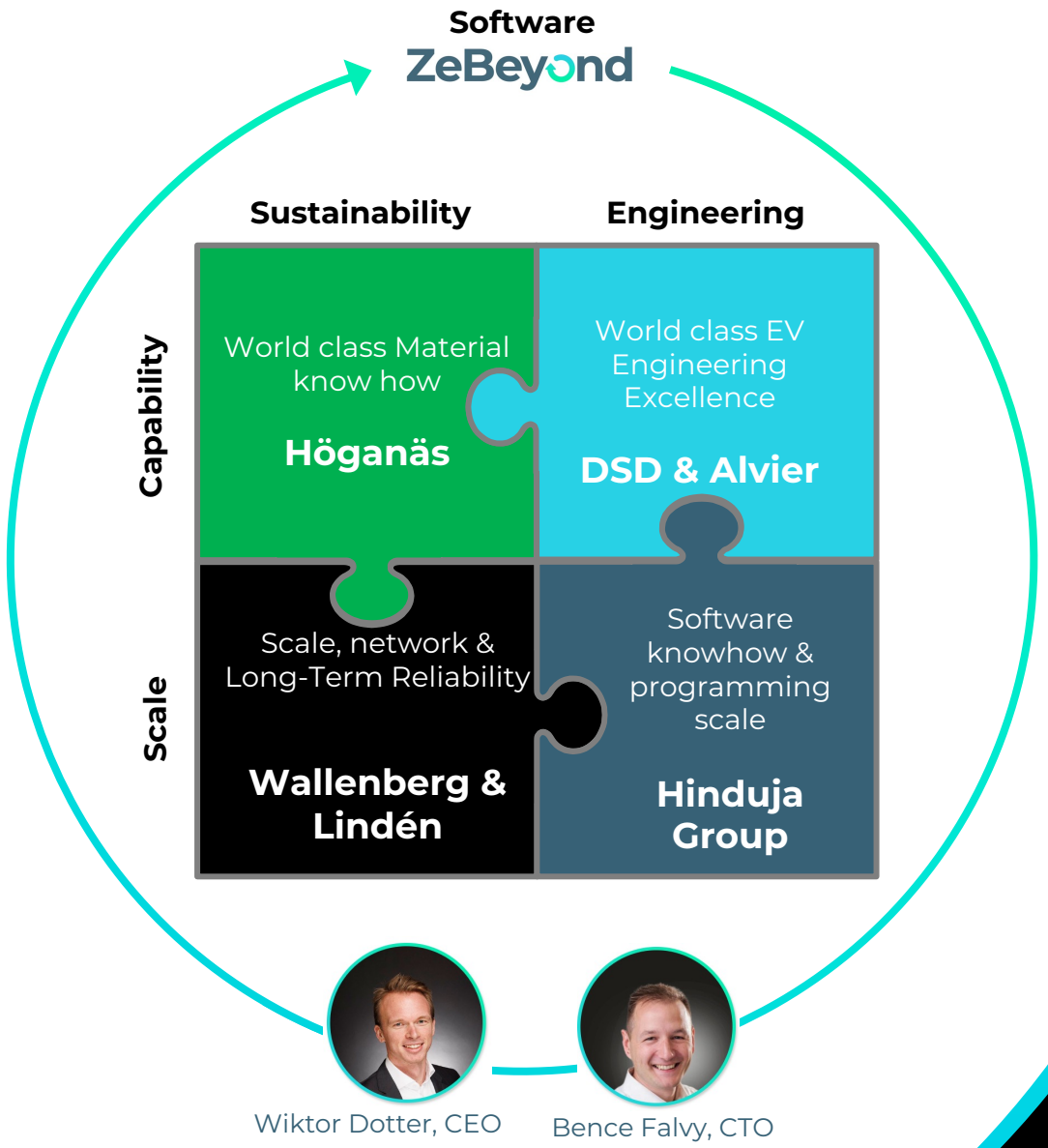
ZeBeyond Value Proposition



About our company

Our owners include:

- Drive System Design
  - Advanced Solutions for Future Powertrains | DSD | Drive System Design
- Alvier Mechatronics
  - Alvier Mechatronics - knowledgedriven high speed
- Höganäs
  - Metal powders | Höganäs (hoganas.com)
- Hindujatech
  - Automotive Engineering | Digital Technology Services (hindujatech.com)
- FAM AB (Wallenberg)
  - FAM AB
- Lindéngruppen
  - Lindéngruppen (lindengruppen.com)

Journey Through Time

Horse

- Performance 👍
- Profitability 👎
- Sustainability 👍

ICE

- Performance 👍
- Profitability 👍
- Sustainability 👎

Next Gen

- Performance ?
- Profitability ?
- Sustainability 👍

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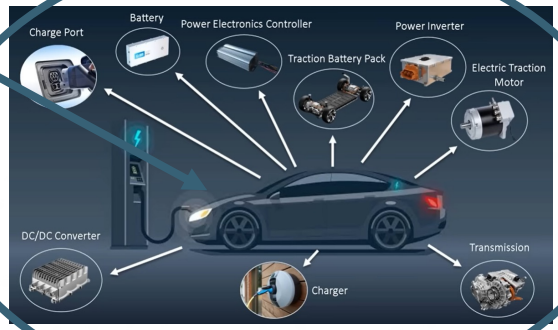
From 2 to 3 Dimensional problems

Current vs Future profitability?
Are we on the right electrification strategy?

Net Zero by 20xx?
Scope 1?
Scope2?
Scope3?

~100 R&D projects
~500 engineers
~5y lead time
CAPEX



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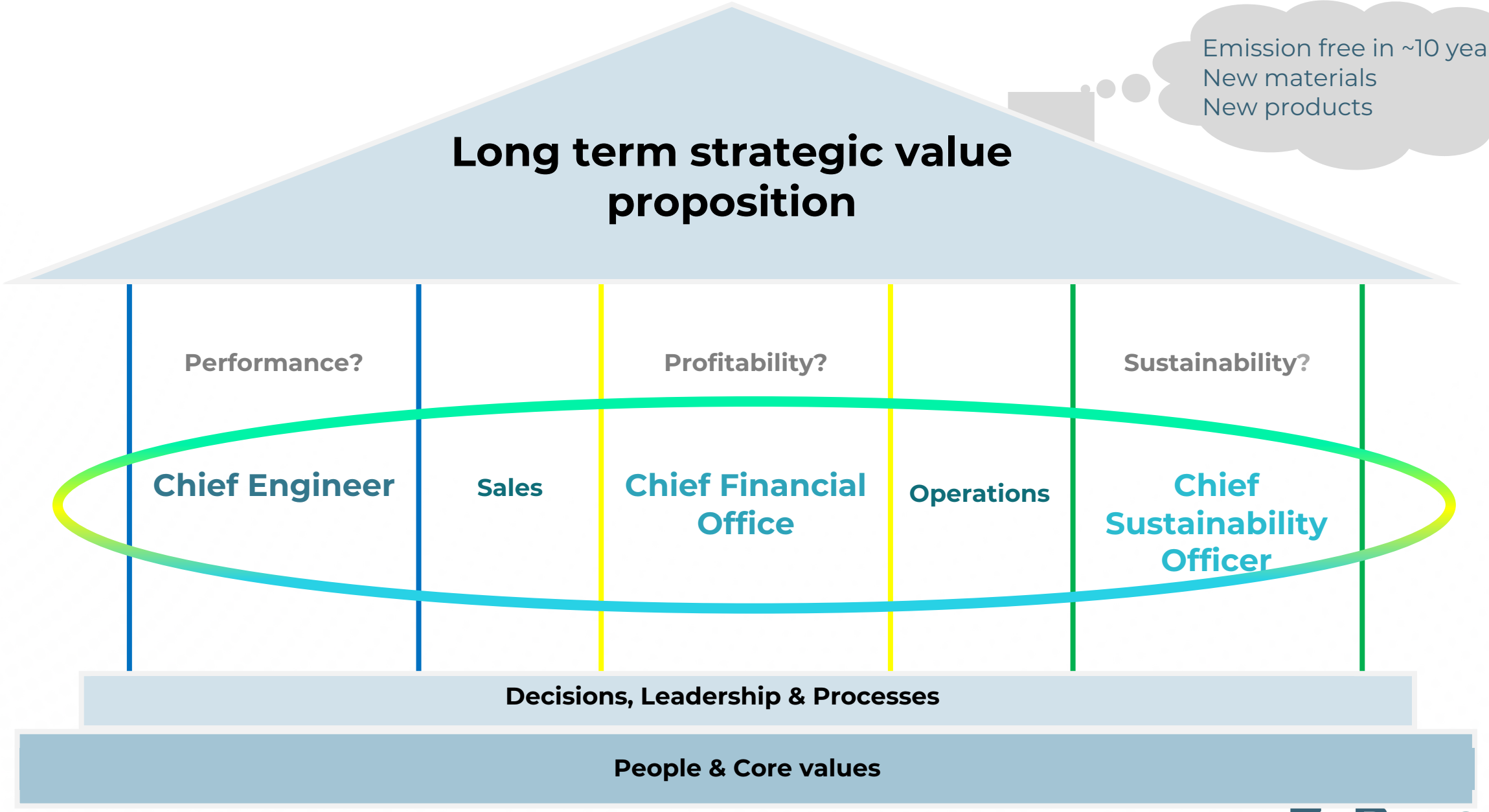
Emission free in ~10 years
New materials
New products

