



# Cost modelling - a tool for sustainable innovation

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# Group Project: Content

- 1. Composite material selection**
  - Justify why you have selected particular fibers / textiles / resins
- 2. Design and structural feasibility established**
  - Identify load case, generate design (CAD), structural analysis (of key elements, FEA ideal, 3D printed demo interesting (but not required))
- 3. Clear value proposition (incl. performance, cost, ...)**
  - Understand how the problem is solved today
  - How your idea will meet customer needs
  - Why should a customer “get out of bed” for your product
- 4. Composites manufacturing process identified**
  - How will you convert your composite constituents into parts?
  - How many part will you make per year?
  - Will process change with time (scale-up)?
- 5. Cost per part modelled**
  - Investments required in equipment and tooling, cost/part calculated
  - Extrapolation to price interesting (but not required)
  - Scaling and industrialization: discussion of next steps/strategy
- 6. Sustainability positioning**
  - Give a sustainability statement regarding your product
  - Give 3 SMART initiatives to reduce impact (short, medium, long term)

2/3 of  
the  
grade

# Learning objectives of this lecture

## Cost assessment

How to paint a cost based picture of an innovation as part of how novel technology could be assessed financially

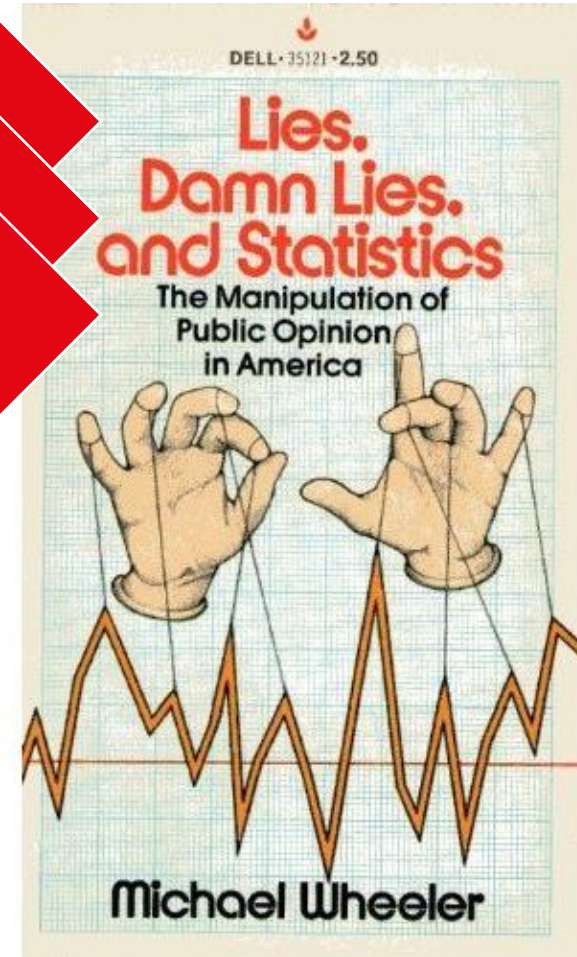
## Build solid models

How to build solid and useful models to aid in assessing innovation and alternative strategies

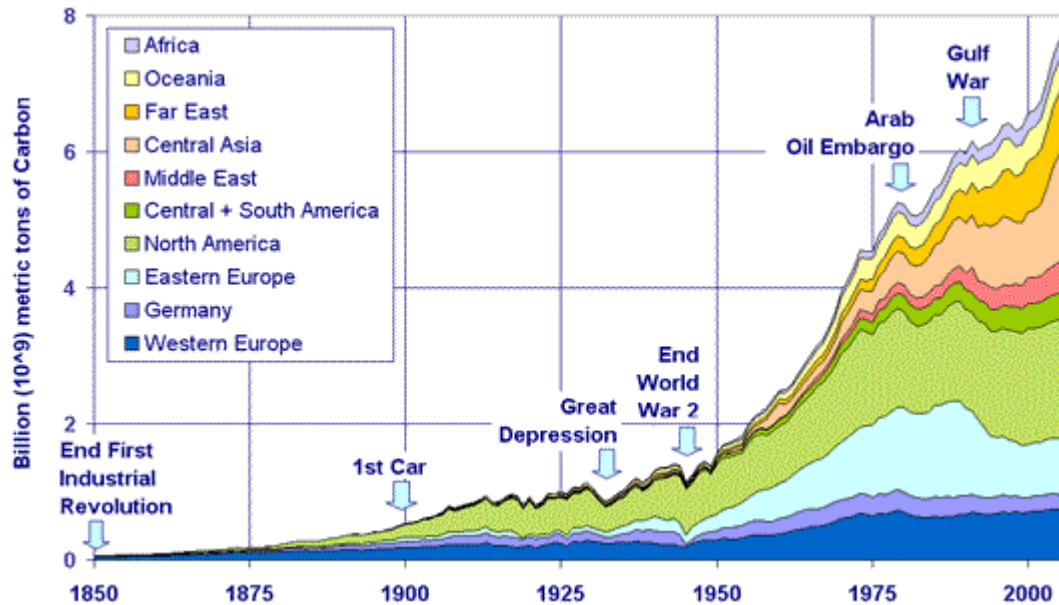
## Equip

Language and skills to apply within organizations (universities to start-ups and large corporations)

Show costing tool

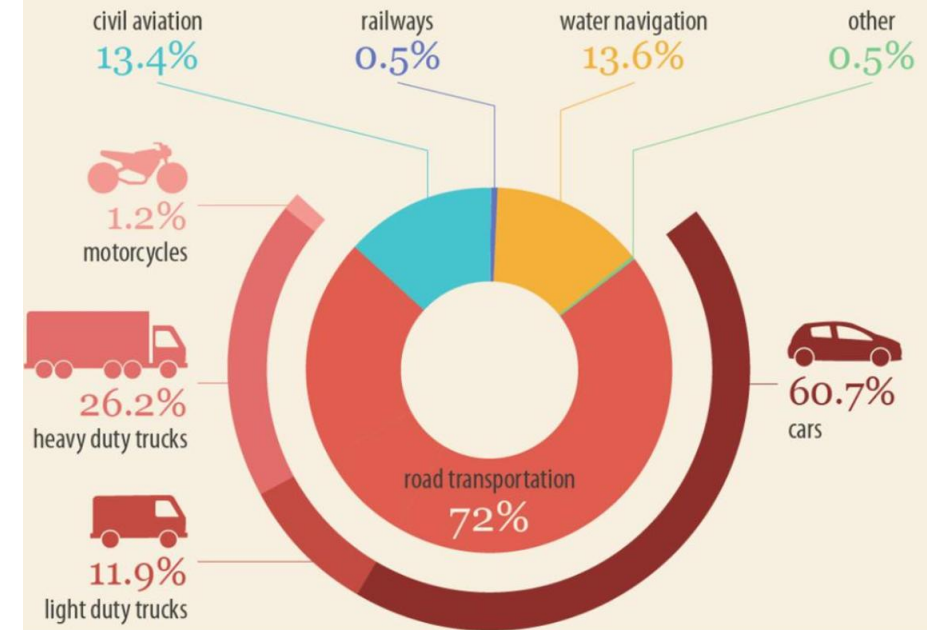


- Social evolution
- Technological evolution
- Vehicles are much more efficient today but this is offset by our driving more km



## TRANSPORT CO2 EMISSIONS IN THE EU

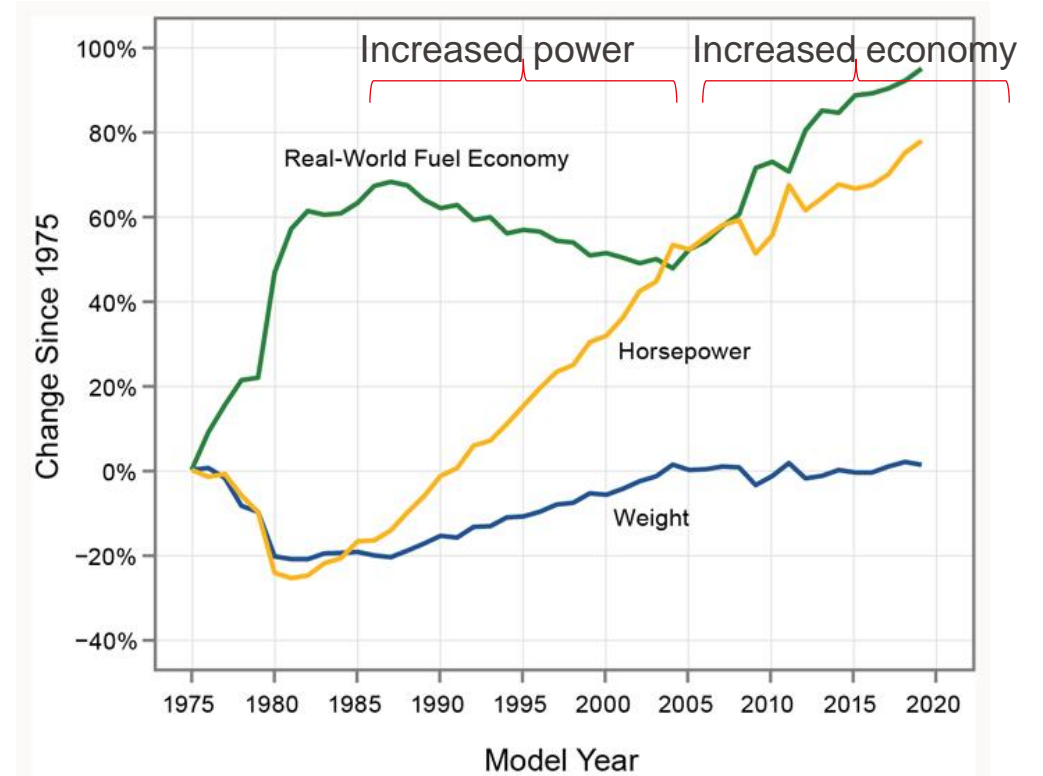
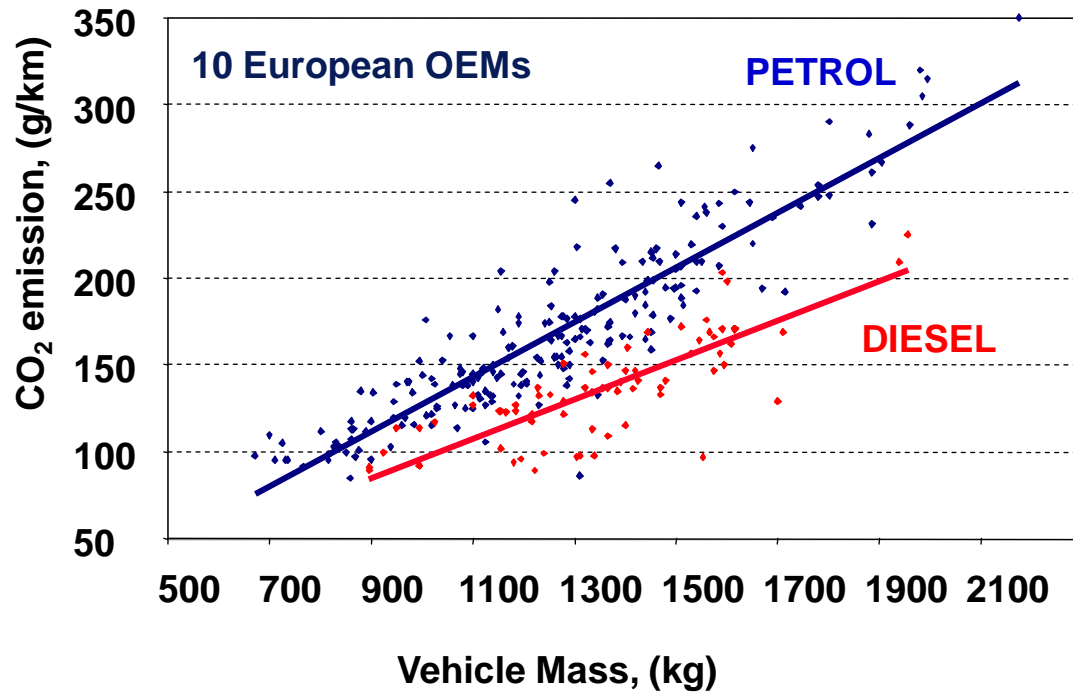
Emissions breakdown by transport mode (2016)



<https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics>

# Weight, time, and vehicle emissions

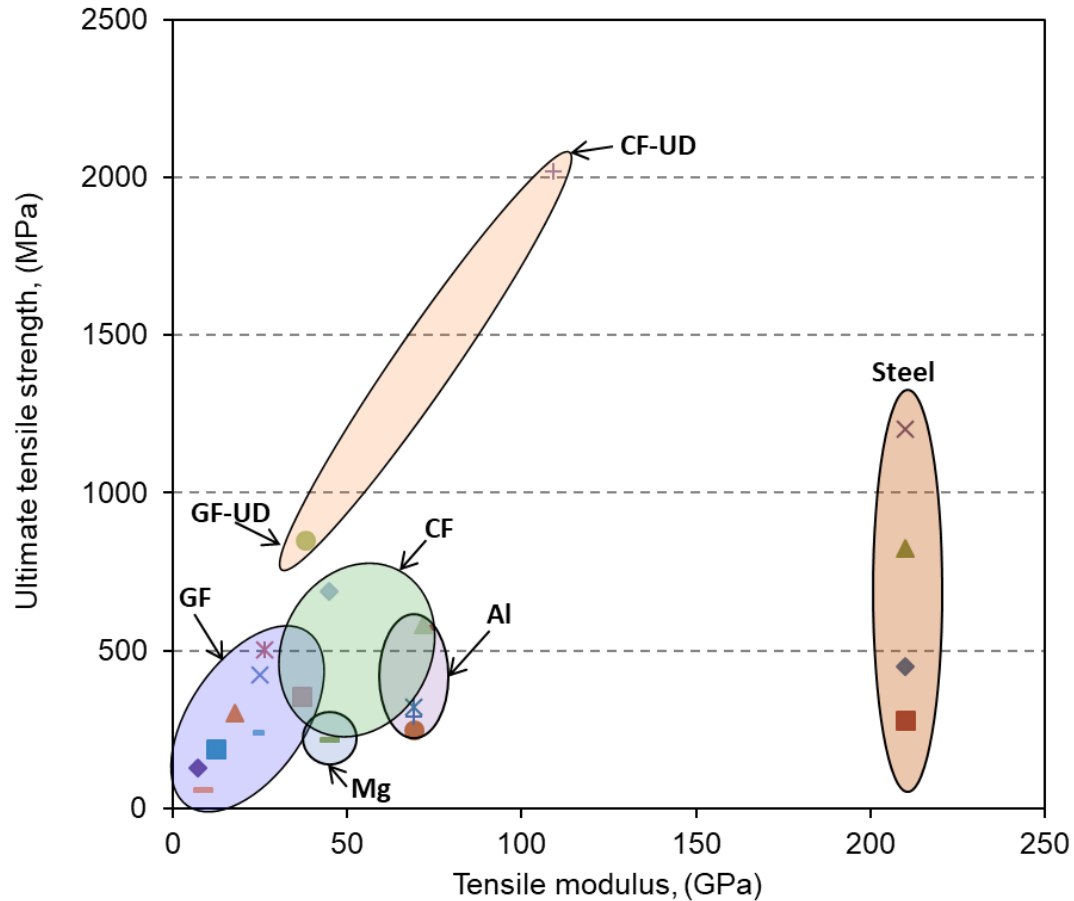
- OEMs need to reduce CO<sub>2</sub> and hence vehicle weight (to meet customer demands & emerging legislation)
- OEMs need robust solutions and available & equipped supply chains
- OEMs “Materials Blind”: need full package