Long term strategic value proposition



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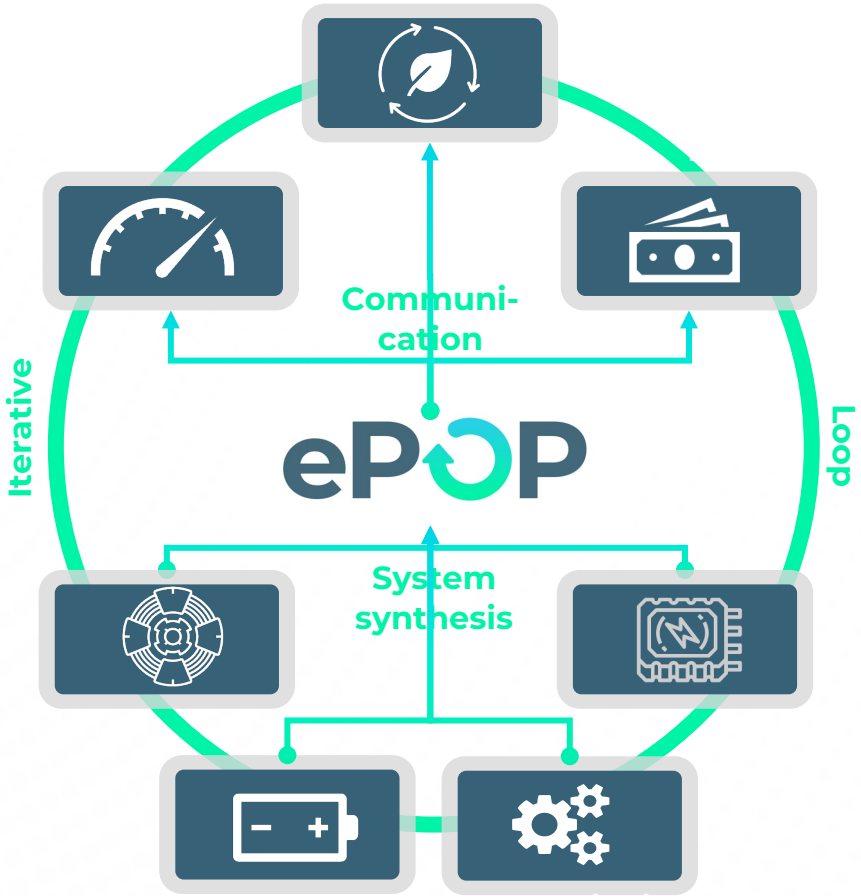
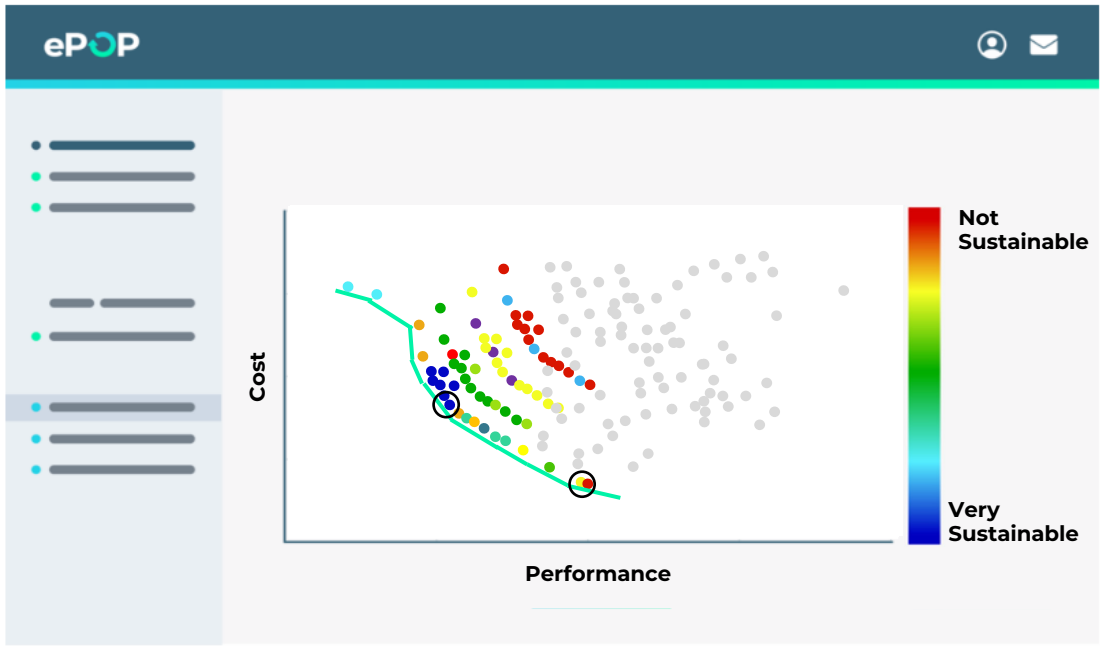
Where to play?

Value Proposition?

How to win?





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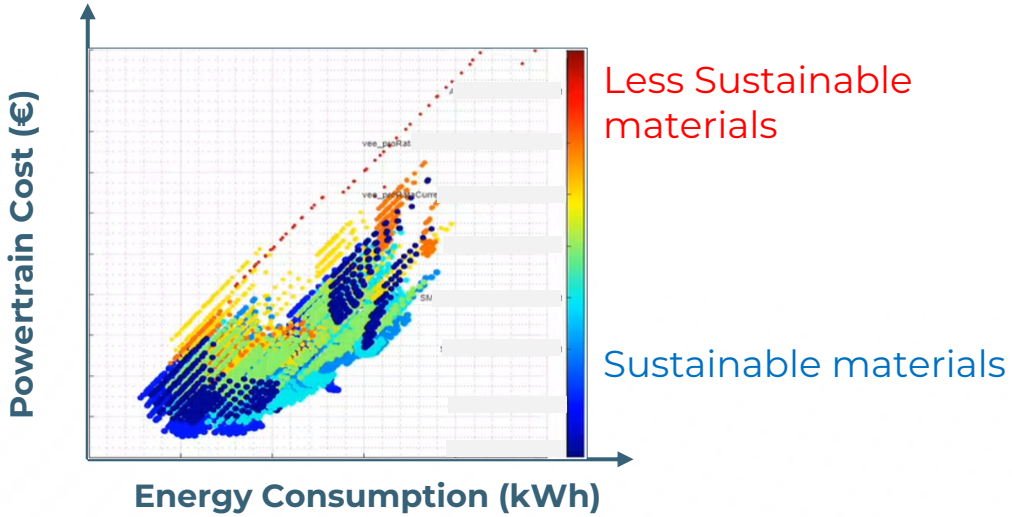
Engineering Beyond Net Zero

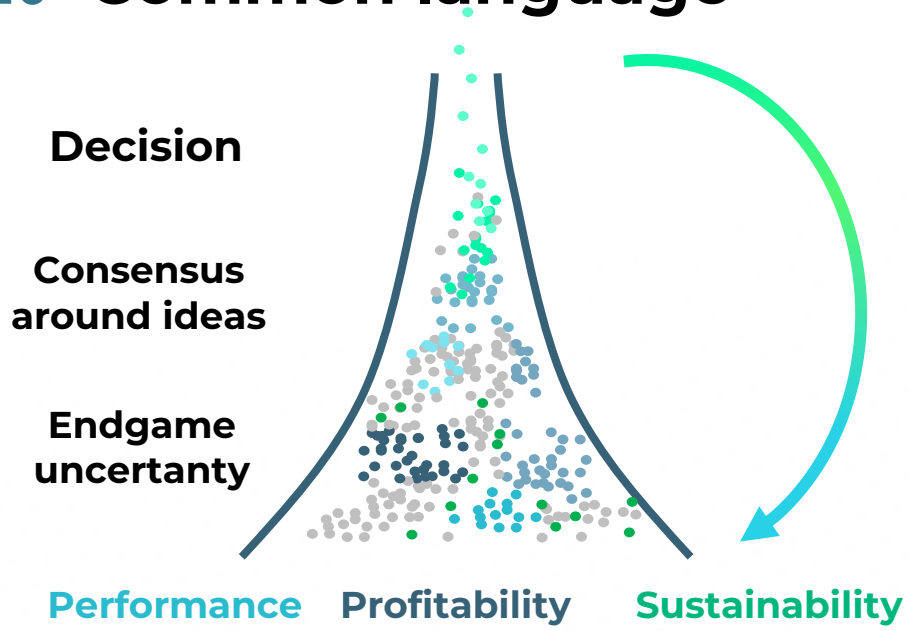
ePOP Unique Value Proposition combination

1. Objective Data Synthesis



Allow manufacturing to embed Sustainability commitments into R&D
= Solving 3D problems at the decision point

2. Common language



Communicate with- and outside R&D disciplines from various disciplines and data sources

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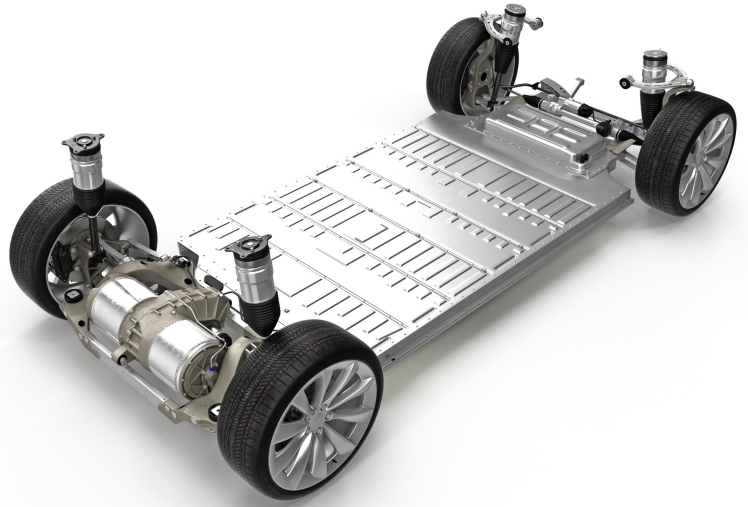
The situation facing OEMs and suppliers in the 2020's in a volatile and rapidly evolving technical and regulatory world

- Electrification in its relative infancy in all sectors with sub-optimal solutions
- Early electrified propulsion systems have confirmed the potential for electric and hybrid
- **OEMs unsure of make / buy decisions in electrified propulsion systems as their added-value diminishes as IC engines ramp-out**
- Tier 1s are chasing a moving target in a growing and volatile market
- Regulatory pressures will be inconsistent
- **Product sustainability and total cost of ownership 'from cradle to grave'** will become a critical attribute and differentiator



Time & Money

Speed of development and securing value along development process has become more crucial during disruption than ever before

End game uncertainty

Seemingly endless potential solutions are in play with rapidly evolving sub-system technologies

Resources & Communication

Engineering expertise limited and challenged to communicate design strategy across disciplines without common industry language

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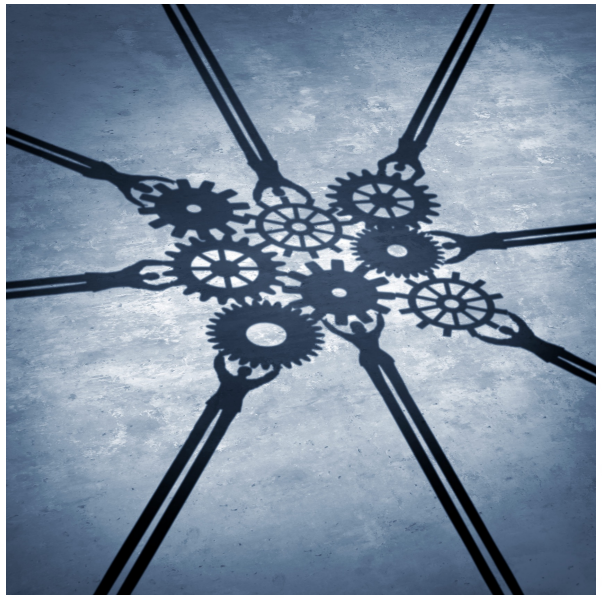
Electrified propulsion system developers demand a toolset that drives products from strategic planning to specification freeze

- How can the electrification solutions be rapidly narrowed down whilst still ensuring next-generation competitiveness with robust challenge to pre-conceived ideas?
- **How can the demands of sustainability be integrated with the usual development processes?**
- **How can modular and family approaches be enabled to ensure cost-competitiveness with 'zero' product performance compromise?**
- How can tier 1s and tier 2s present compelling and differentiated product propositions at the vehicle OEM planning and requesting stage?
- **How can the disparate disciplines within OEMs and tier 1s talk the same language with common and joined-up objectives?**



Cost competitiveness?

What are the lowest cost and most efficient '3 in 1' eAxle architectures for a modular eAxle family across vehicle segments

Best solution?

What is the best powertrain architecture for our new vehicle?

Cross sector?

How to demonstrate a lightweight efficient mid-size truck eAxle for a Tier 1 creating new aAxle capabilities?

Differentiate at planning stage?

Determine cost penalty vs range for 2-speed eAxle

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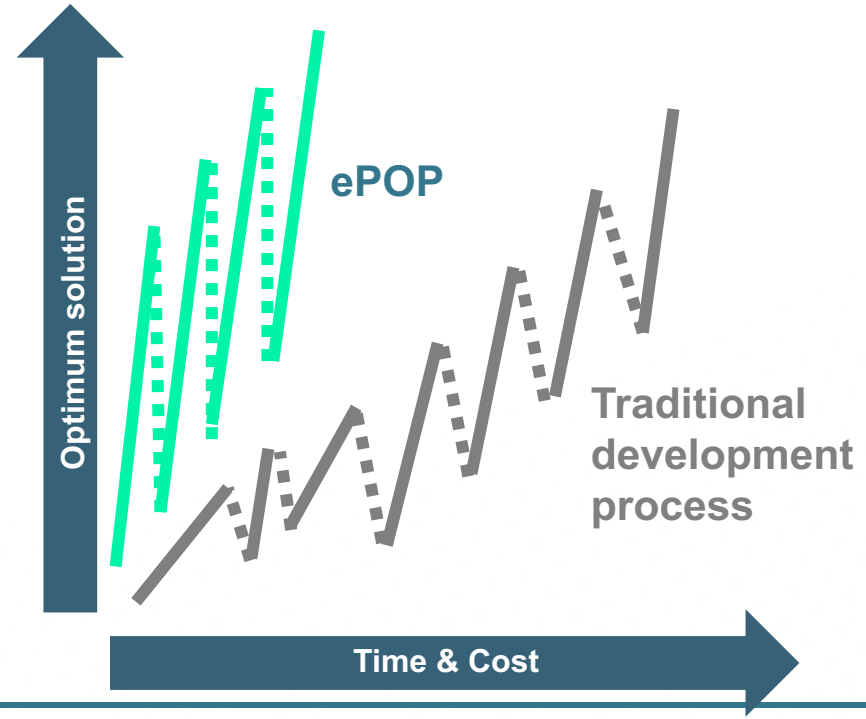
ePOP tool will show you where to challenge your assumptions and how you can improve before you spend 99% of your budget and 95% of your time

An ability to efficiently address the challenges will be key for successful OEMs and suppliers

- Identify the **right / best-in-class (BIC) technology fast**
- Draw conclusions from **large number of combinations** from continuously **growing library**
- Ensure **Life Cycle Assessment (LCA) and sustainability** is a fundamental **concept criteria**
- Adapt rapidly to continuously changing **sustainability legislative** ambitions
- Discover underlying trends and identify the **optimum solution**
- Communicate design strategy across disciplines and sectors via **common industry language and process**



ePOP allows early stage development without specialists in the classic R&D areas, enough to know customer requirements to feed ePOP

Utilise a tool that has a near-term development path to address challenges in a robust yet nimble manner whilst influencing the development direction of the tool

ePOP allows analysis of >10,000s different concepts where traditionally only 3-10 were considered prior to freeze

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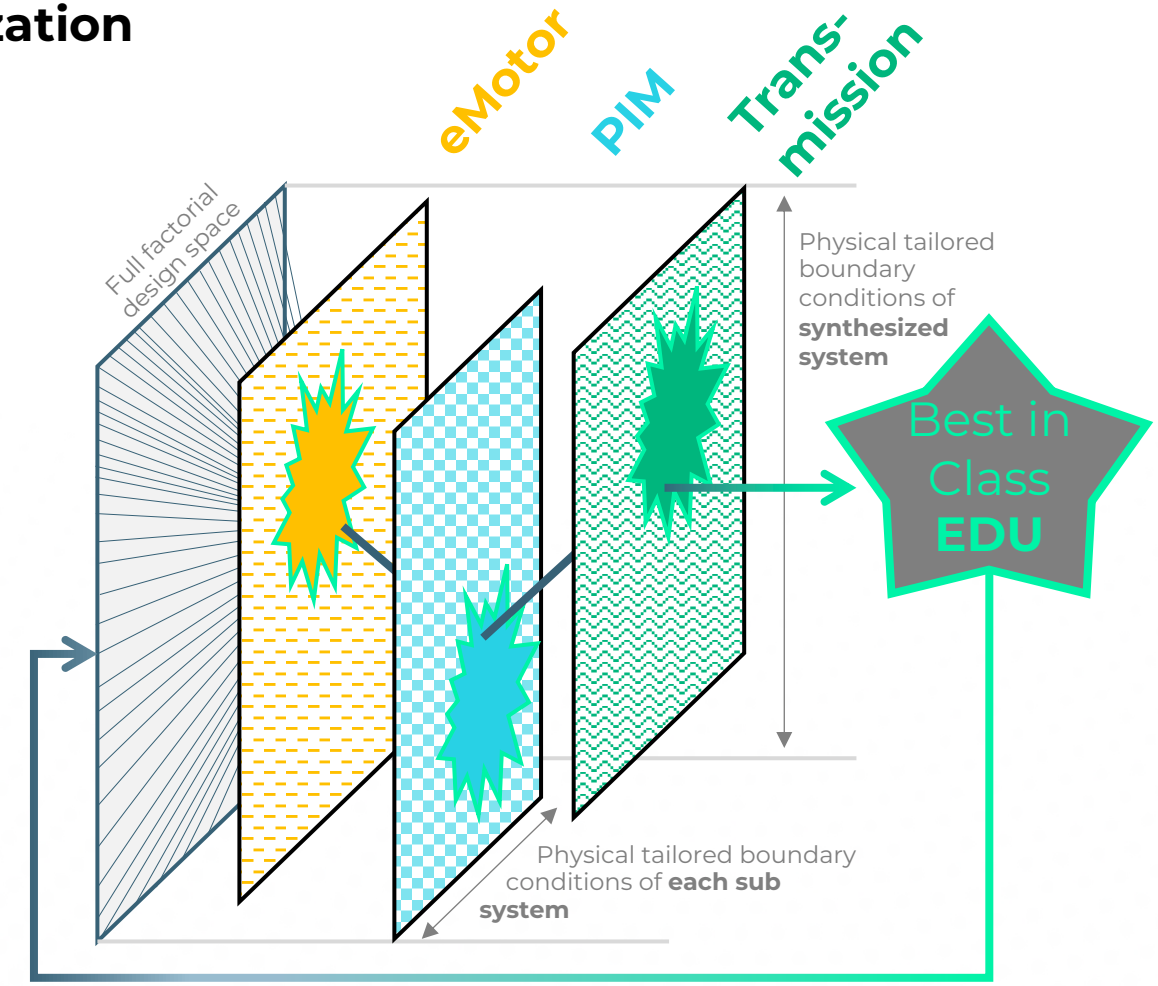
ePOP optimises within the physically viable full factorial design space

Design space Optimization algorithm

- Vast design space created via **full factorial algorithm** which has been pre-conditioned to create the study in physical ways at the input level within viable solutions
- From **there both identifies** and **defines** how to achieve **each island** ( ) specification within physical boundaries of what each sub system team should achieve
- ePOP excludes solutions that are **non viable** by applying **realistic concepts** in a vast design space.
- Multi dimensional pareto fronts (TCO, efficiency, sustainability) narrowed down and short listed for each sub system



Output capability & functionality

- ✓ Optimizing Algorithm within combinations of design for those sub systems
- ✓ Covers vehicle requirements
- ✓ Combinations of all defined sub systems
- ✓ Optimizing Algorithm that then covers the best version of that

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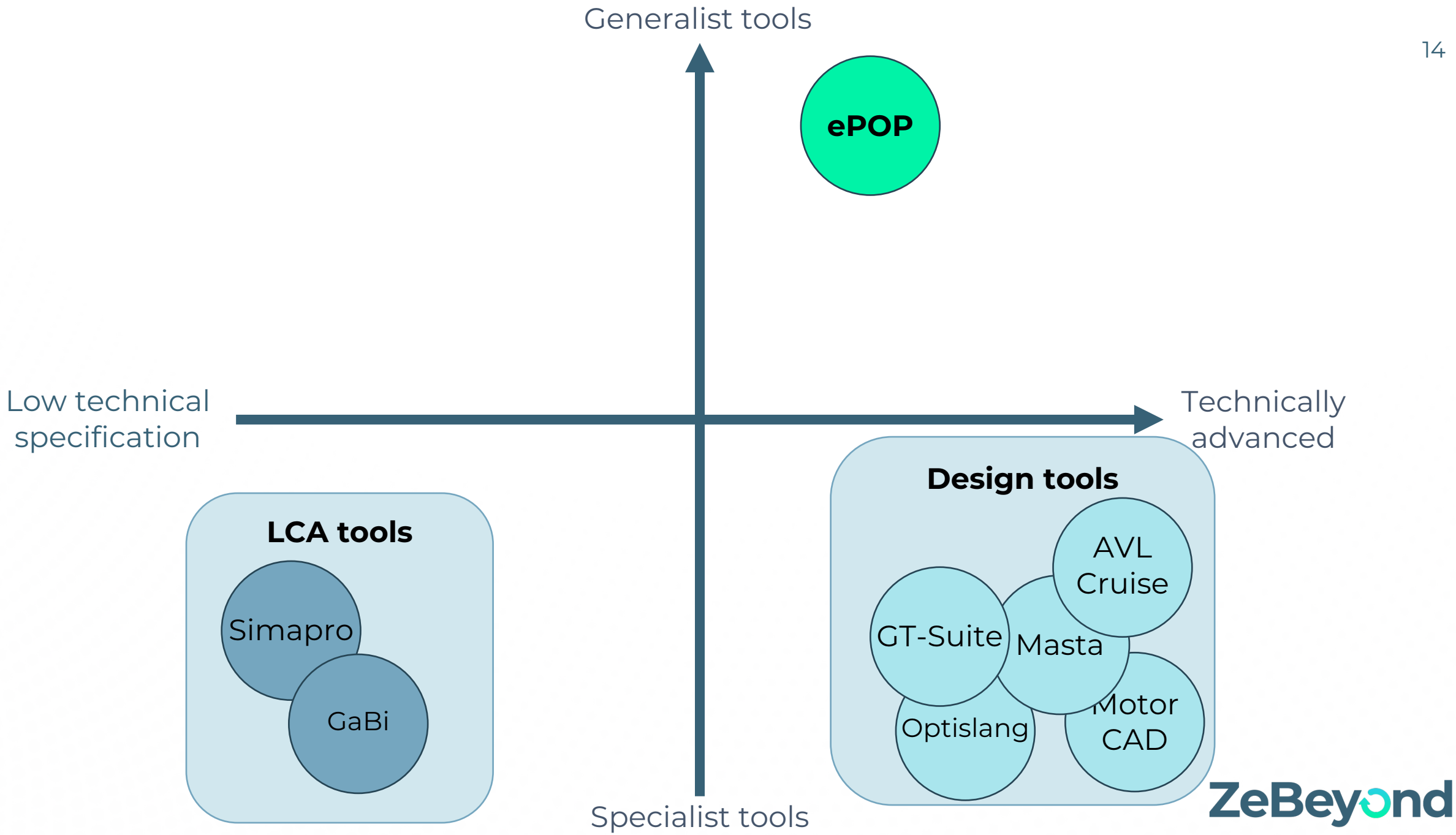
Generalist tools
ePOP
Low technical specification
Technically advanced
Design tools
AVL Cruise
GT-Suite
Masta
Optislang
Motor CAD
LCA tools
Simapro
GaBi
Specialist tools