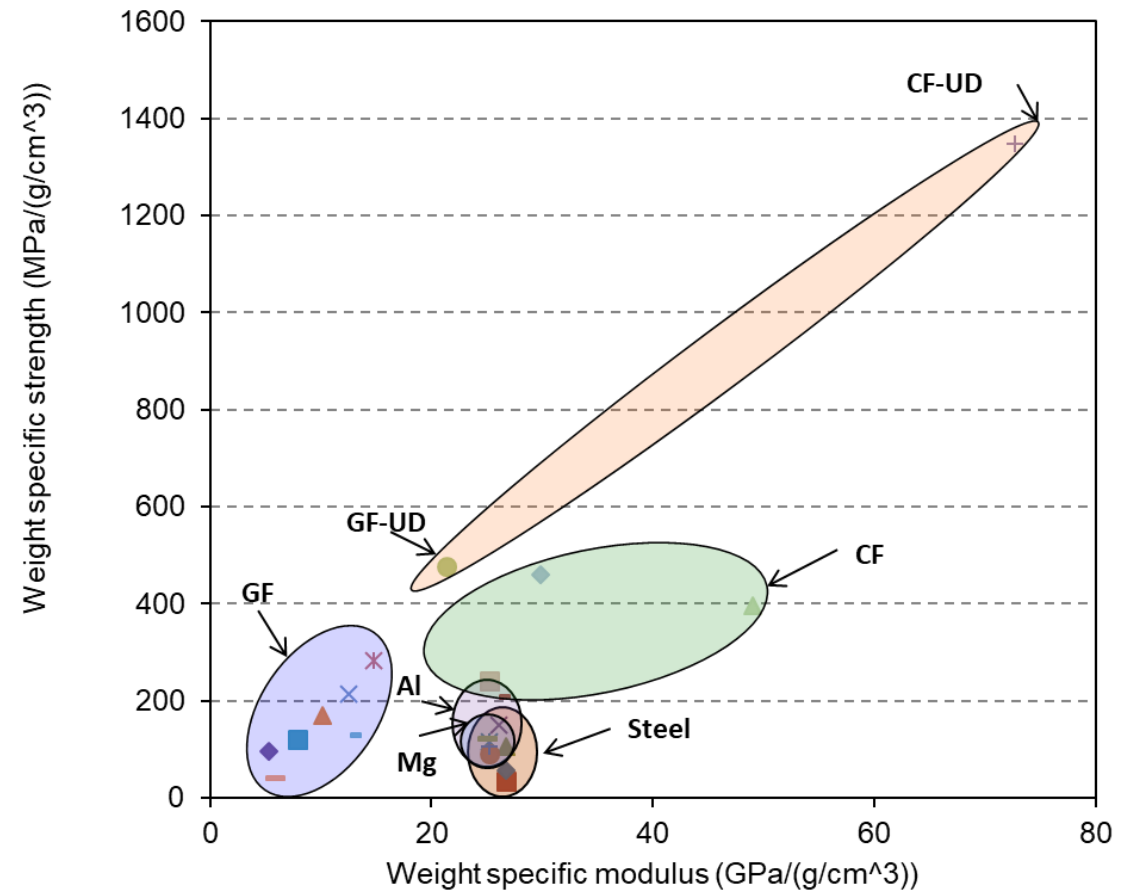
<https://www.epa.gov/automotive-trends/highlights-automotive-trends-report#Highlight5>

- Cost modelling approaches
- Technical cost modelling deep dive
- Cost modelling and technology strategy
- A simple cost tool
- Wrap up
- A simple cost tool

# Comparison of properties: strength and modulus

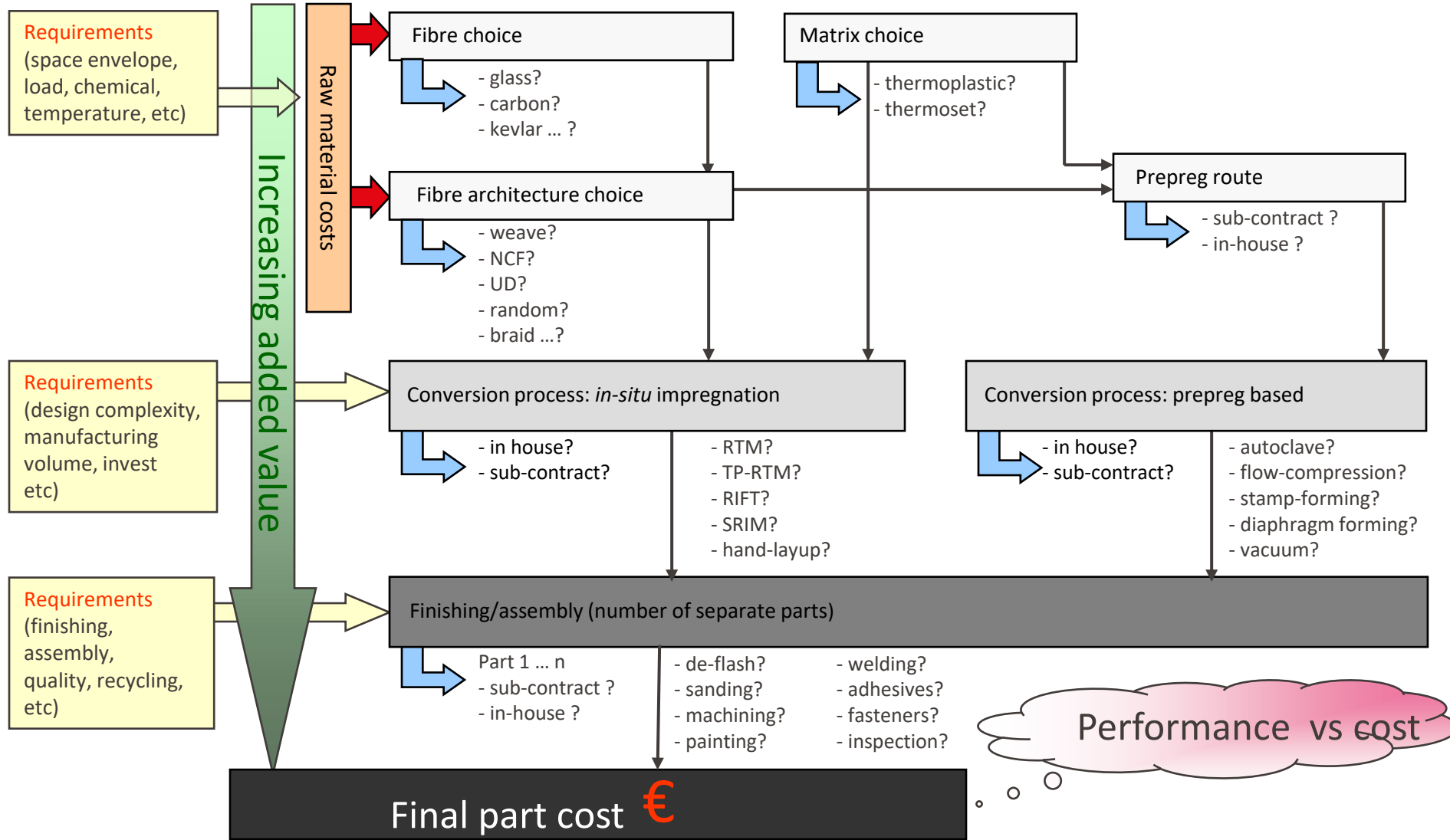


- **Steel is a very stiff material**
- **Other metals and plastics do replace steel while meeting stiffness needs by modifying the design (cross sections, ribbing etc)**



- **When density is included, steel, AL and Mg have similar weight specific stiffness.**
- **GF offers increased weight specific strength (crash)**
- **CF offers increased weight specific modulus and strength**
- **The most COST effective material is UD carbon fiber PA tape.**

# Using composite materials? ... a decision map!



# Questions

- What questions would you need to ask to work out how much these parts cost to make?



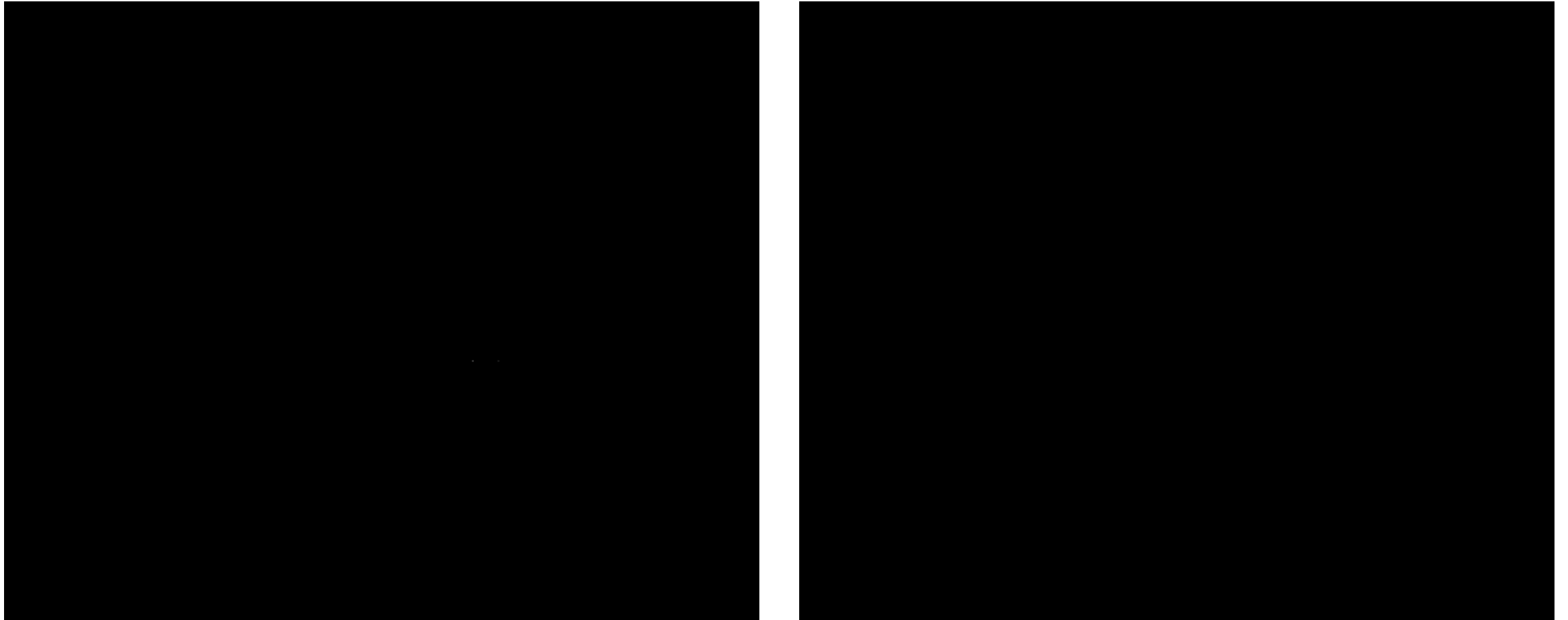
- **Weight save**  
 ???% vs. steel
- **Systems cost reduction**  
 ???%



(view from rear)  
 Stamped laminate insert

Finished part  
 laminate over-molded  
 with short-fiber resin

**Example of new approach:**  
 - design freedom & functional integration



**How can we understand the cost picture  
(investments and resulting part & assembly costs?)**

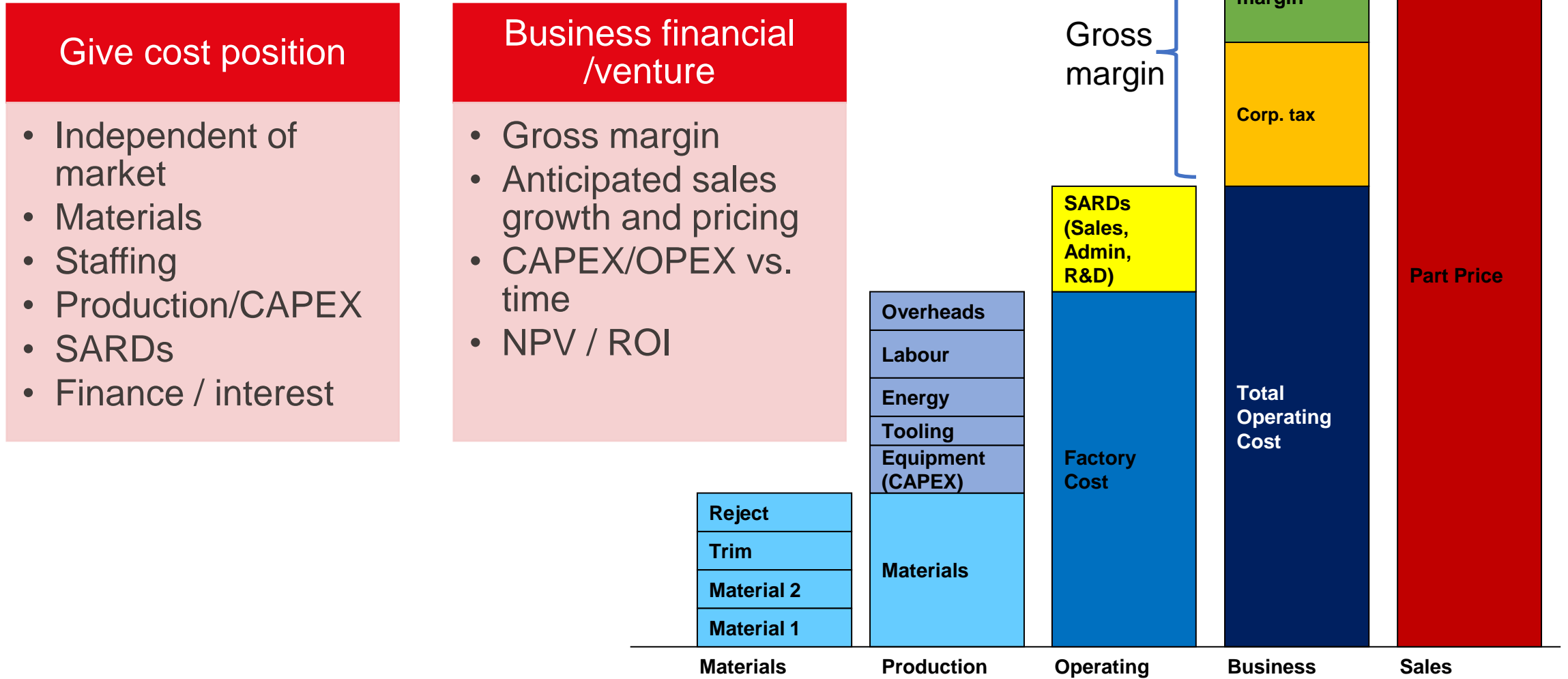
# slido



## Which variables need to go into a cost model?

① Start presenting to display the poll results on this slide.