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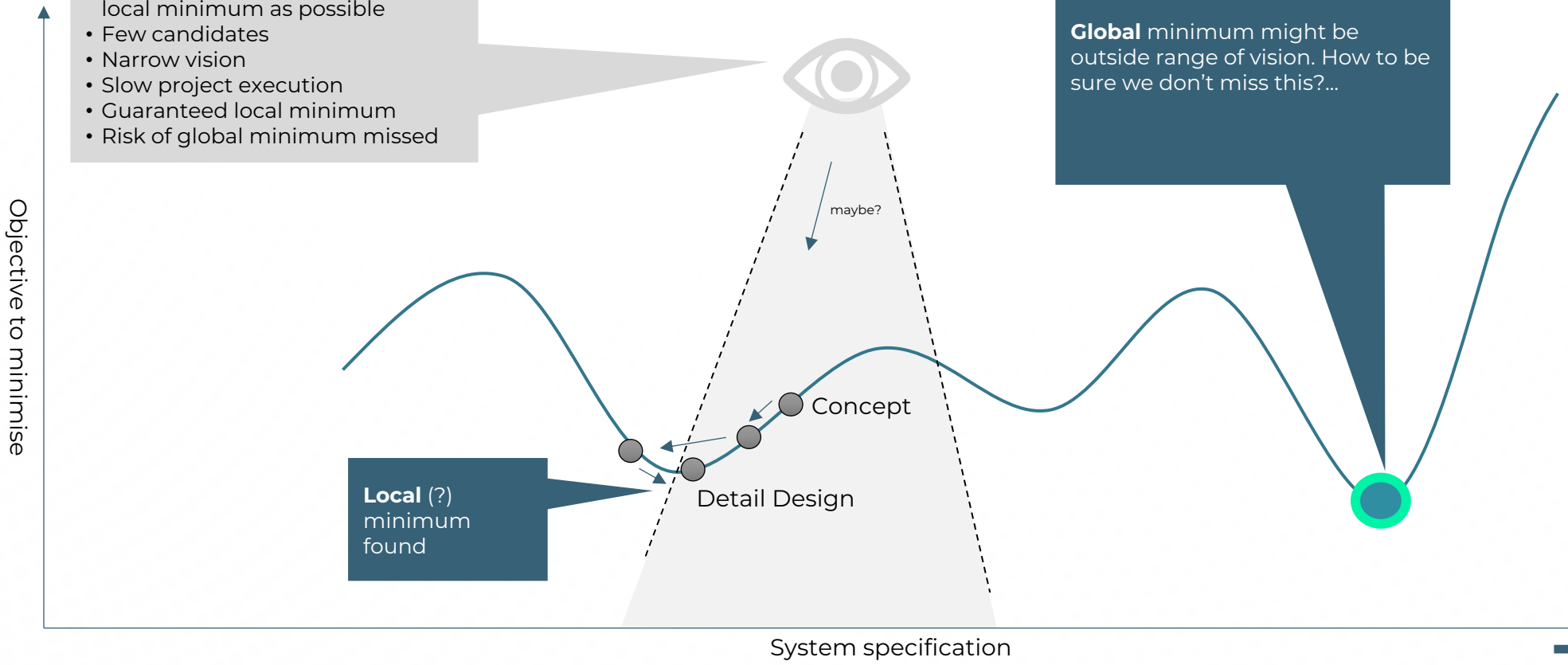
ePOP Speed, Size and Flexibility

Best of breed design tools:
- High fidelity
- Highly accurate models
- Best process to get as close to local minimum as possible
- Few candidates
- Narrow vision
- Slow project execution
- Guaranteed local minimum
- Risk of global minimum missed



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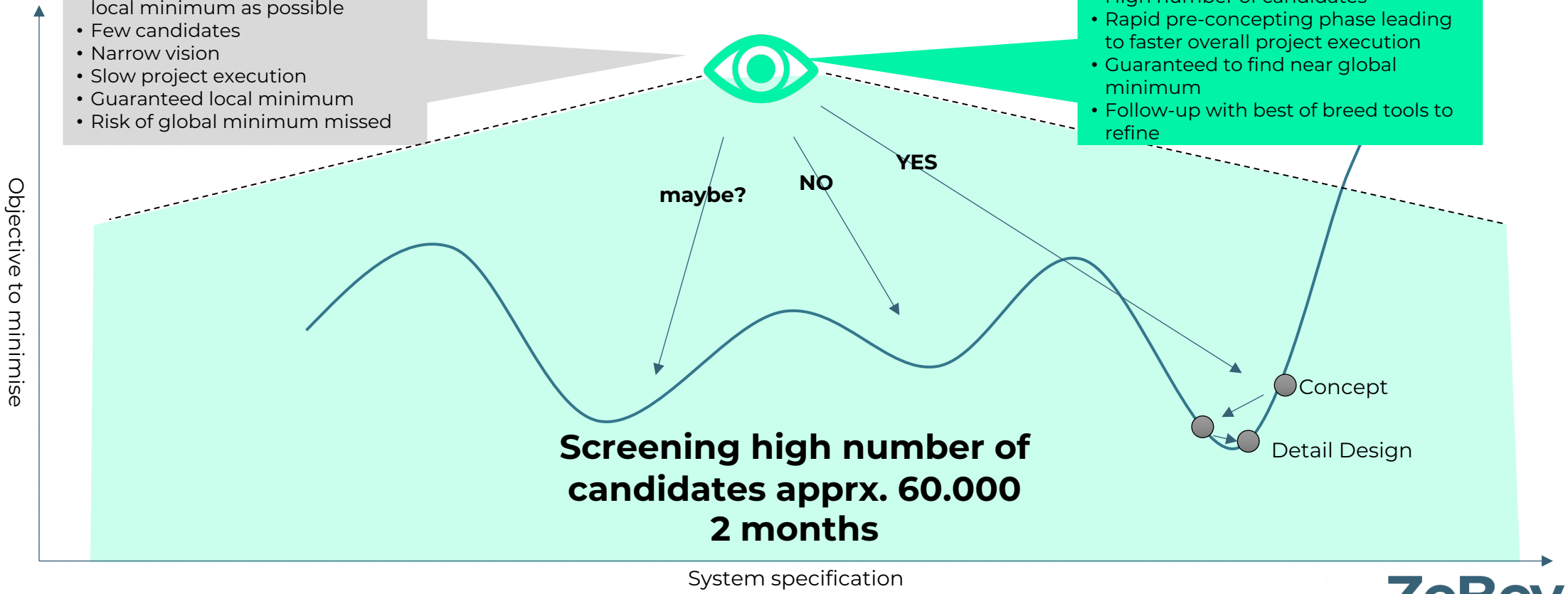
ePOP Speed, Size and Flexibility

Best of breed design tools:
- High fidelity
- Highly accurate models
- Best process to get as close to local minimum as possible
- Few candidates
- Narrow vision
- Slow project execution
- Guaranteed local minimum
- Risk of global minimum missed

ePOP:
- Moderate fidelity
- Accurate models
- Widest possible vision
- High number of candidates
- Rapid pre-concepting phase leading to faster overall project execution
- Guaranteed to find near global minimum
- Follow-up with best of breed tools to refine



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ePOP consists of three main process steps

1. Input Data

Setting boundary conditions

- Input Data required for running studies in ePOP can be generated in multiple ways.
- As ePOP defines a common data format interface, the resulting component models are agnostic of origin, and may only differ in fidelity of initial modelling.
- Once in this common format, they can be mixed/matched in any way dictated by the design space.

2. Simulation

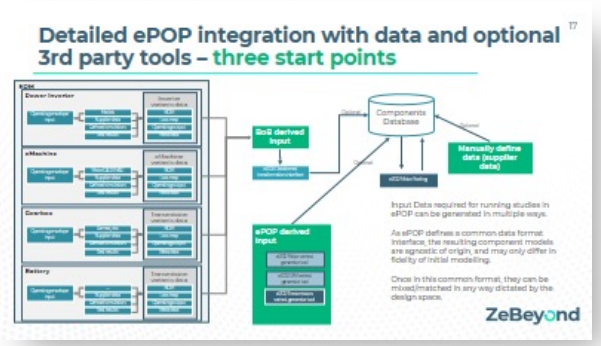
Defining concepts (+100 combinations)

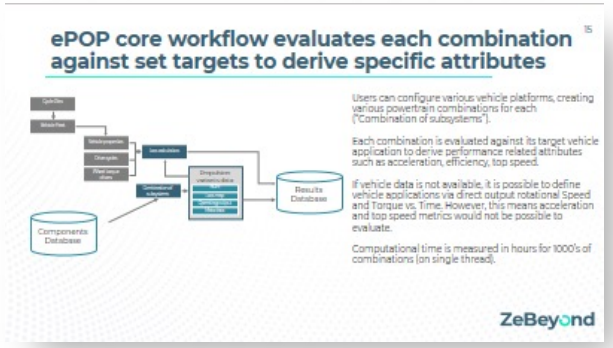
- Users can configure various vehicle platforms, creating various powertrain combinations for each ("Combination of subsystems").
- Each combination is evaluated against its target vehicle application to derive performance related attributes such as acceleration, efficiency, top speed.
- Computational time is measured in hours for 1000's of combinations (on single thread).

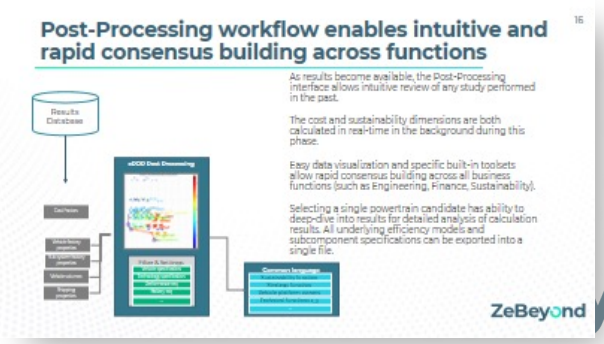
3. Post Processing

Filtering & Performance simulation

- As results become available, the Post-Processing interface allows intuitive review of any study performed in the past.
- The cost and sustainability dimensions are both calculated in real-time in the background during this phase.
- Selecting a single powertrain candidate has ability to deep-dive into results for detailed analysis of calculation results. All underlying efficiency models and subcomponent specifications can be exported into a single file.







How ePOP works

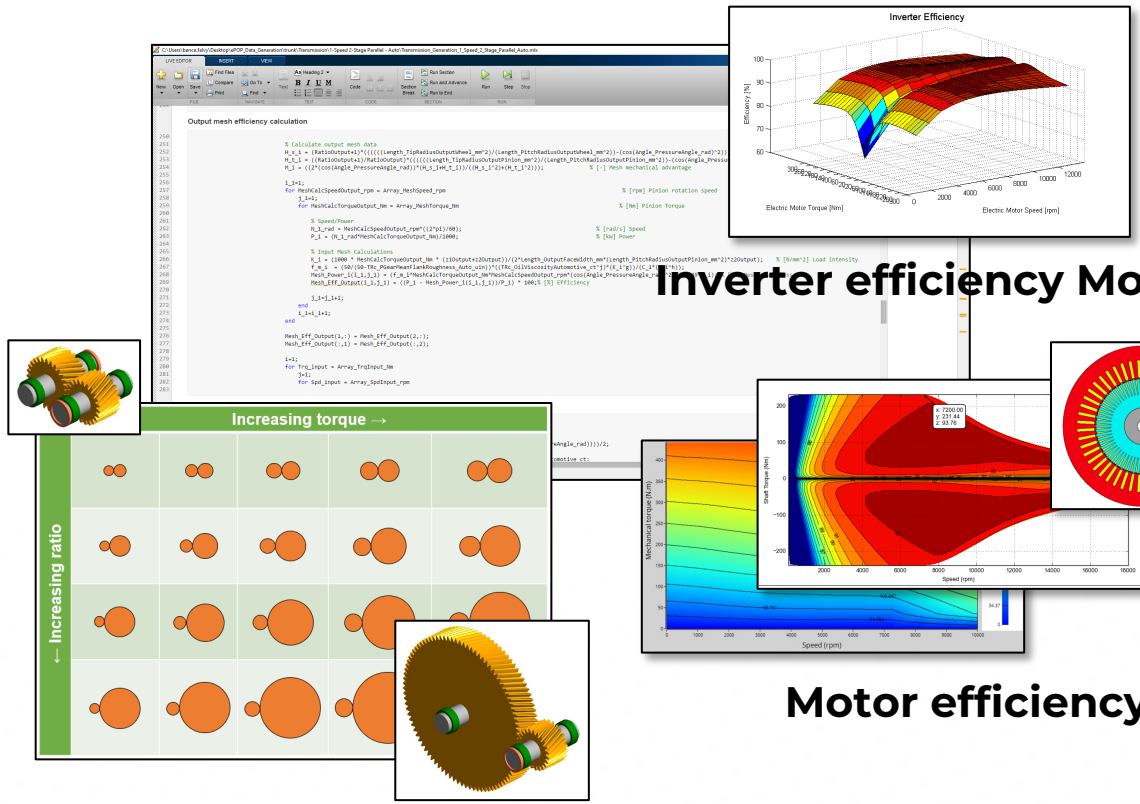
ePOP Component Generation

Component Sizing and efficiency maps are generated for each main component (motor, transmission, inverter).

A combination of scripts and configurable efficiency models allow for automated and quick generation of required maps.

Inverter and transmission efficiency maps are built based on years of design experience, and they include effects such as switching frequency, gear mesh losses, bearing losses,...etc.

Motor maps are generated using third party motor design tools.



Inverter efficiency Model

Motor efficiency Map

Automatic transmission sizing & efficiency model based on requirements

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How ePOP delivers

ePOP redefines electrification strategy analysis

Customer needs → **1. Input Data** — Setting boundary conditions → **2. Simulation** — Defining concepts (+100 combinations) → **3. Post Processing** — Filtering & Performance simulation

Where do we start?

Target

- Drive Cycle(s)
- Vehicle Attributes

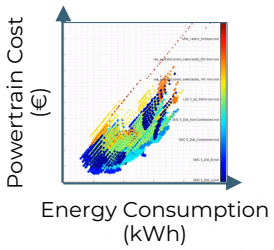
+

Variables

- Motor
- Materials
- Ratios
- Fluids

+

Possibilities



Trade offs

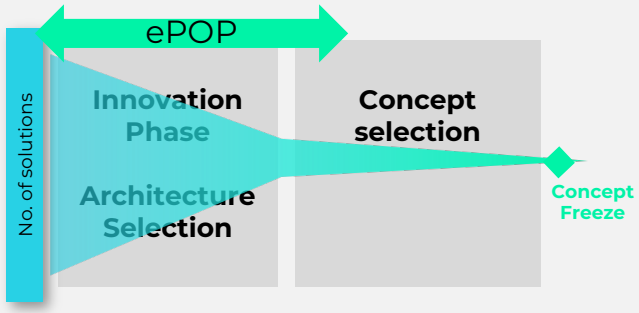
- Cost
- Efficiency
- Sustainability
- Mass
- Range

=

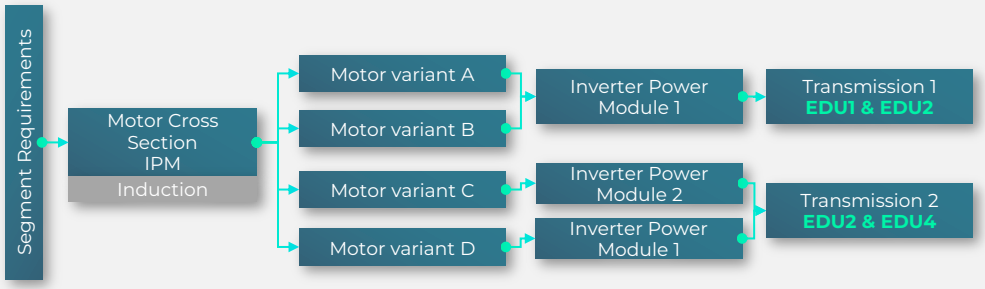
Result

Competitive EDU Solution

Accelerate innovation phases



Derive cost effective e-powertrain solutions



Maximise modular architecture opportunities

Vehicle Segment	EDU1	EDU2	EDU3
A	●		
B	●		
C		●	
D		●	
E			●
F			●

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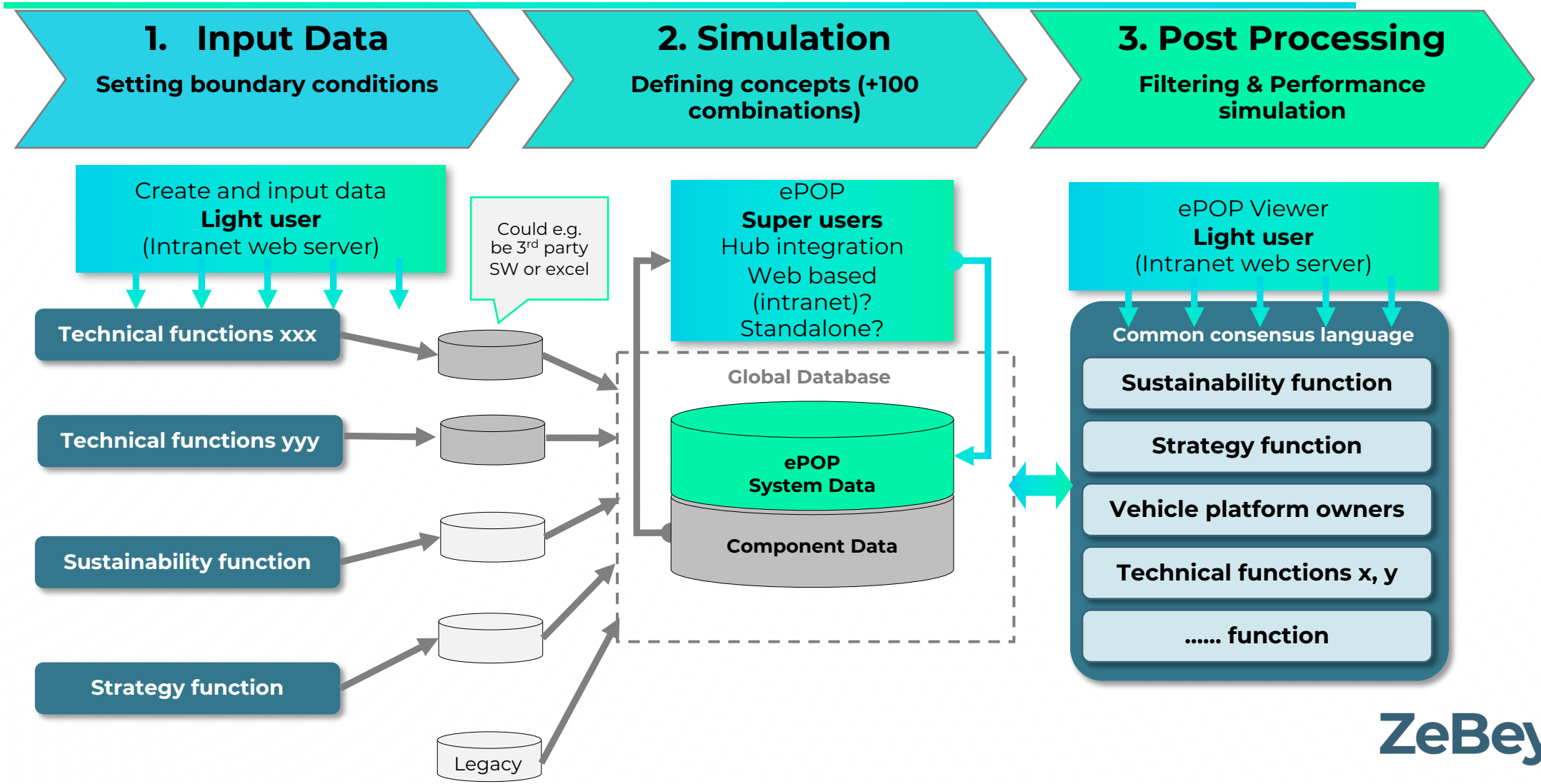
How ePOP consolidates various sources

From component data to shared system insights



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How ePOP delivers

Case studies of how existing customers have integrated ePOP usage into their processes

Common consensus language

- Sustainability function
- **Strategy function**
- **Adv. engineering / R&D**
- **Vehicle platform owners**
- **Technical functions x, y**
- Sales and marketing (TIs)
- ..... function

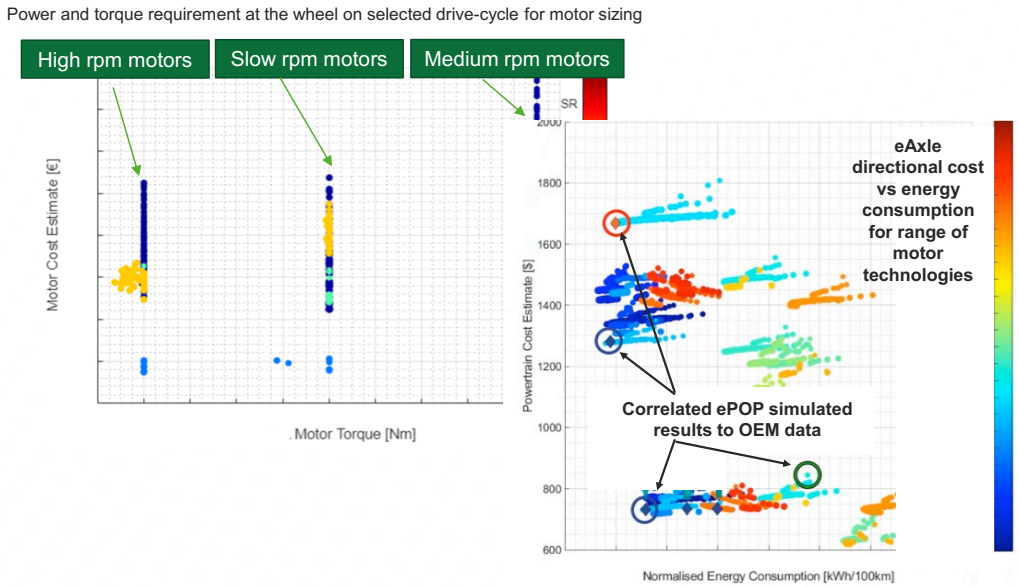
Best future technology consensus?