# Elements and uses of a cost model



# What can cost modelling help you with

## Start-up

- Assess viability of your idea
- Work out cost of your product
- How the cost develops as you scale up the concept with time
- As supply chain evolves
- Fundraising

## Engineer in industry

- e.g. composites engineer
- Screening material and process options from existing qualified suppliers

## Industry initiatives

- New product/known market
- New product/new market
- Quantified value proposition, VOC,
- Financials: anticipated margin, CAPEX versus time, NPV & ROI

## Corporate R&D strategy

- Cost projections with market penetration models and needed CAPEX build
- Give comparative NPV and ROI predictions versus other investment candidates

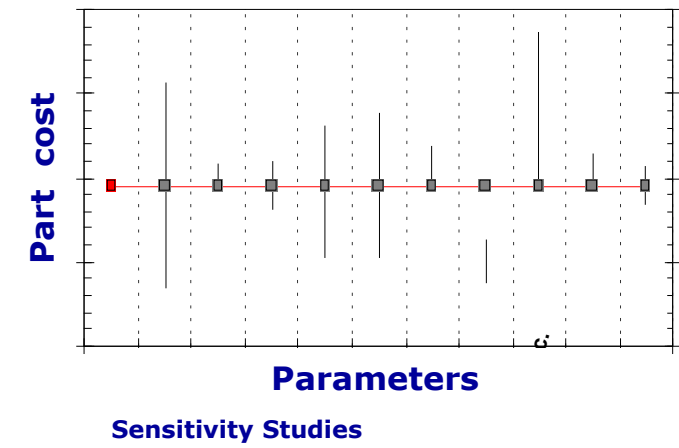
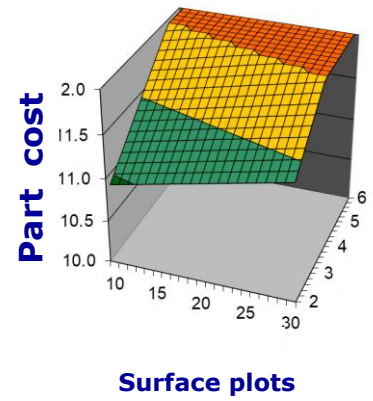
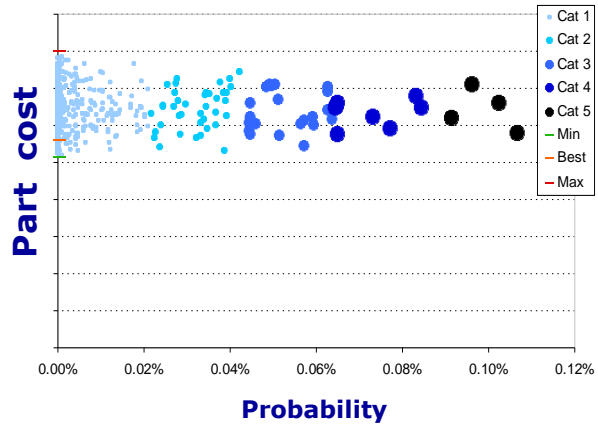
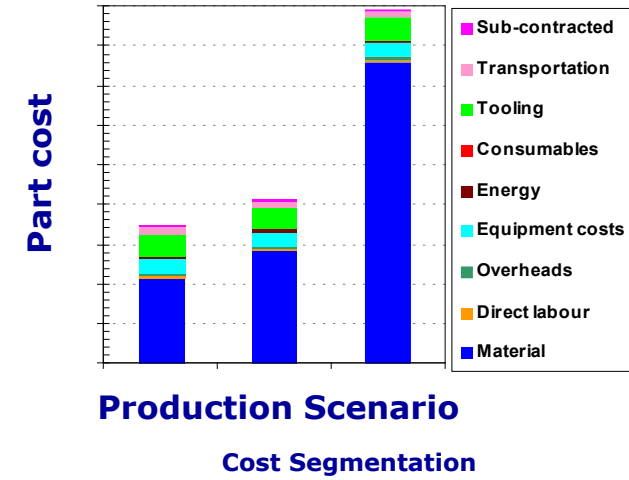
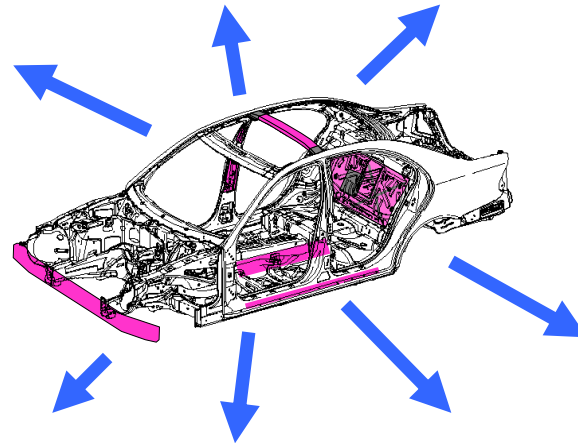
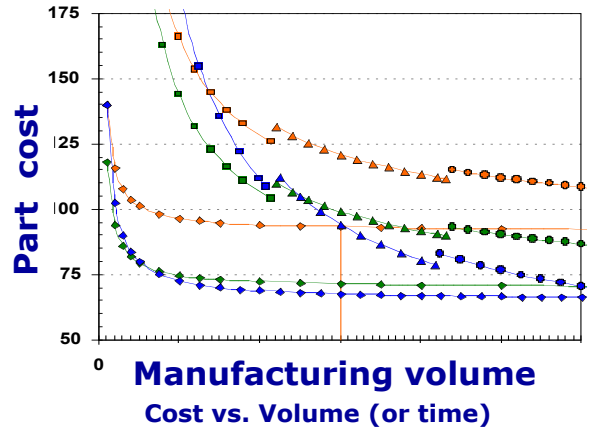
## Activity based costing

- Attributes direct and overhead costs to products and services based on the underlying activities that generate the costs
- Based upon historical data
- Can go to plant and clock process
- Of limited use when new processes are considered

## Technical cost modelling

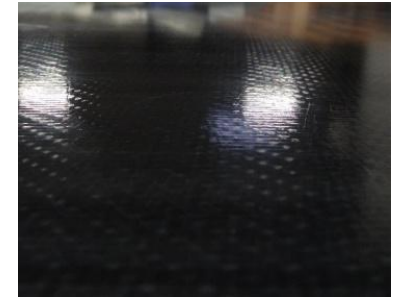
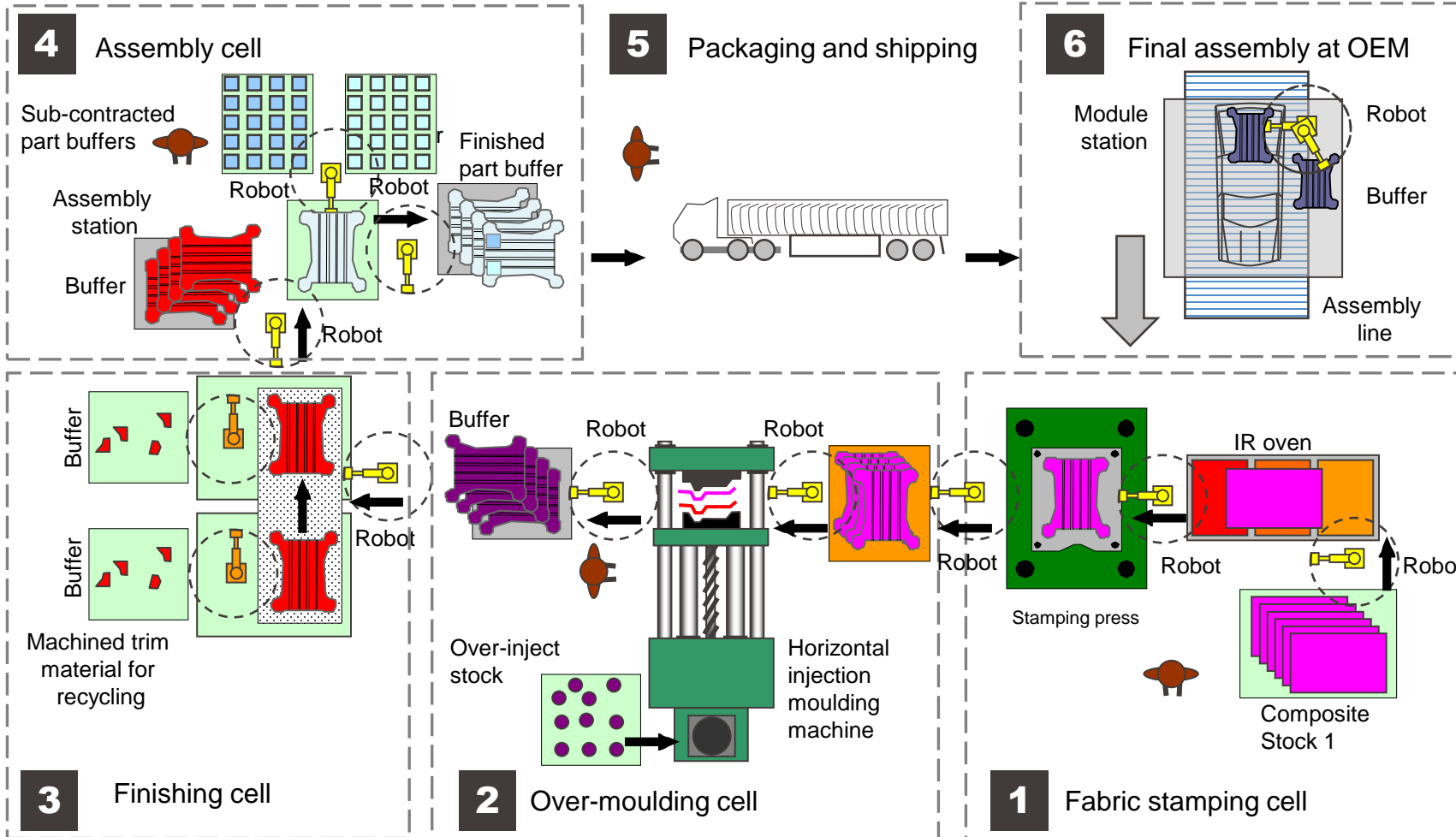
- Related to ABC
- Uses engineering, technical and economics characteristics associated with each manufacturing activity to evaluate its cost
- Where detailed overhead costs not available, volume based approximations are applied (ratio of direct to indirect labor)

# Examples of cost model output

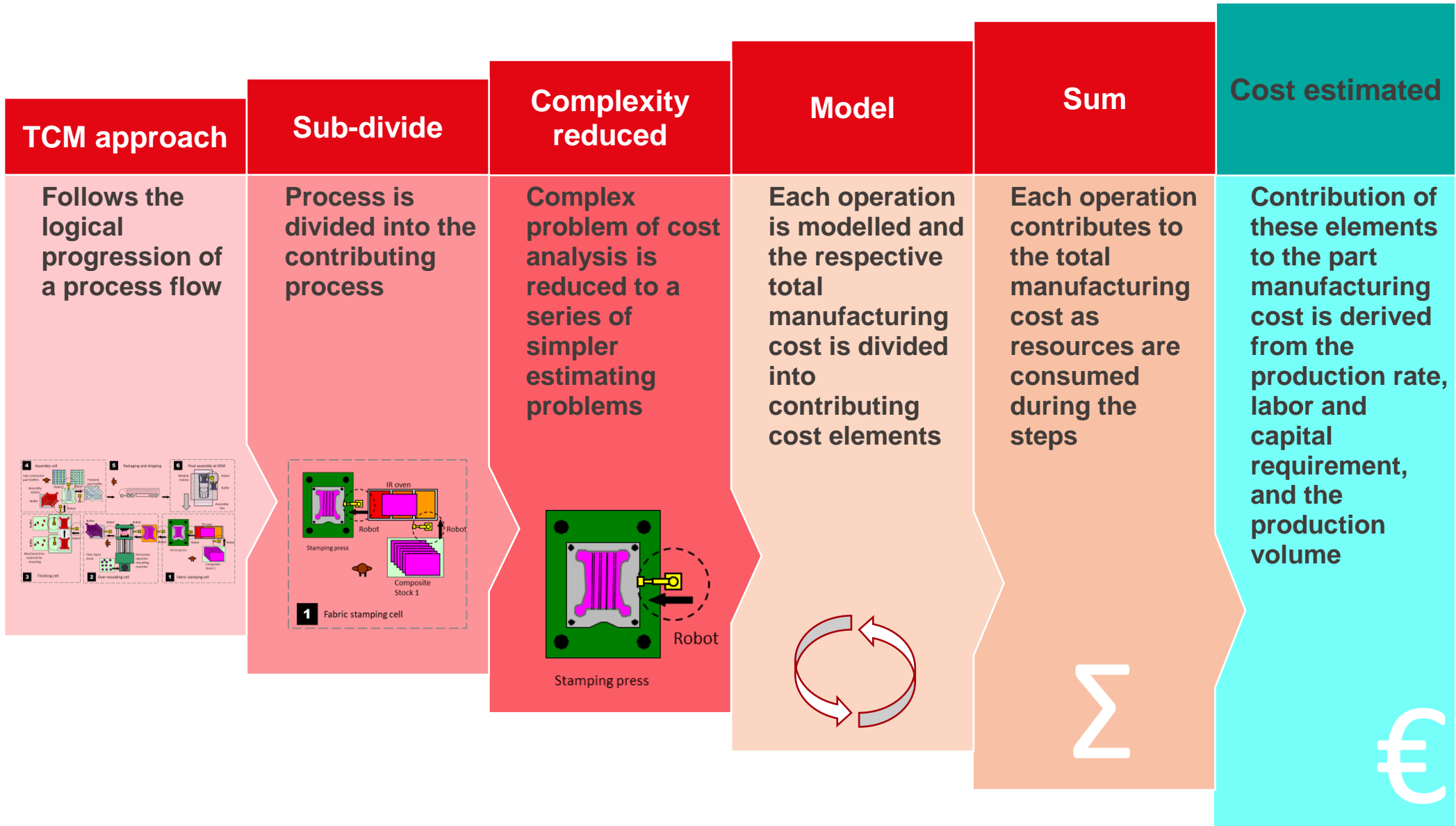


- Cost modelling approaches
- **Technical cost modelling deep dive**
- Cost modelling and technology strategy
- Wrap up
- Annex: A simple cost tool

# Example of a conceptual manufacturing plant



# Technical cost modelling approach



■ Plant

- Overall manufacturing system, could be composed of multiple lines

- Line

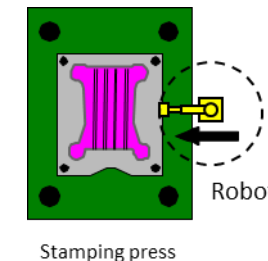
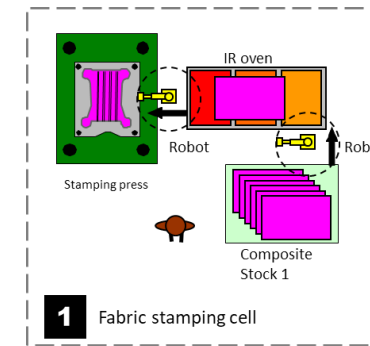
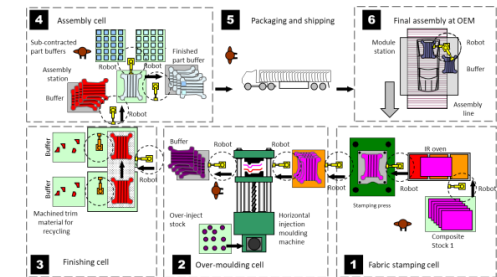
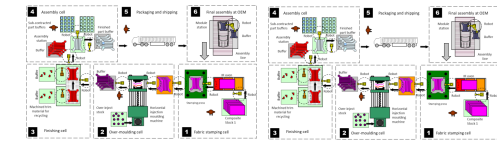
- The equipment needed to produce one part,
- e.g. the two cells of a stamping press and an injection cell

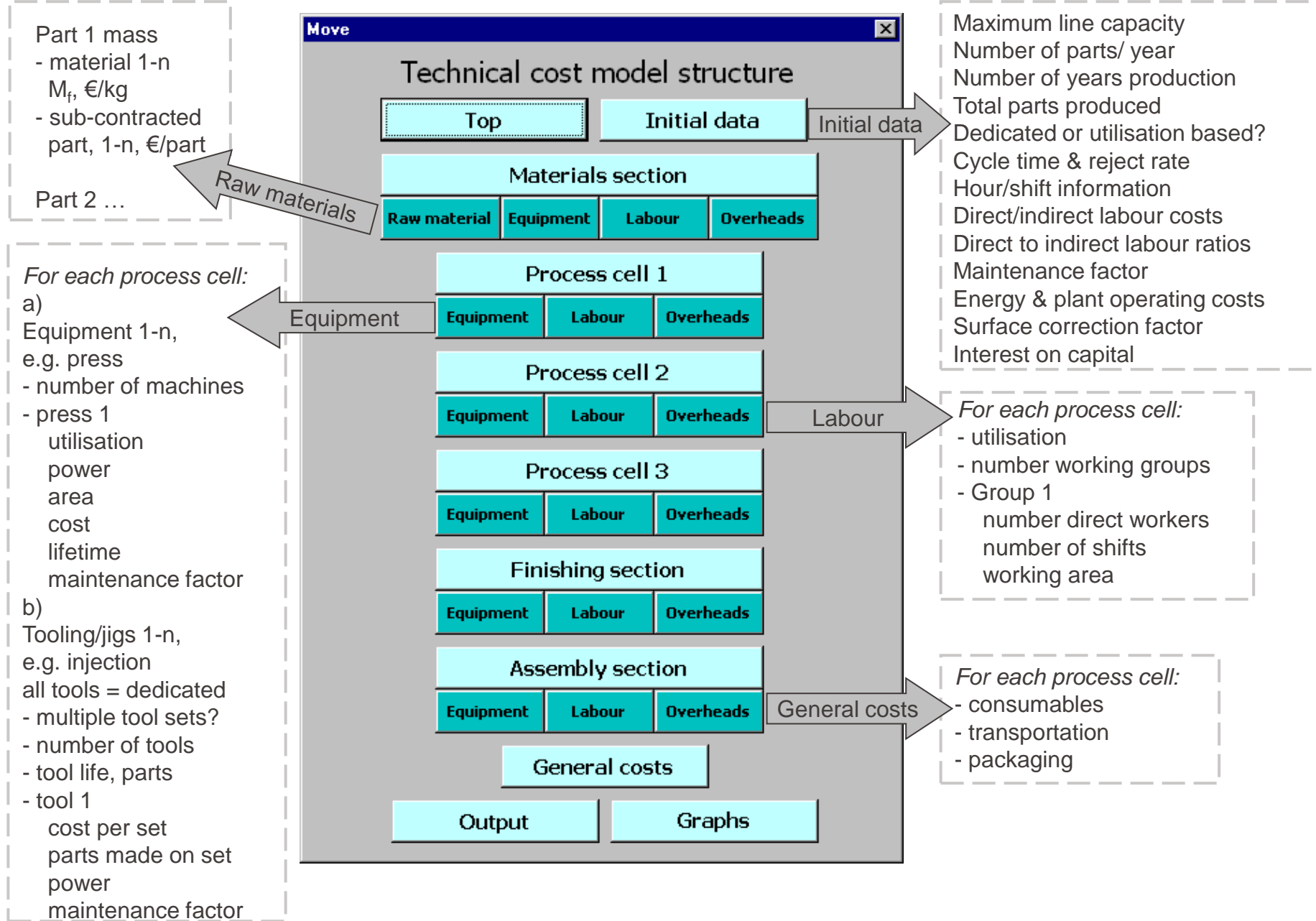
- Cell

- Key grouping of equipment that performs an integral linked operation within a line, e.g. an oven, robot, and stamping press

- Machine

- A piece of equipment within a cell, e.g. a hydraulic press





# Importance of data quality

Rigorous scientific exercise

Using experiments

FEA simulations / virtualization to aid data generation

Include the physics

Quotations: Building relationships with future suppliers

Regression models

Known to those skilled in the art

Consultants

Sensitivity analysis

“Garbage in, garbage out”



Your analysis is as good as your data.



Garbage in, garbage out.  
Data preparation is the most important step.  
Incorrect or insufficient data equals  
bad business decisions



**Chuck Robida**  
Chief Scientist, Experian  
@ExperianDA

#DataTalk  
ex.pn/datatalk

## ■ Papers

- Academic
- Press
- Trade / conferences
- Web

## ■ Patents

- Competitive intelligence

## ■ People

- Social media / LinkedIn
- Stakeholder interview
- Direct request



Design and Manufacture of Textile  
Composites

Woodhead Publishing Series in Textiles

2005, Pages 364-404



## 10 - Cost analysis

M D WAKEMAN, J-A E MÅNSON



# Overheads / general input data

- Your overall assumptions for the factory where the part will be made
- Can change by cell (to simulate different internal costs or a supply chain with each cell as a factory)

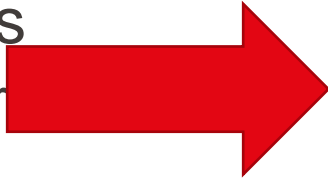


General input data	
Number of years production, [yrs]	4
Production period, [days/yr]	220
Hours/shift, [hrs]	7.3
Combined indirect & direct wage [€/hr]	40
Ratio indirect/direct labor	1
Unit energy cost, [€/kWhr]	0.1
Plant operating cost, [€/(m <sup>2</sup> /yr)]	120
Surface correction factor, [multiplier]	4.25
Interest on capital, [%]	0.06
3 shift: machine life, [yrs]	7
1 & 2 shift: machine life, [yrs]	7
Maintenance factor (% purchase), [€/yr]	0.07
Consumables/direct person, [€/hr]	0.5

An overhead view of a mold room in the new Lego factory in Nyíregyháza, Hungary. 672 newly purchased mold machines are installed at this location  
<https://lego-tenthings.weebly.com/legos--manufacturing.html>

# Labor costs by country

- Pay excl. social costs
  - EU average = €30/hr
  - Germany = €40/hr

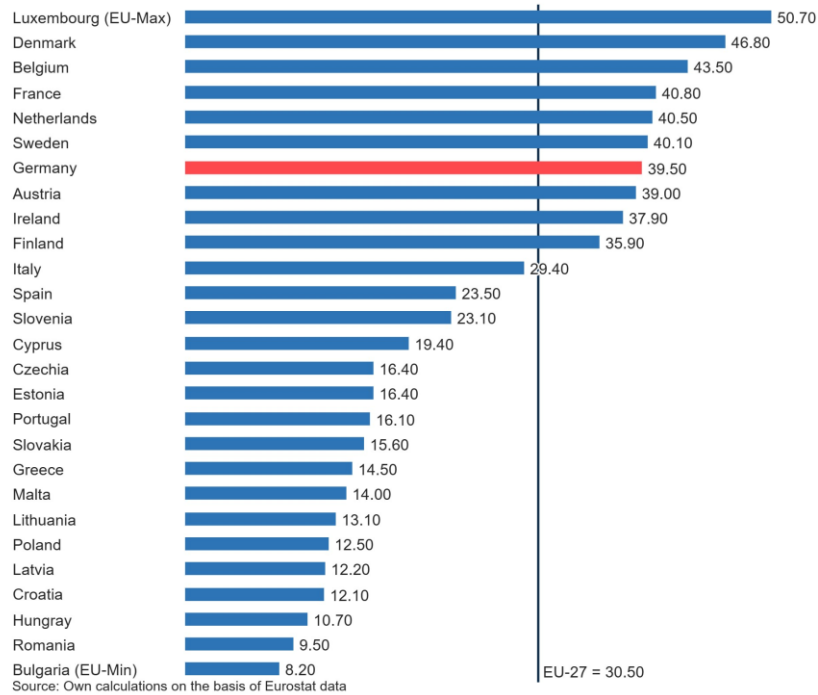


- Average EU social overhead is 20%
- **Direct labor cost in model is hence  $40 * 1.2 = €48 /hr$**
- **Indirect labor cost in model €56 /hr**

[Mercedes-Benz Group Technical Lead Salaries in Germany | Glassdoor](#)

Labour costs comparison across EU countries per hour worked, 2022

Industry, construction and services (except public administration, defense, compulsory social security), euros



© Statistisches Bundesamt (Destatis), 2023

One hour worked cost an average of 39.50 euros in 2022 - German Federal Statistical Office (destatis.de)

Hourly labour cost by economic section, 2020

Switzerland (private and public sectors), including apprentices, in Swiss francs



Source: FSO - Labour cost structural statistics

© FSO 2023

[Labour costs | Federal Statistical Office \(admin.ch\)](#)

[Social Security Tax Rates for Employers in Europe 2022 \(eurodev.co\)](#)

CHE  
Incl. overhead

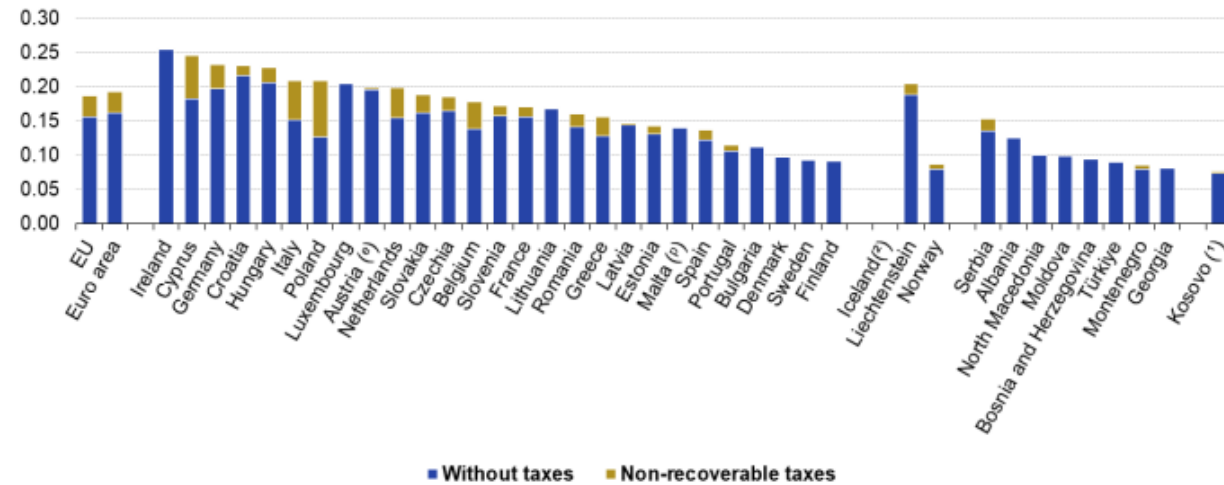
Country	SST Rate 2022	Population (2022)
France	40,00	65,273,511
Czech Republic (Czechia)	33,80	10,708,981
Sweden	31,42	10,099,265
Italy	30,00	60,461,826
Russia	30,00	145,934,462
Spain	29,90	46,754,778
Belgium	25,00	11,589,623
Portugal	23,75	10,196,709
Netherlands	23,59	17,134,872
Greece	22,54	10,423,054
Poland	22,14	37,846,611
Ukraine	22,00	43,733,762
Austria	21,38	9,006,398
Finland	20,66	5,540,720
<b>Germany</b>	<b>19,98</b>	<b>83,426,789</b>
Bulgaria	19,02	6,948,445
Hungary	17,00	9,660,351
Luxembourg	15,17	625,978
Norway	14,10	5,421,241
<b>United Kingdom</b>	<b>13,80</b>	<b>67,886,011</b>
Ireland	11,05	4,937,786
Canada	7,66	37,742,154
United States	7,65	331,002,651
Denmark	7,65	5,792,202
Switzerland	6,40	8,654,622
Iceland	6,10	341,243
Romania	2,25	19,237,691
Lithuania	1,77	2,722,289

# Electricity costs, non-household consumers

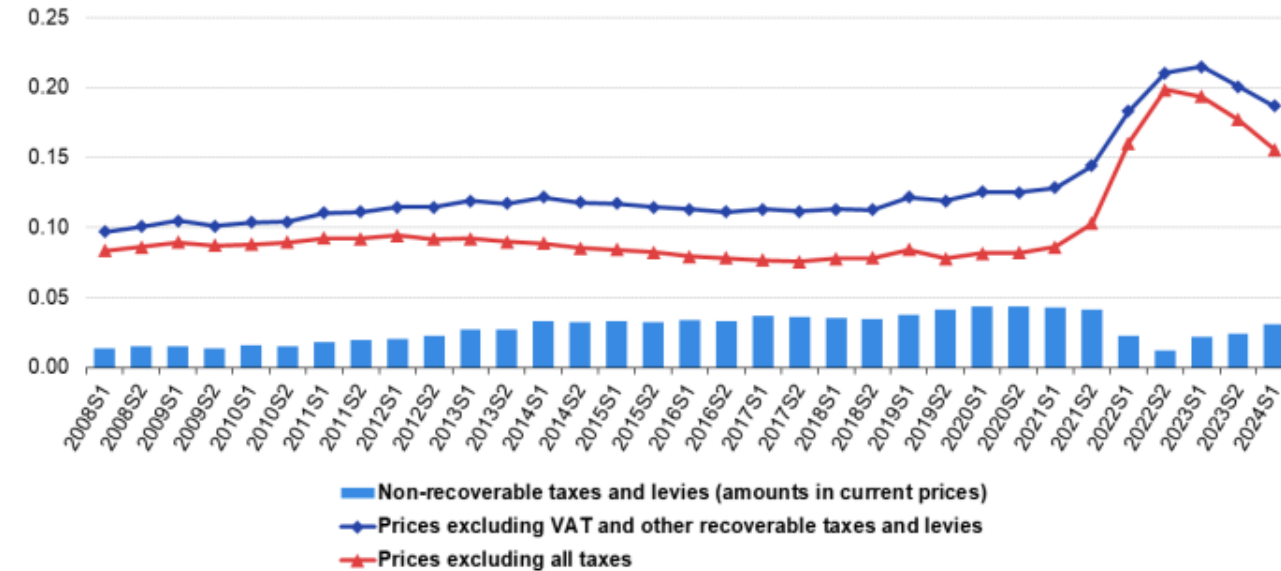
- EU average price 1<sup>st</sup> half of 2024 = €0.187 per kWh

- Pricing trend vs. time (VUCA world)

Electricity prices for non-household consumers, first half 2024 (€ per kWh)



Development of electricity prices for non-household consumers, EU, 2008-2024 (€ per kWh)



Source: Eurostat (online data codes: nrg\_pc\_205)



(\*) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.