Project Objective and Responsibilities

- Determine long term OEM EDU strategy based on 3 in 1 efficiency vs production cost directional analysis covering large range of sub-system technologies

Outcome and Customer Benefits

- Strategy developed providing OEM with fundamental EDU strategy and reference, considering multiple transmission types and a matrix of >20 motor technologies / topologies
- Strong correlation of energy simulations from ePOP and OEM more detailed and slower toolset
- Good correlation of the ePOP directional cost models with the OEM high volume production cost predictions



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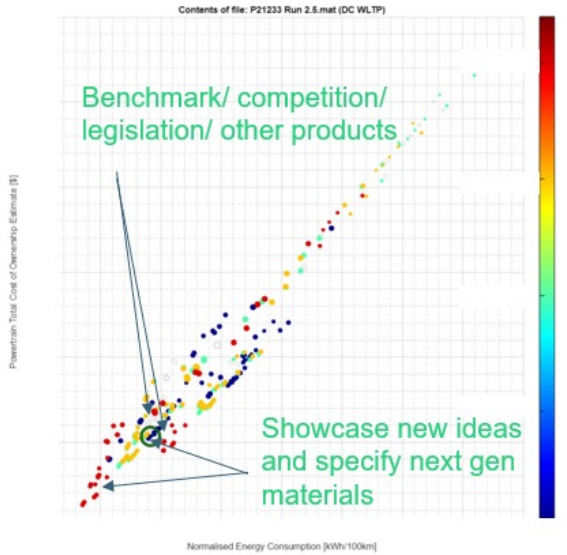
The best material technology?

Project Objective and Responsibilities

- Show the material and system value proposition across supply chain from Tier5 to OEM
- What material do we need in our portfolio in order to beat state of the art LSS value prop in emotor systems for future platforms and what is the TCO and performance?

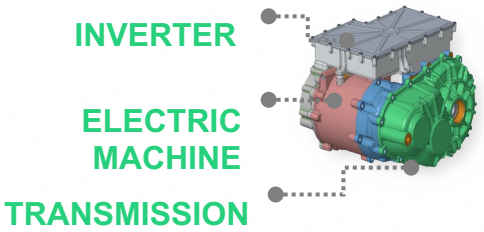
Outcome and Customer Benefits

- Showcase different material benefits on system level of an ID3 as benchmark for customers customer (OEMs).
- Tear down of a full VW ID3 and use as benchmark and simulate system spec along that benchmark (Voltage: 400VDC, Peak Power: 150 kW, Peak Torque: 3000 Nm, Target Volumes: 100-350 k/a, Highest Drive Cycle Efficiency, Weight: <80 kg Size - Height: 310 mm, - Length: 480 mm, - Width: 540 mm)



Each dot represents a feasible system combination meeting the system requirements.

Inverter type, Electrical Machine Design, Material, Gear Ratio, etc, are varied to find the optimal system.



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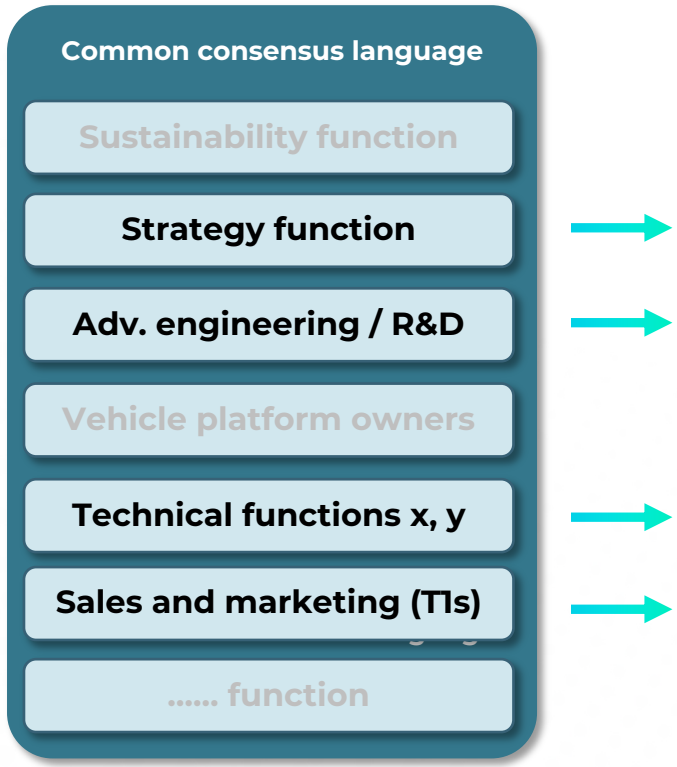
How ePOP delivers

Case studies of how existing customers have integrated ePOP usage into their processes



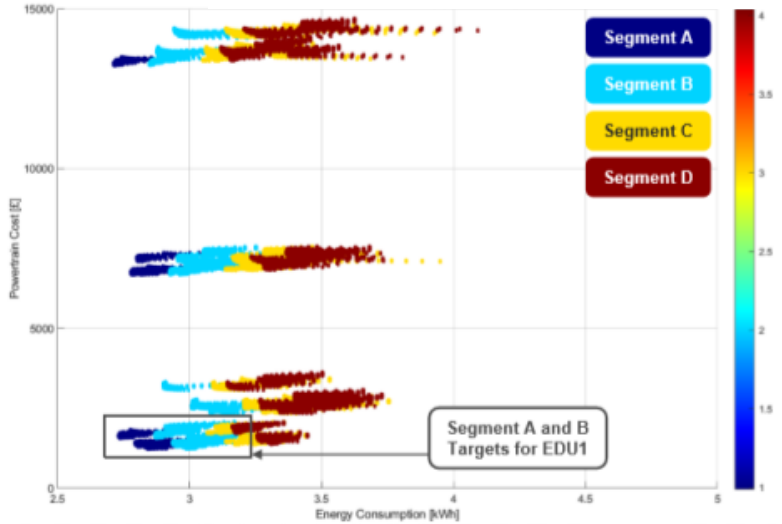
The most cost competitive?

Project Objective and Responsibilities

- Determine lowest cost / most efficient '3 in 1' architectures for a modular EDU family
- Mapping of global vehicle requirements
- Evaluation of 260,000 configurations
- Definition of EDU specifications

Outcome and Customer Benefits

- Highly modular cost-effective strategy defined – minimised investment
- Low number of transmission variants / EDU part nos.
- 'Simplified' motor strategy
- DSD now developing single and multi-speed EDUs at A and B sample for the Tier 1, ready for vehicle demo



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- ..... function

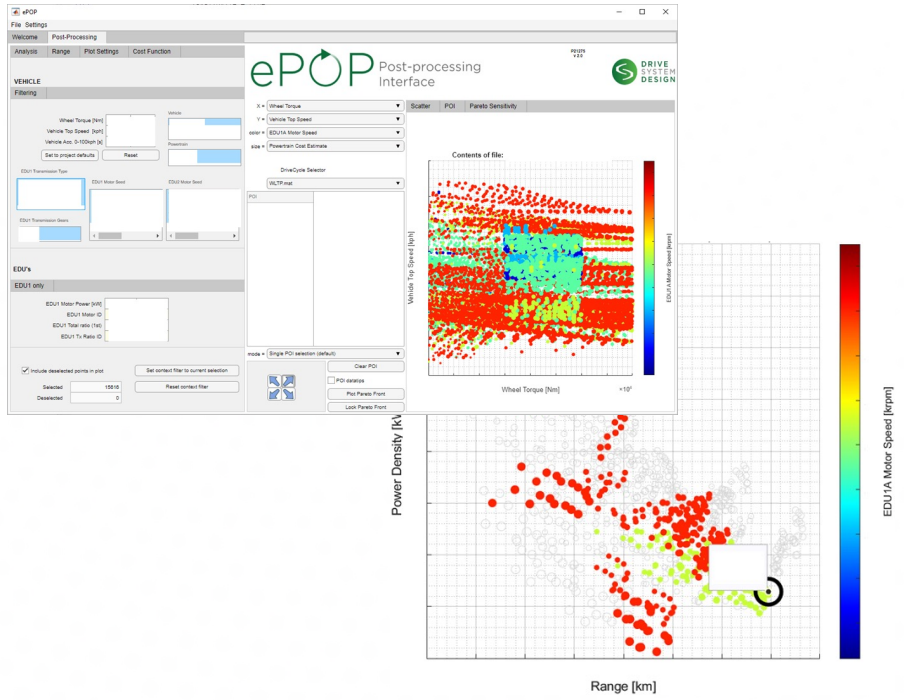
The best vehicle solution?

Project Objective and Responsibilities

- New electric vehicle start-up developing their own EDUs
- Best architecture for the new vehicle

Outcome and Customer Benefits

- 1,000s of potential architectures analysed and the best EDUs down-selected
- ePOP post processing tool delivered to customer for their own ‘what-ifs’



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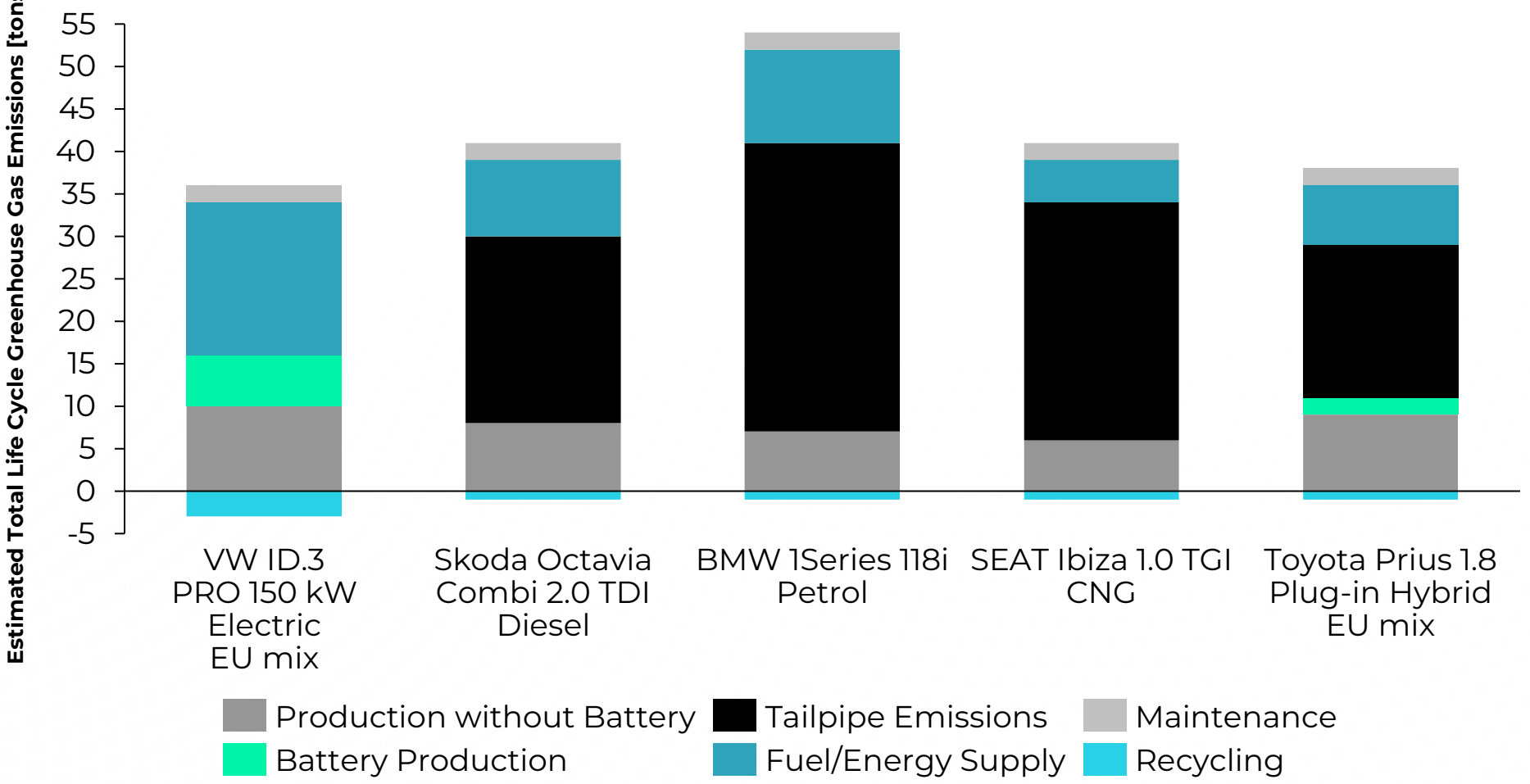
Similar vehicles with different powertrains and effects on emissions