(<sup>2</sup>) Not available

(<sup>e</sup>) Estimate

(<sup>p</sup>) Provisional

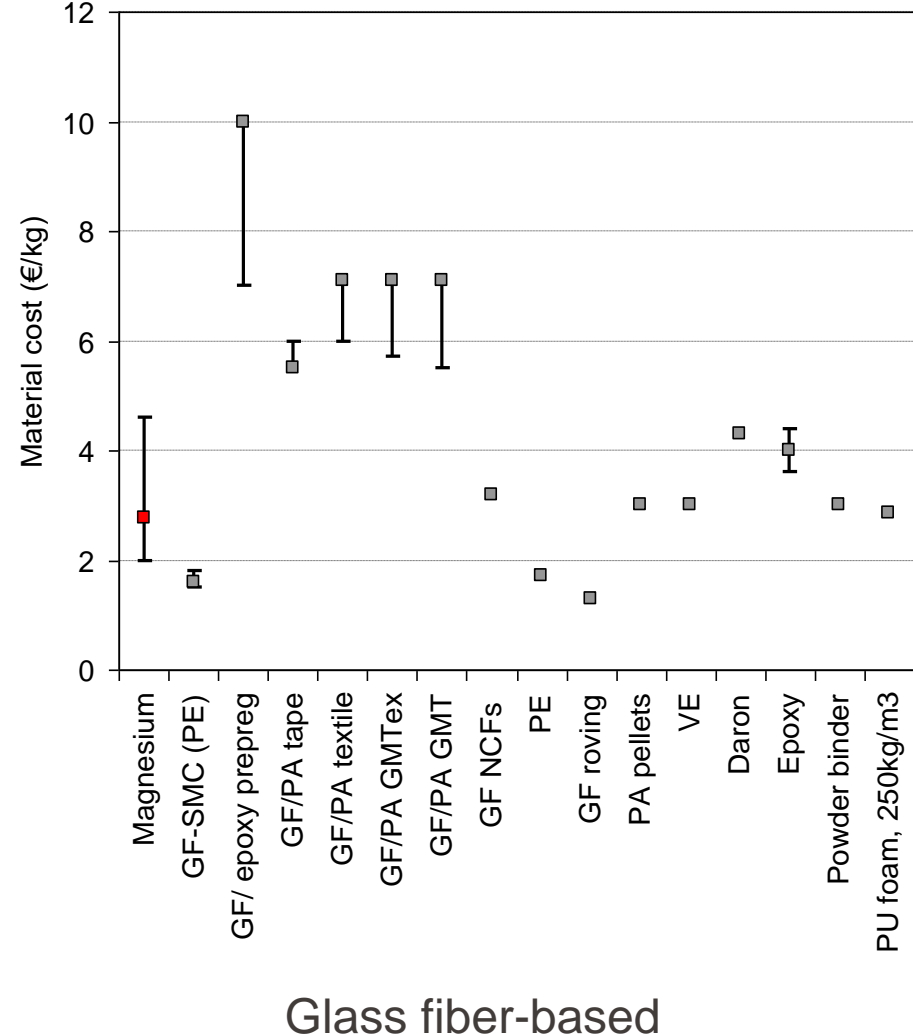
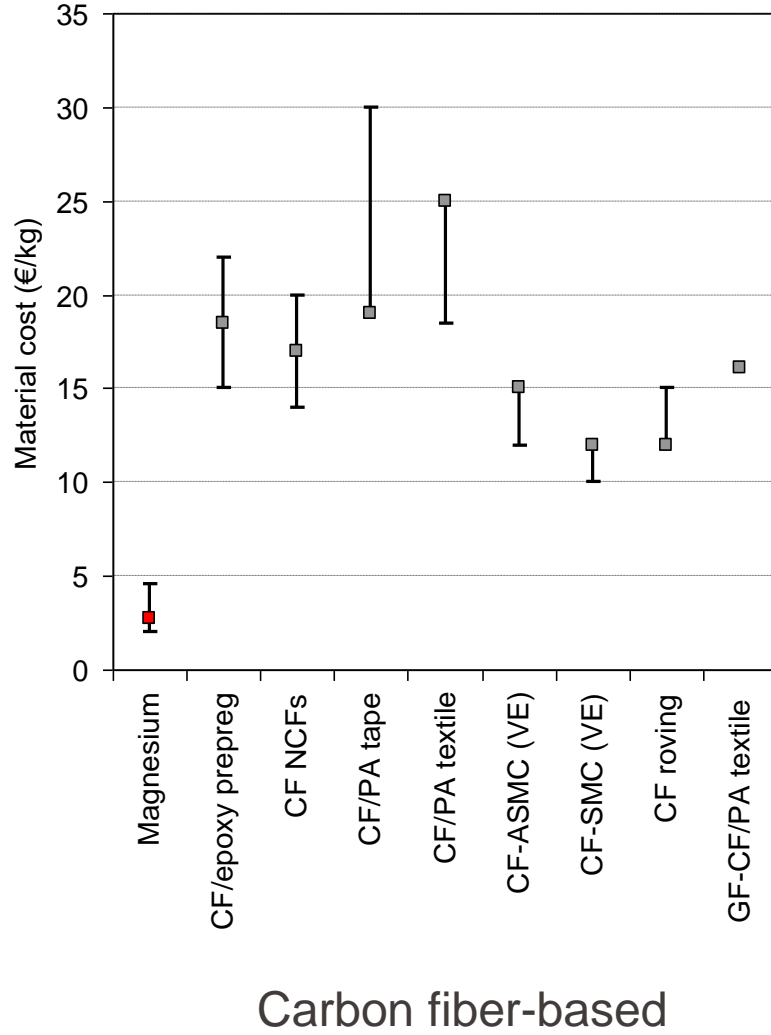
Source: Eurostat (online data codes: nrg\_pc\_205)



File:Electricity prices for non-household consumers, first half 2023 (euro per kWh) 23-10-2023.png - Statistics Explained (europa.eu)

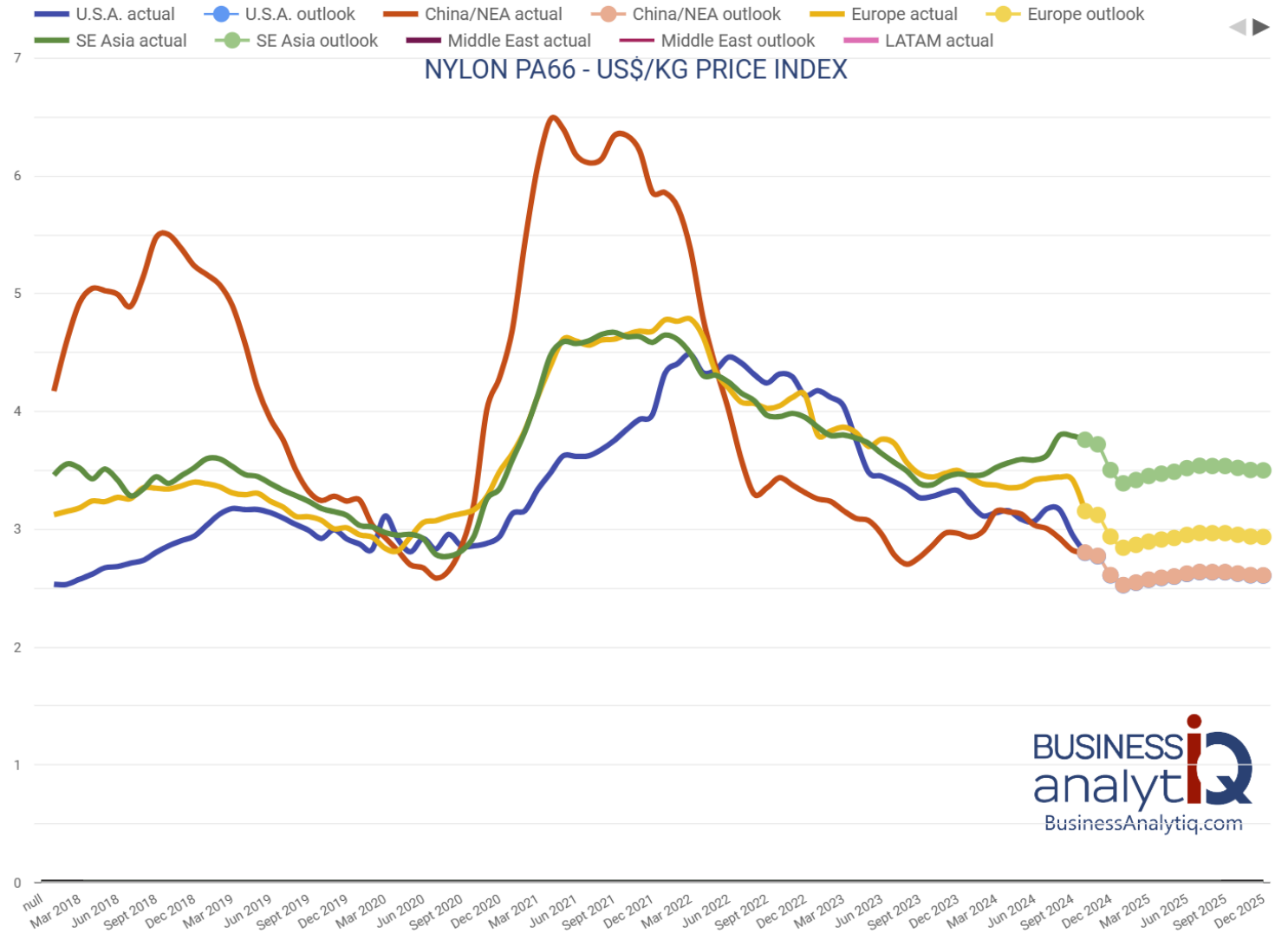
Electricity price statistics - Statistics Explained (europa.eu)

# Material cost assumptions (historical data ...)



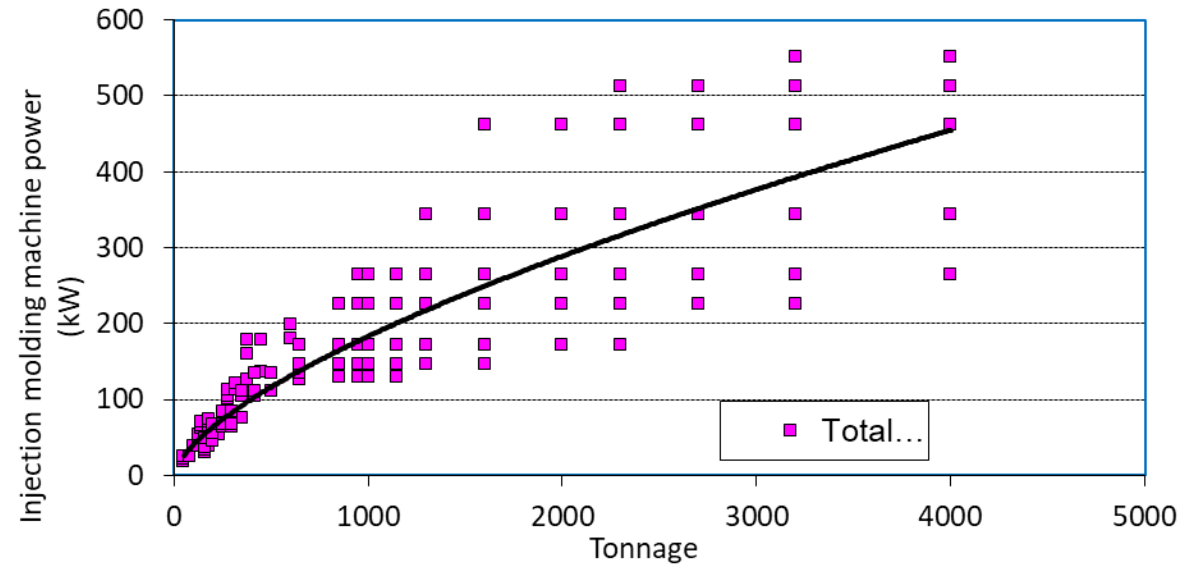
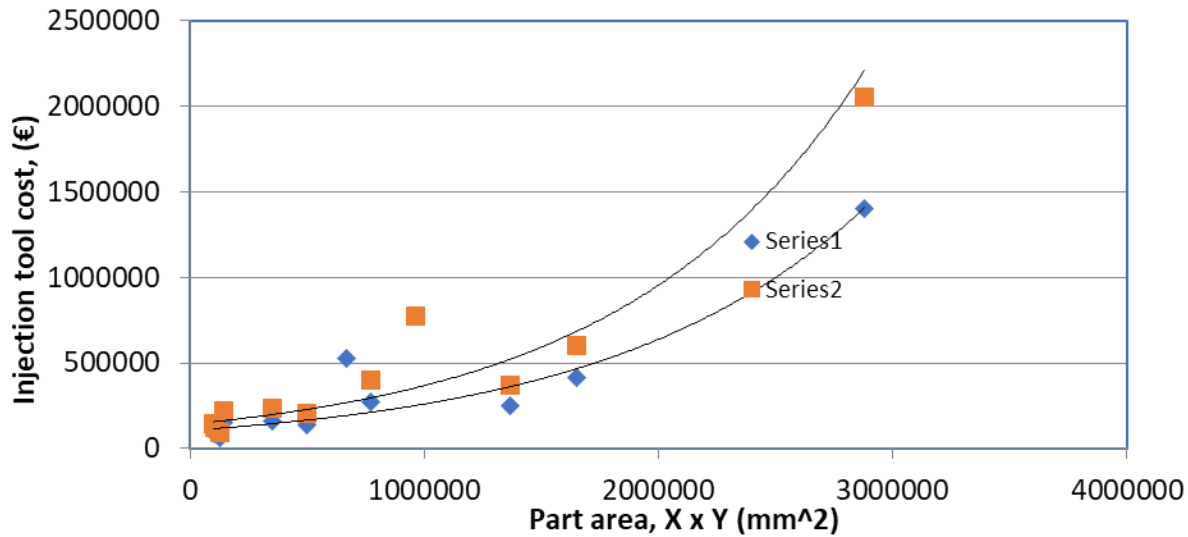
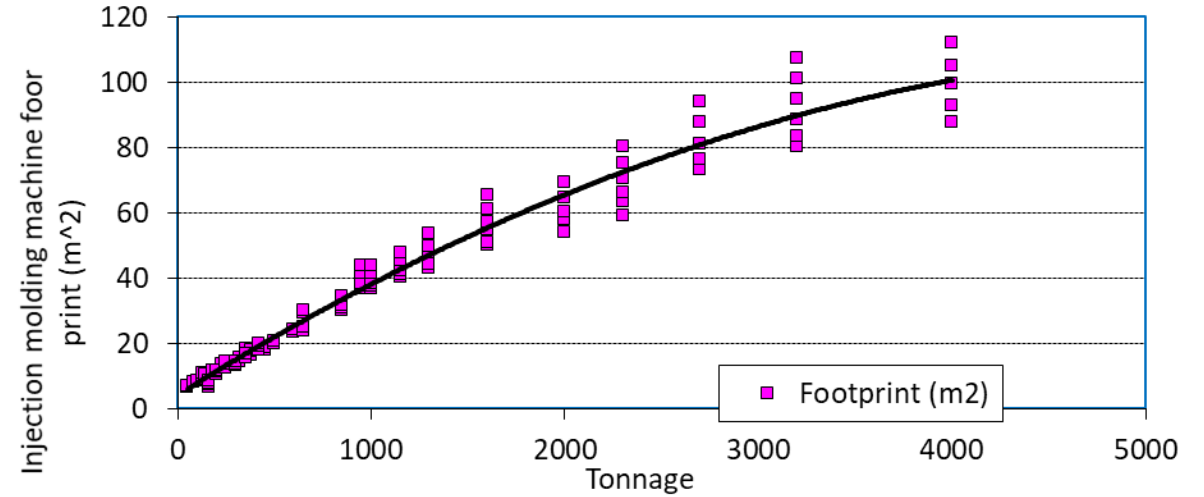
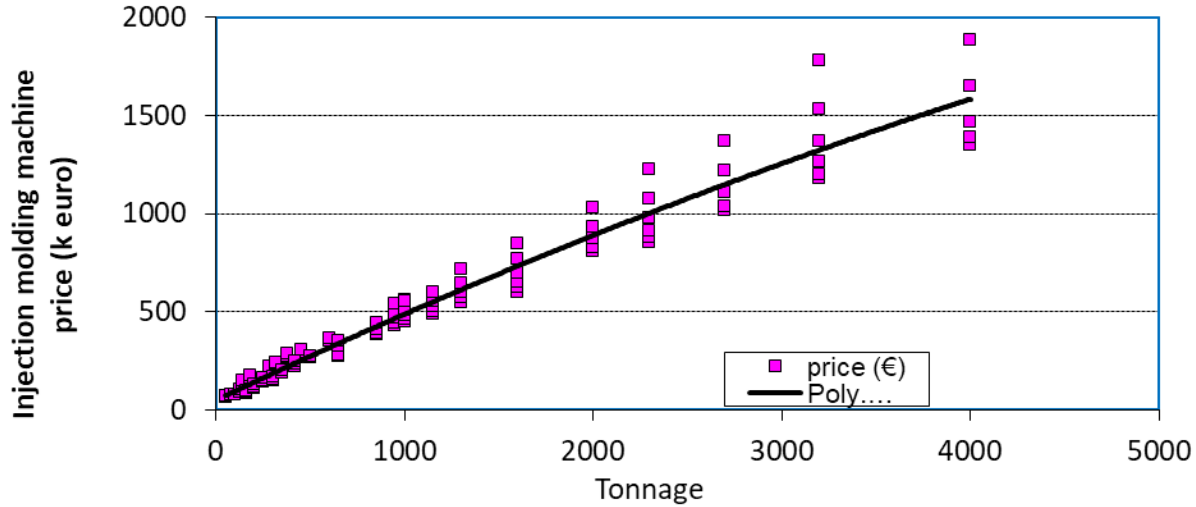
# Historical PA66 pricing

- Material cost varies with market conditions, oil price, geo-political tensions, extreme weather events, supply and demand, business strategy M&A



PA66 (Nylon 66) price index - businessanalytiq

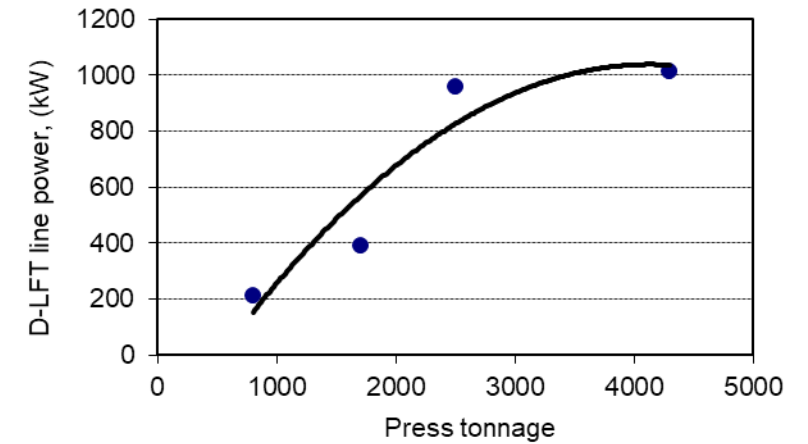
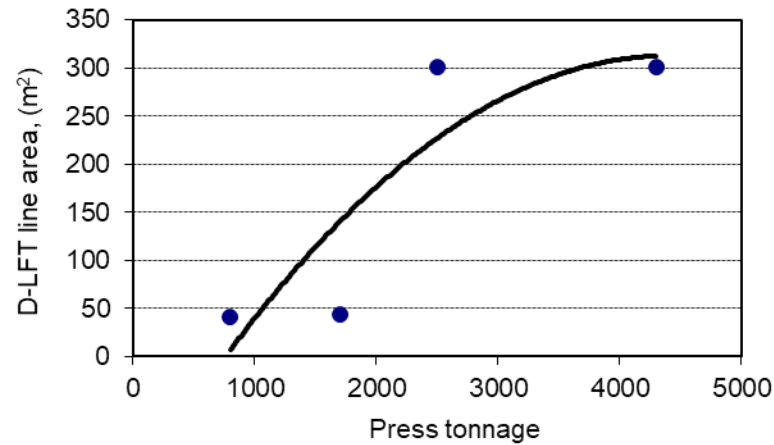
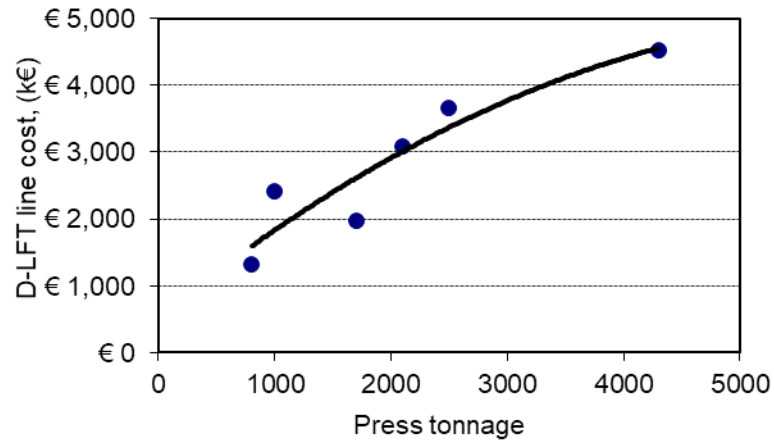
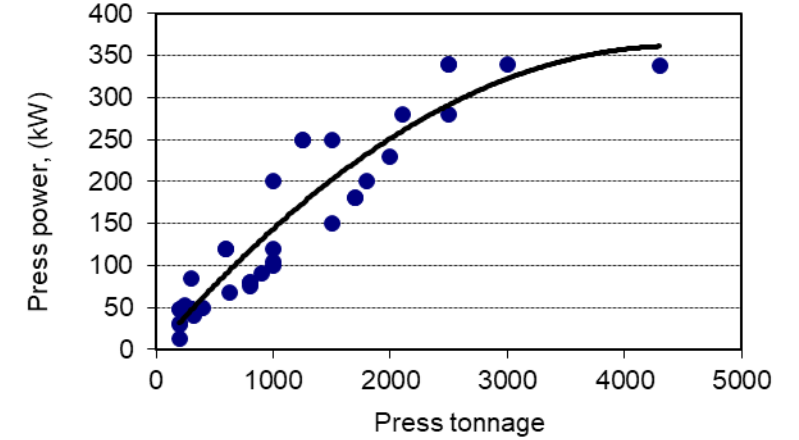
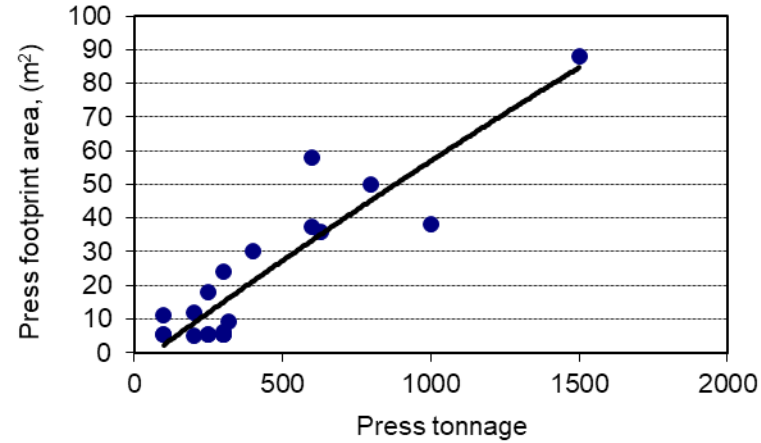
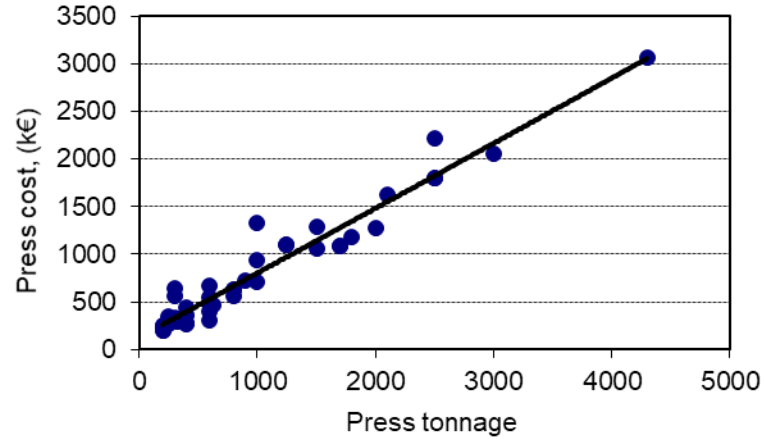
# Input data for injection molding



■ MSE-440

Cycle time approx. 7s/mm thickness, plus 5 sec allowance/part  
AND robotic transfer (fast is 7s one side, up to 14s)

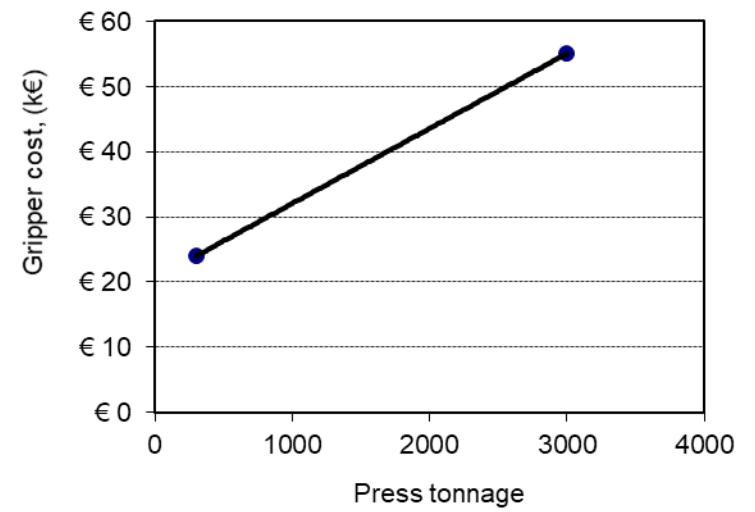
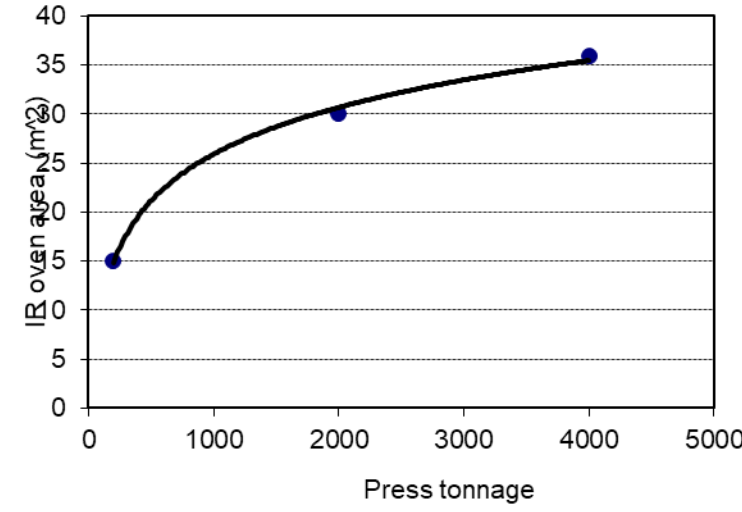
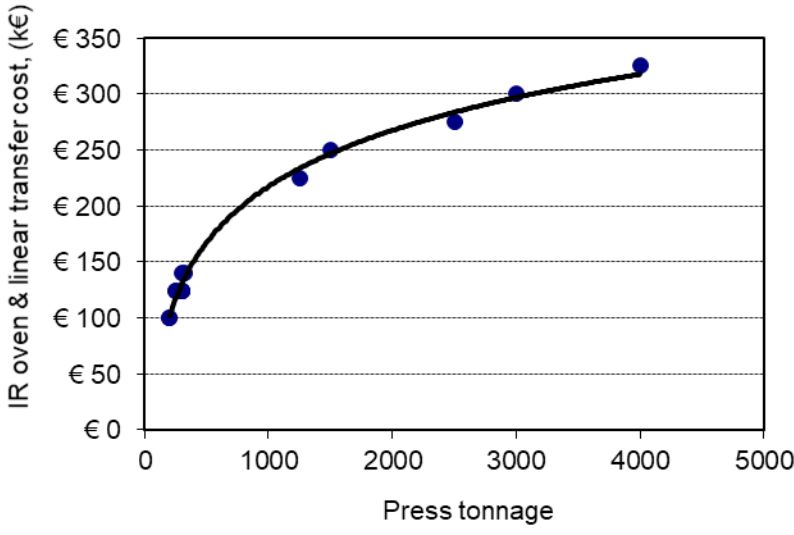
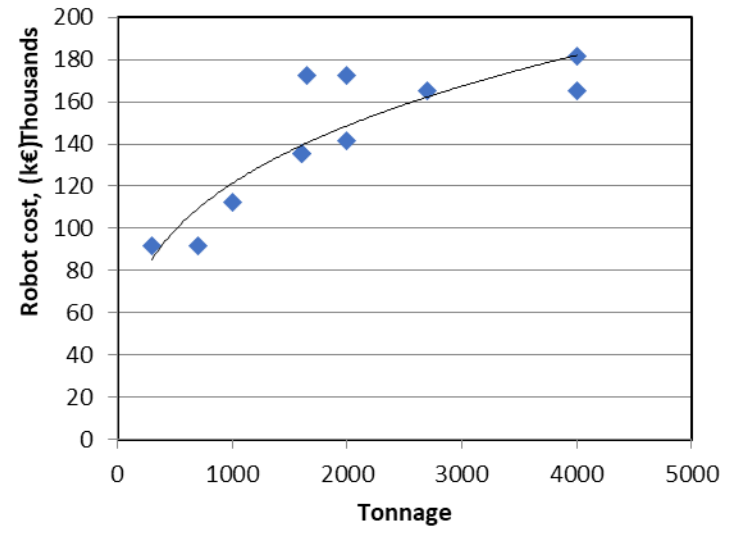
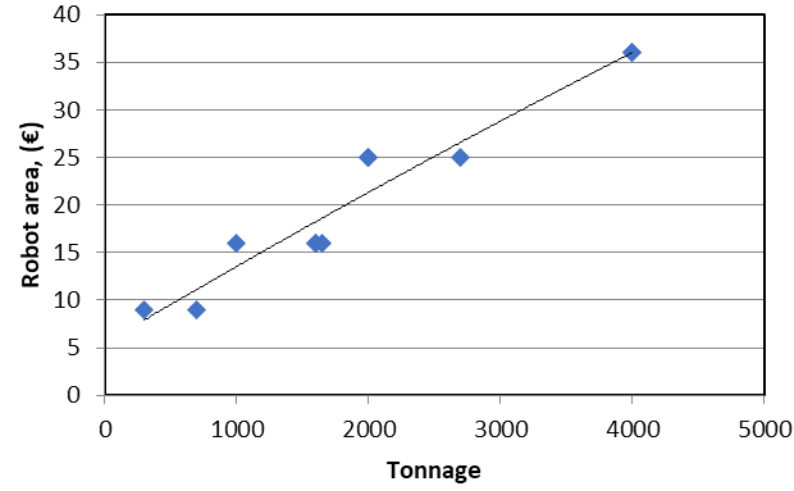
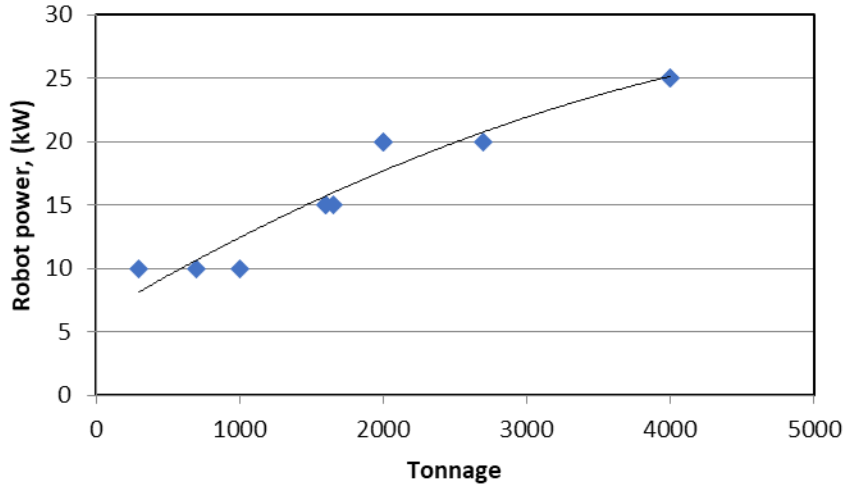
# Input data for press molding (HP-RTM, D-LFT, TPC)