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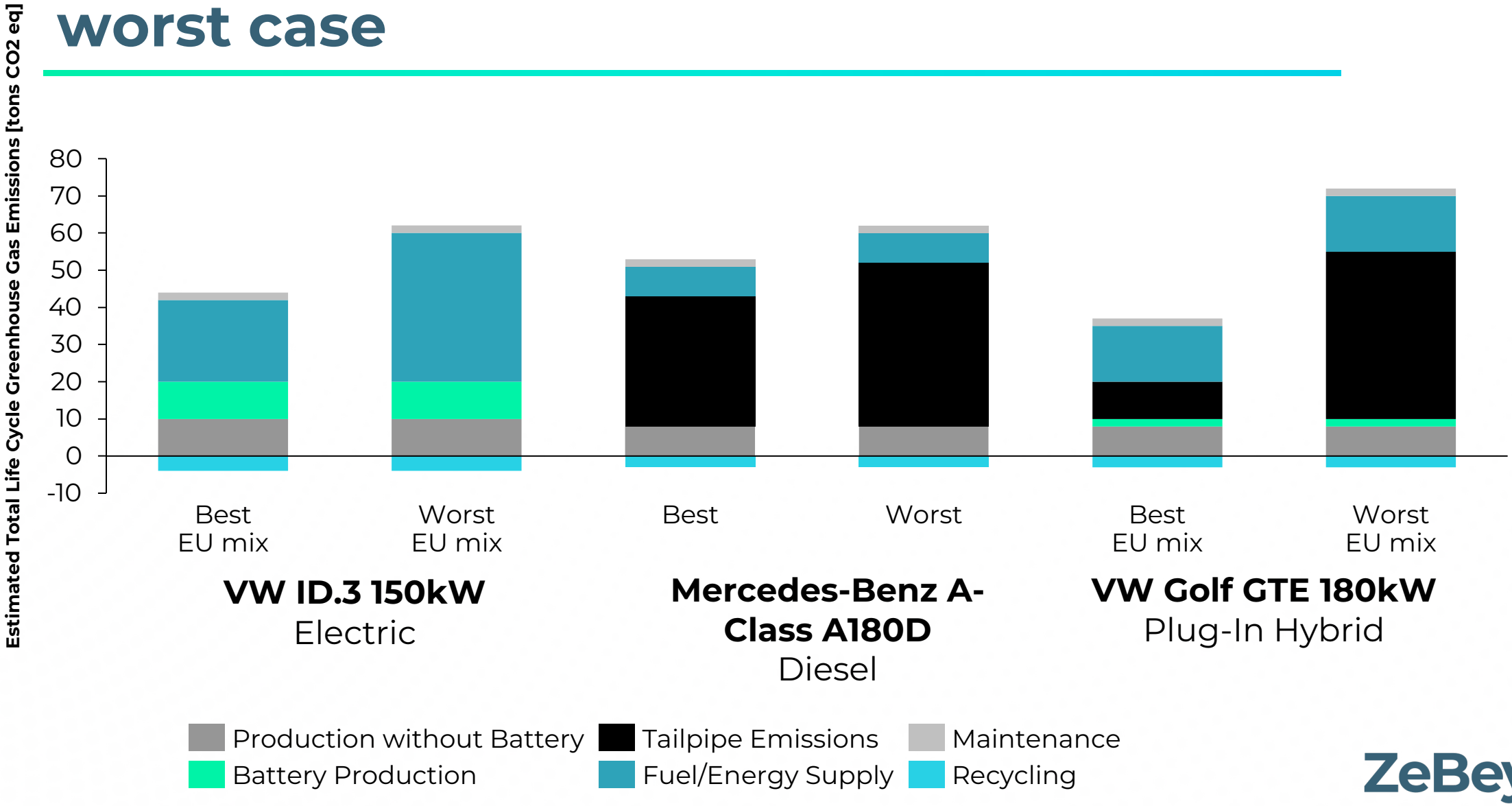
Usage conditions for same vehicles – best and worst case



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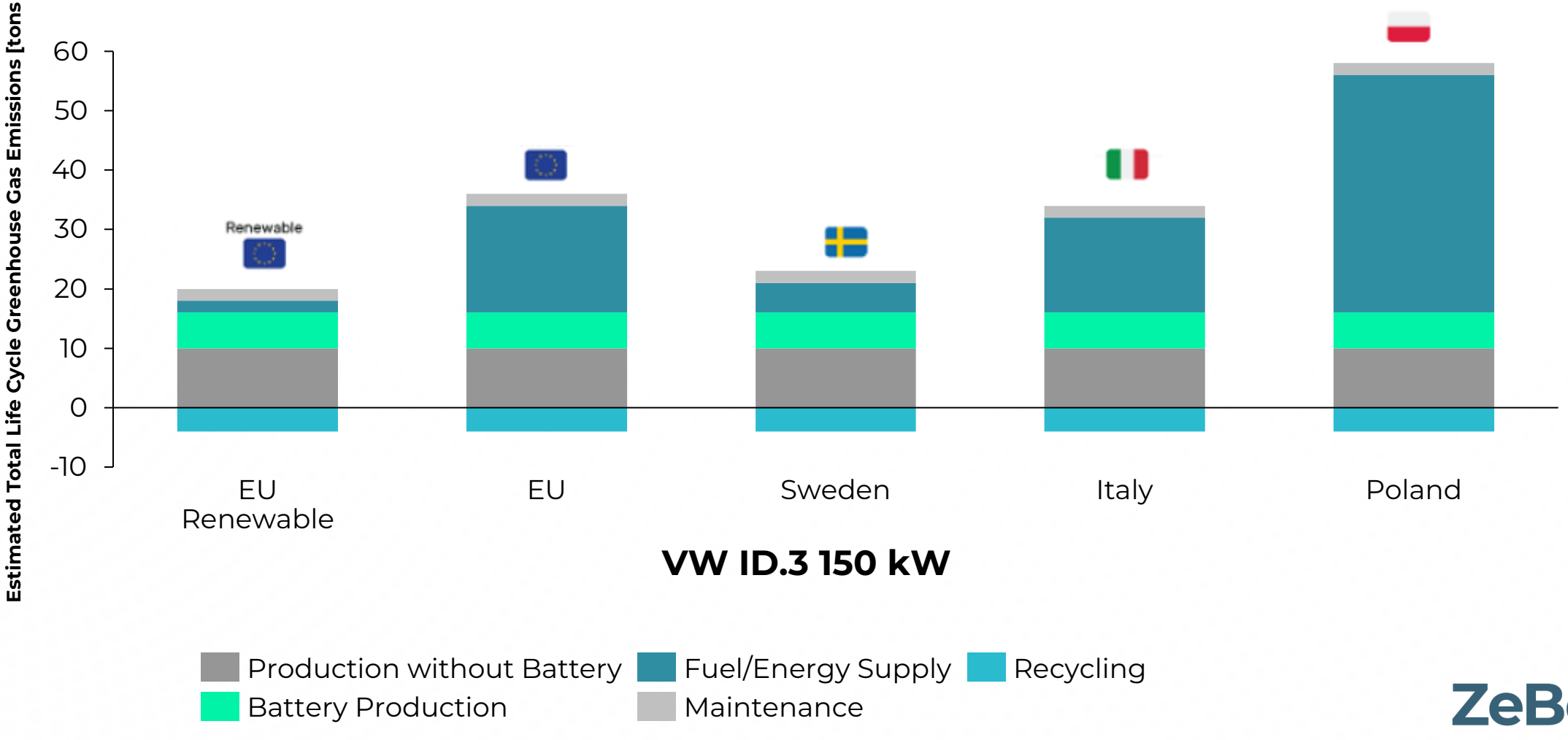
Impact of Electricity mix used for recharging over the lifecycle of an BEV



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ePOP & Sustainability

ePOP value prop for Sustainability teams

1. Embed sustainability targets in forward looking prod. development

- Sweep the space for forward-looking optimum of 3D equations
- Allow embedding impact on environment, resources and health (like most LCA tools) plus how the product delivers (performance) and impacts on costs. (just reducing CO2 is not enough)
- Agile tailoring for production scenarios, include changes in assembly.
- Don’t only focus on LCA (predefined) also discover the unknown

- **Could make test and take 3-5 scenarios from LCA and insert into ePOP to evaluate cost & Performance**

2. Communicate sustainability gains and losses on profit & performance

- Understand and quantify how far away are we and what are the gaps
- Communicate with internal & external stake holders and quantify in cost and performance
- Tailor for agile priorities, carbon footprint or toxicity, or use of water
- Go from backward looking reporting to cross discipline what-if scenarios. What happens if we change material..
- Easy export for LCA certification

- **Could communicate to stake holders that sustainability strategy has been embedded in products & footprint choices**

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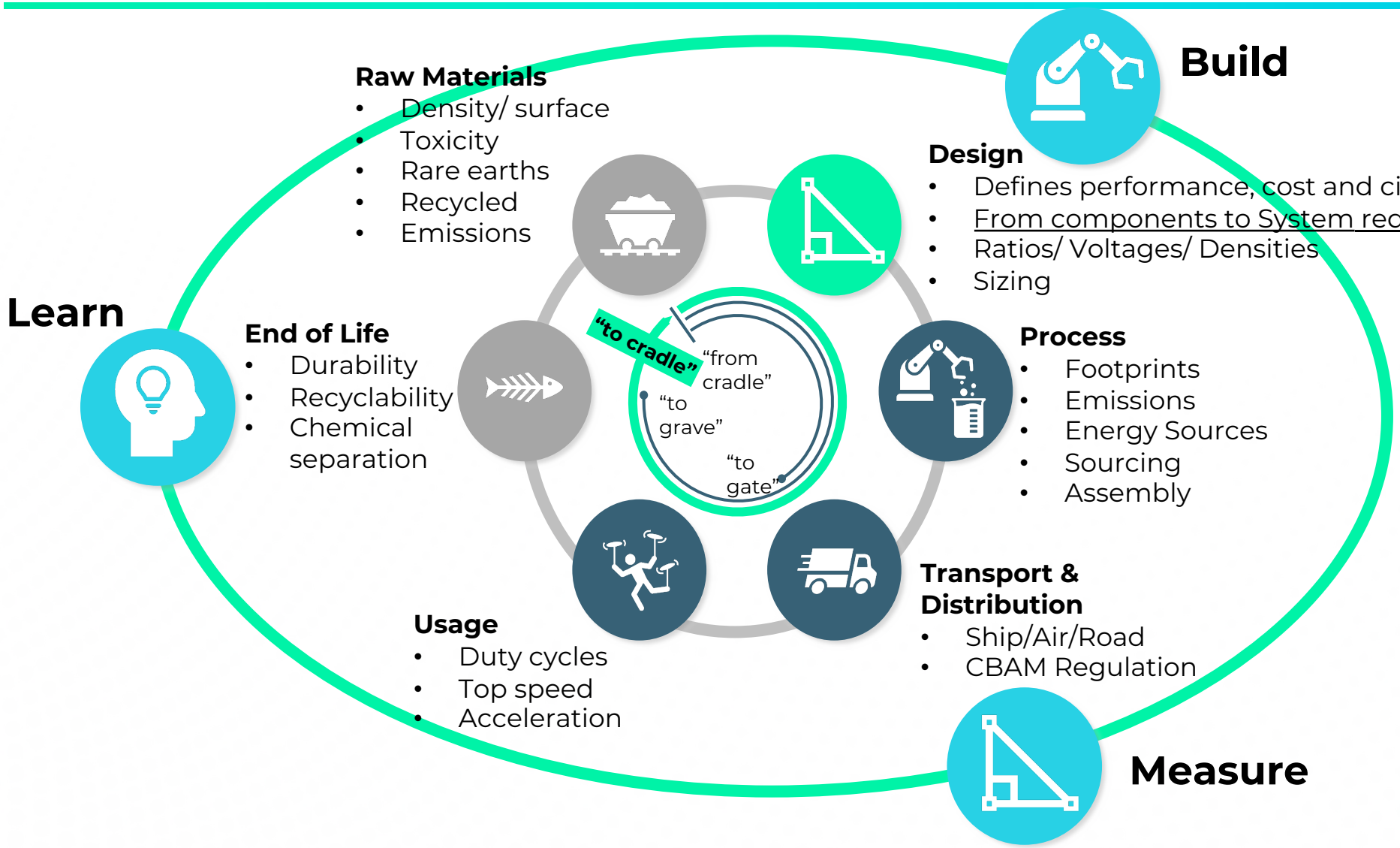
Manufacturing faced to re-invent both components, systems and supply chain