press tonnage rule  
50-60 k euro per 1000kN press force



# Automation, ovens



MSE-440

Wakeman

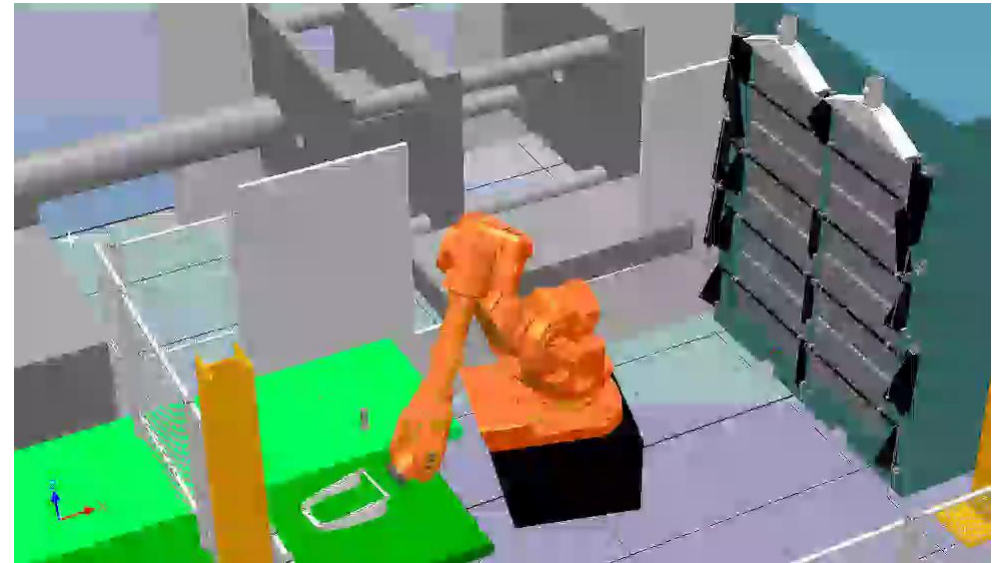
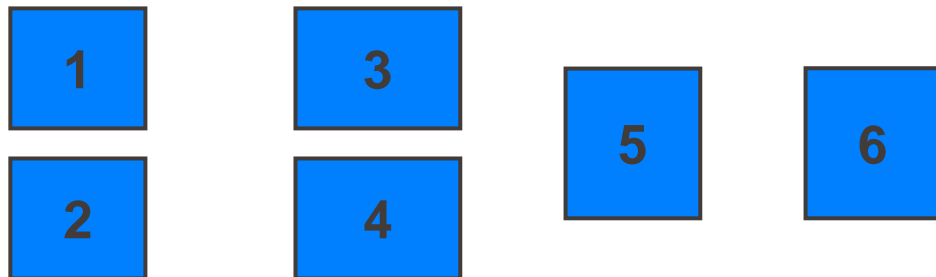
# Process Flow - Series & Parallel

- Steady State

- Series

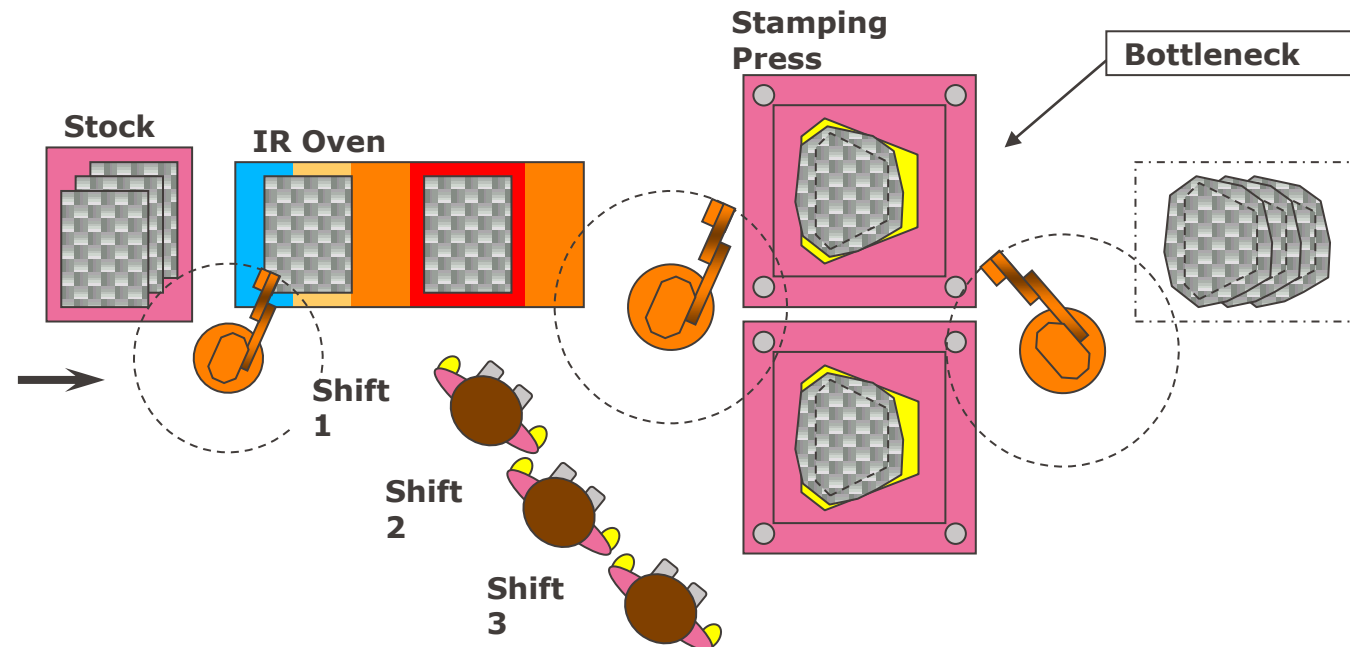


- Parallel Converging (assembly)



# To meet desired manufacturing volume

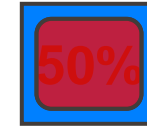
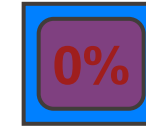
- Multiplication to meet Target Production Volume
  - If production capacity of the specified setup is lower than the target volume required, labour, activities and tooling must be added in parallel as follows:
  - **First** - add extra shifts until maximum number per day
  - **Second** - add machines or entire cells in parallel



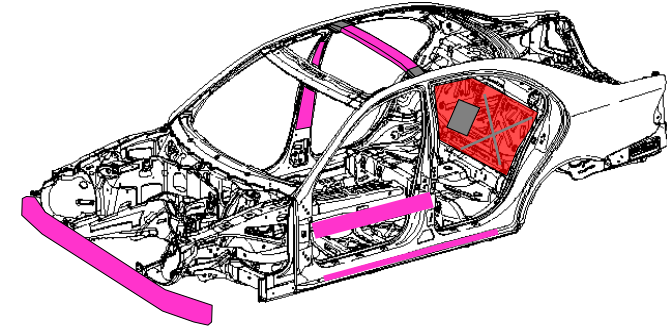
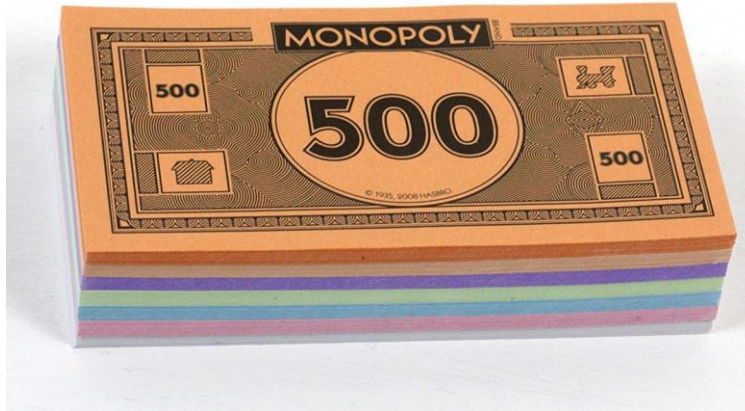
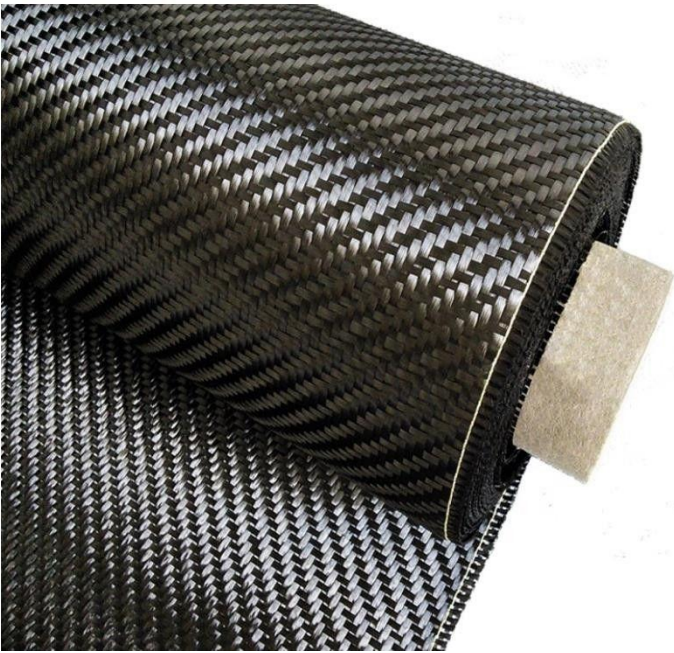
- Manufacturing line not necessarily the same at low and high volume,
- Need to use different plant diagrams and assemble the cost curve

# Inclusion of reject and trim in the process flow

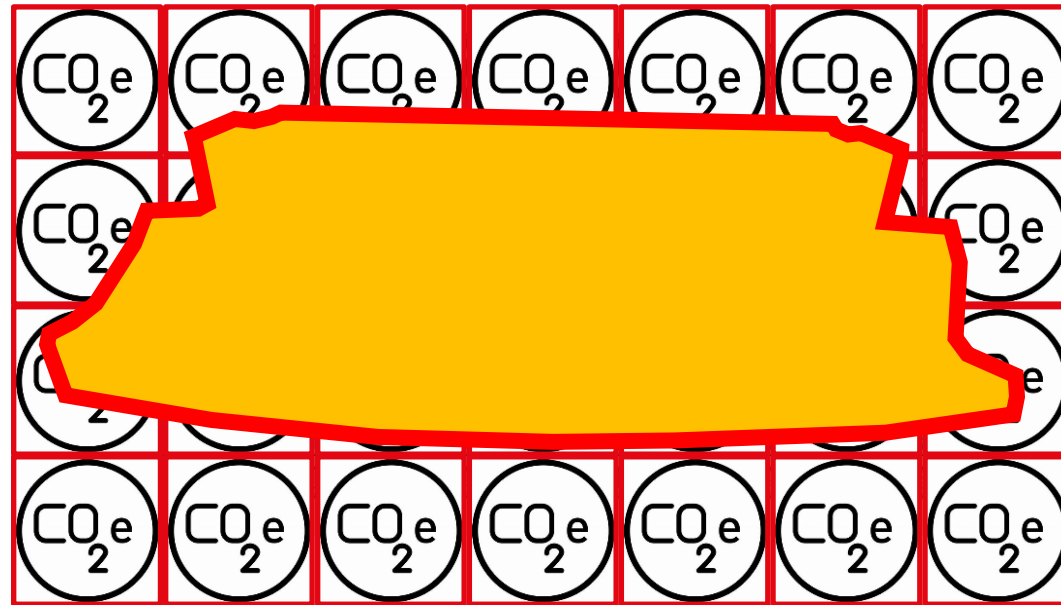
- Trim – needed for a good part
  - Increases the required material mass IN and hence part cost (does not affect machine utilization)
- Reject – (bad part) increases the required production rate
  - Cumulative over cells and machines
  - Need to buy more material and machine time
  - Affects plant utilization downstream of the rejects
  - Rework possible
- **Avoid Trim and Reject!**



# Post industrial CF waste ?



Buy to fly 1.5:1



# Segregation of cost elements

## CAPEX

- **Capital expenditures (CapEx)**
- Funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment
- CapEx is often used to undertake new projects or investments by a company
- **CAWC**
  - cost associated with capital (installation), sometimes CAPEX + CAWC = 1.5 to 2.5x CAPEX

## OPEX

- **Operating expenditure**
- Ongoing expenses inherent to operation of the asset
- Includes items like electricity, salaries, R&D, travel, SG&A (selling, general and administrative expense)

# Segregation of cost elements

## Fixed costs

- Typically a one-time capital expenditure
- Capital investments that are necessary for the manufacturing facility
- Fixed costs per piece vary according to the production volume
- As volume increases, fixed costs are reduced because the investment can be amortised over more parts
- e.g. machine, tooling, maintenance, cost of capital, and building costs

## Variable costs

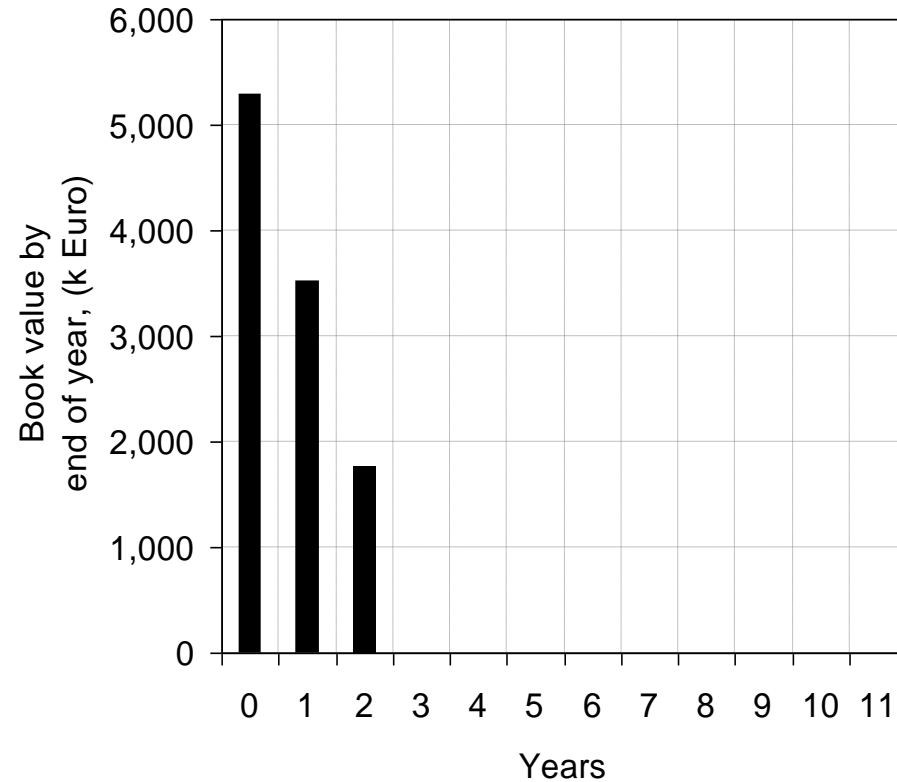
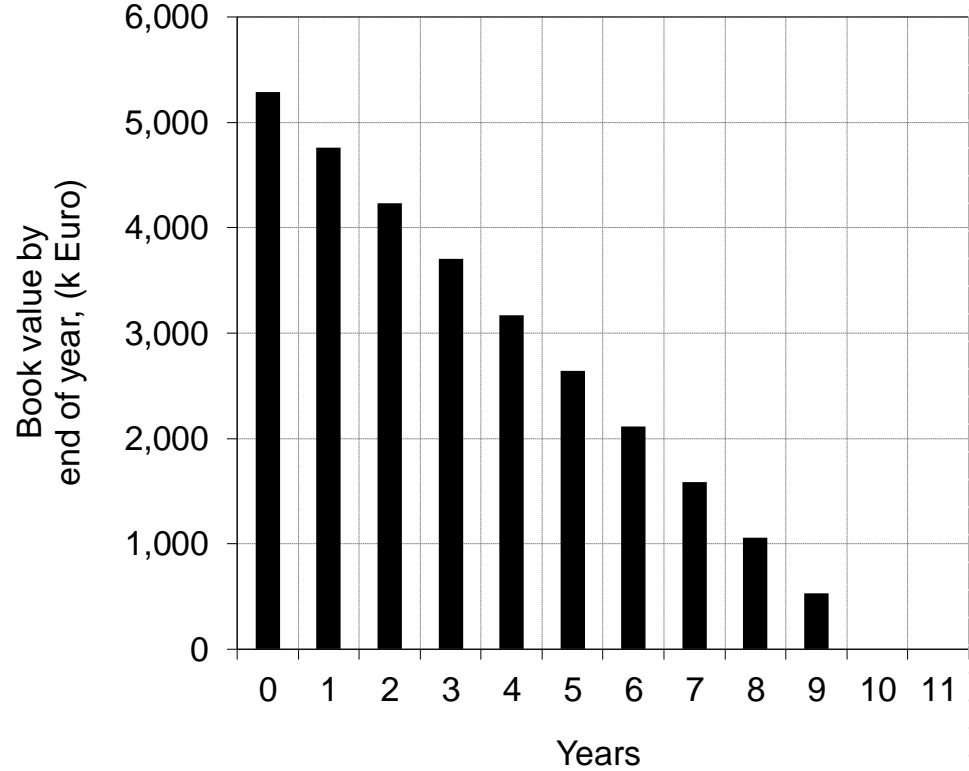
- Independent of the manufacturing volume within a given time frame
- e.g. raw material cost, labour, energy, and sub-contracted costs
- Can push fixed costs towards variable costs by contract or toll manufacturing (don't own asset)