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Early Adopters leverage of each other hours on same modules – to maximise insights and minimize time

Tailored to each early adopter man hours

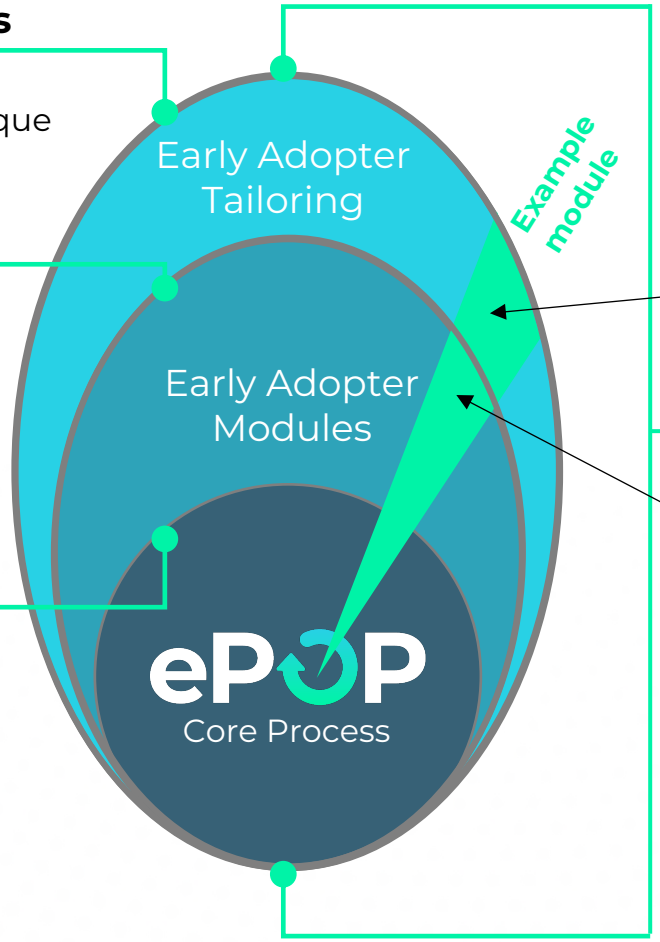
- Man hours dedicated to co-developing and tailoring ePOP modules to Early Adopters unique requirements and know how

Shared effort building modules

- Continuous build and release of new modules
- Core functionalities of major desired modules
- Already standard and built modules
  - Efficiency characterization
  - Performance prediction, CO2 emissions,
  - Mass, Volume, Packaging, Directional cost
  - What if, Automation batch running…

Core Process & Functionality

- Data import
- Pre-Processing
- Drive Cycle definition
- Design space creation
- Creating efficiency maps
- Drive cycle(s) performance simulation
- Results processing
- Data export

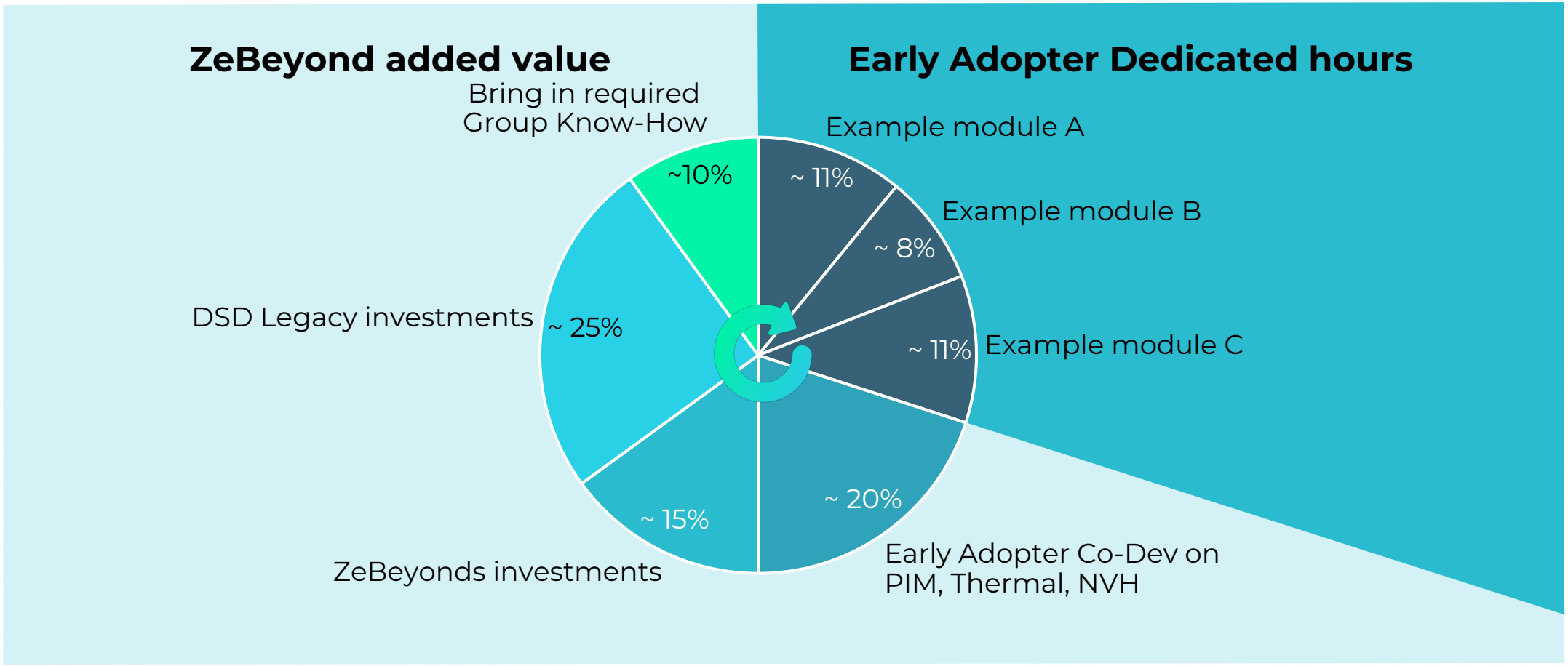


Total value of SW license

- Total whole value greater than the sum of its parts
  - ePOP Process
  - Early Adopter Modules
  - Tailored to OEM requirement
  - One intuitive user interface
- Collaboration required to achieve on **speed of execution** at **widest relevant design space**

ZeBeyond

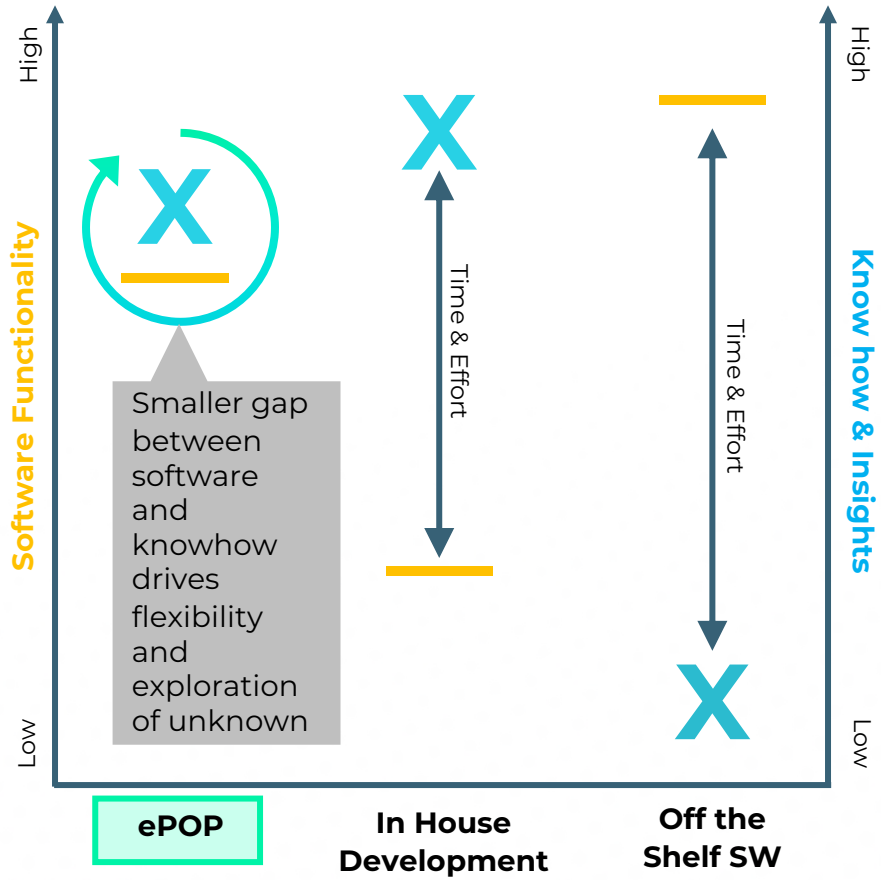
ZeBeyond's co-development approach allows Early Adopters to get leverage on their time from whole program



ZeBeyond

ePOP differentiates by combining Know How and Software in one loop

- ePOP is a unique combination of process, toolset and experience which allows to embed 3Dimensions into one problem simulation.
- Technical EDU knowhow embedded already in ePOP and will be available throughout Early Adopter Journey
- Proposing and committing to successful future strategies requires confidence, speed, and a detailed insight into the trade offs.
- ePOP is a culmination of 5 years of work to help customers solve the Performance, Profit, Sustainability equation. All before investing major resources. That is what we call ePOP - Engineering Beyond Net Zero.



ZeBeyond

We believe each winning **system integrator** has a unique place in the sustainable future for automotive and other mobility sectors.

We also believe the way forward is to navigate the climate disruption via **objective data synthesis** and a **common language** to go with it.

We **invite you** to challenge us on how ePOP can help solve your **sustainability, profit, and performance** equation!

ZeBeyond

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