# Depreciation of fixed capital *(heavy process equipment)*

(3 shift pattern = 7 year plant life)  
(2 shift pattern = 10 years plant life)

3 years depreciation  
(dedicated line assumption)

Linear depreciation



Tooling cost is always dedicated to the part (cost/number parts), e.g. steel IM tool = €1,000k

# Amortization of plant costs

- Amortization of plant costs can be approached in two manners

## Dedicated

- Whole line dedicated to one product
- All of the fixed plant costs are amortised over the number of parts produced for the total years of production
- Cost against volume graphs can be generated simply by assuming that the full plant costs are spread over the parts produced
- Strongly increasing costs at lower volumes

## Utilized

- Multiple products
- Only a fraction of either a line capacity or a plant would be assigned to one product while the remaining capacity would be sold to a second client
- Fixed plant costs are amortised as a fraction of utilisation and the number of shifts and years that the plant is used
- Effectively giving a charge rate per minute for a manufacturing line

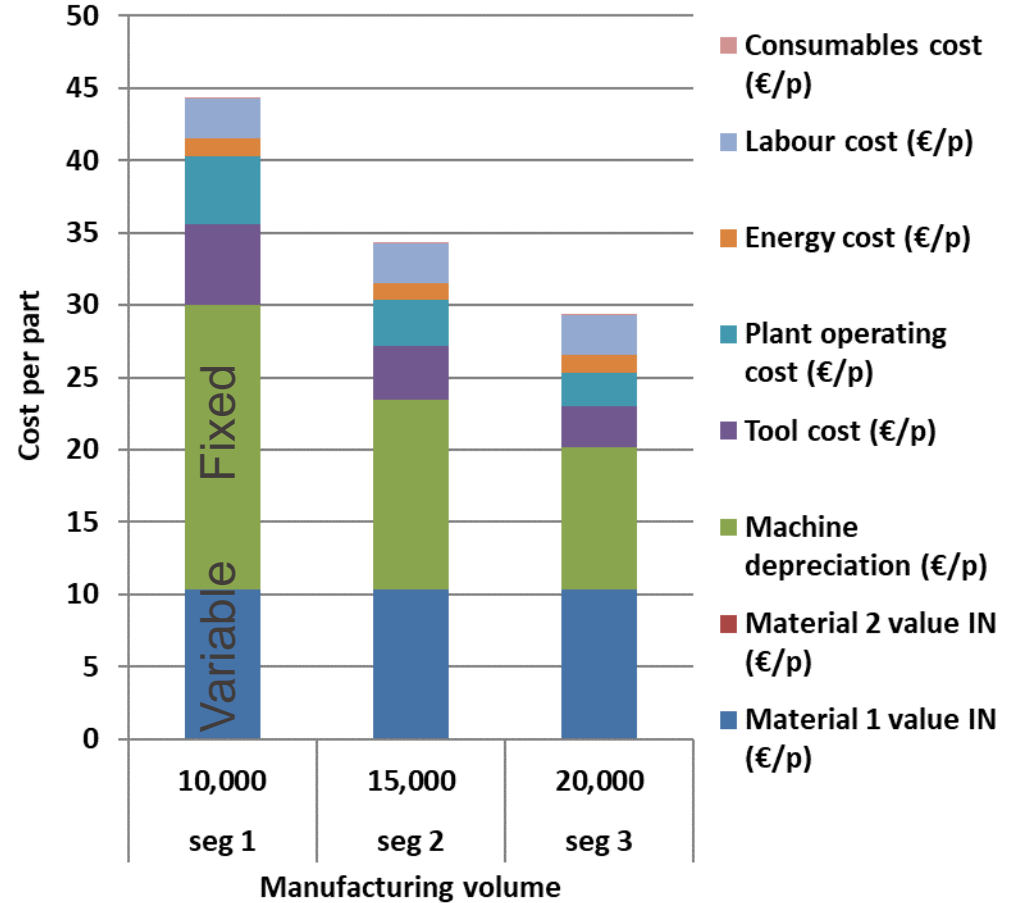
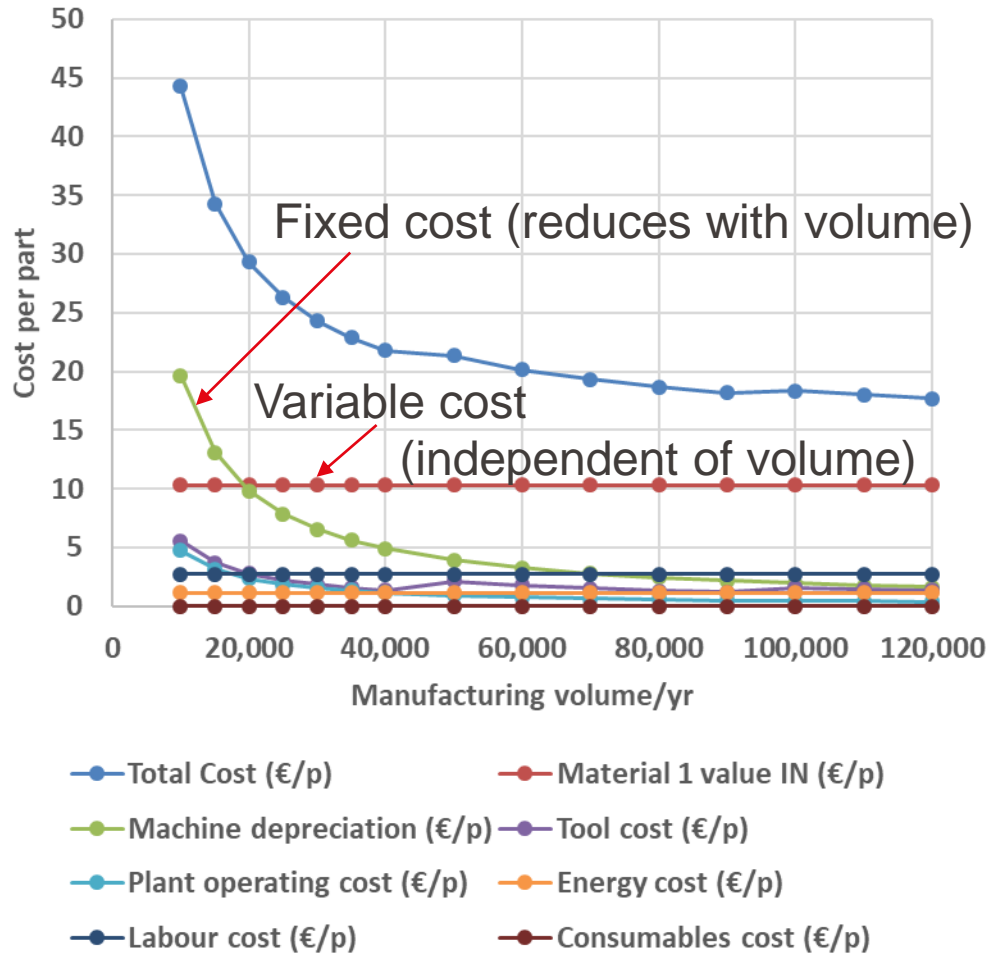


Dedicated



Utilized

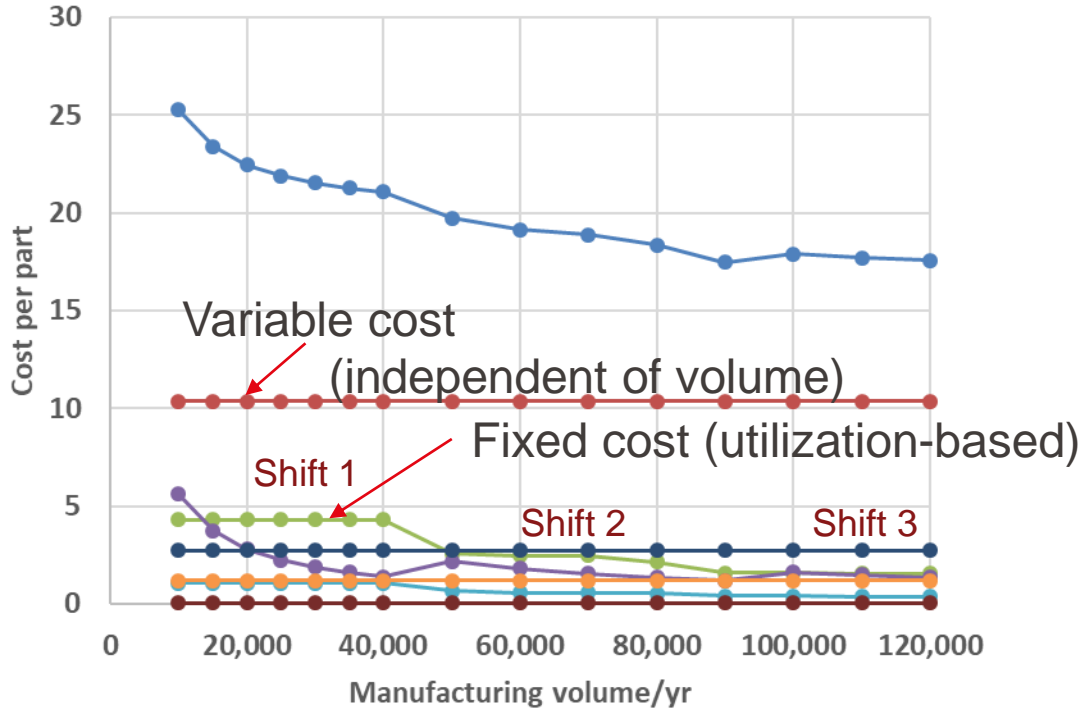
# Example of fixed and variable costs from simple tool



Dedicated plant

# Utilized vs. dedicated: fixed and variable costs

Remaining capacity paid for by different product or client

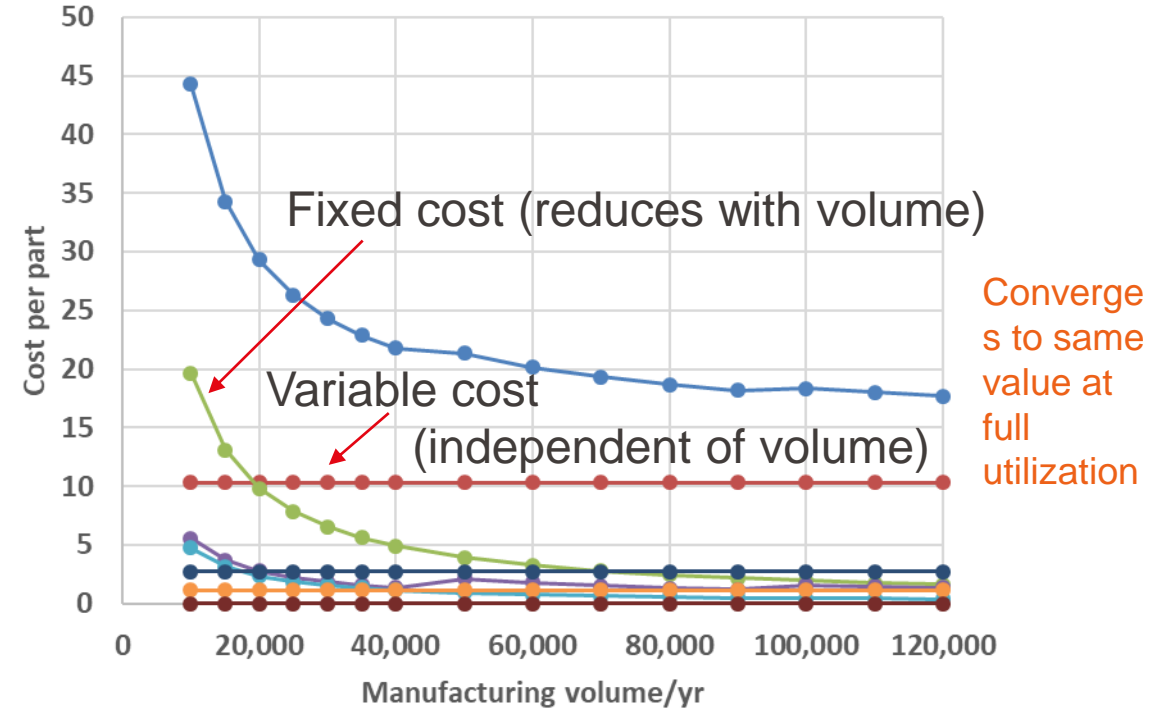


- Total Cost (€/p)
- Machine depreciation (€/p)
- Plant operating cost (€/p)
- Labour cost (€/p)
- Material 1 value IN (€/p)
- Tool cost (€/p)
- Energy cost (€/p)
- Consumables cost (€/p)

Utilized plant

Tooling here is part specific, so dedicated

ALL capacity paid for by ONE product or client



- Total Cost (€/p)
- Machine depreciation (€/p)
- Plant operating cost (€/p)
- Labour cost (€/p)
- Material 1 value IN (€/p)
- Tool cost (€/p)
- Energy cost (€/p)
- Consumables cost (€/p)

Dedicated plant

Converges to same value at full utilization

# Cell utilization and technology maturity

## Established technology

Utilization based  
Open booking  
accounting within  
automotive  
standard practice

Assume that any  
remaining capacity  
is used by

- a different product
- a different client

## Novel technology

Dedicated equipment for a  
cell or for a full line

Where the investment is  
highly part specific

Where the OEM requires  
exclusivity, or risk

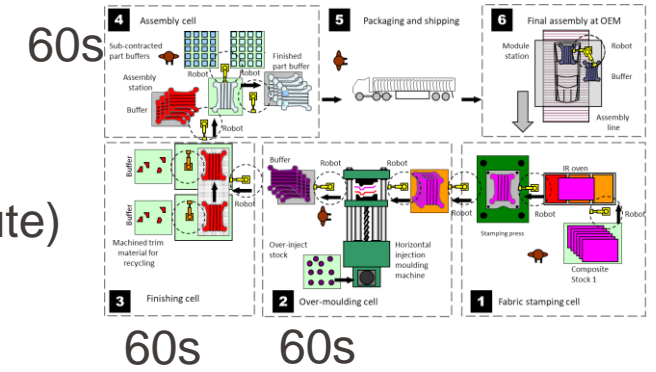
For the first applications,  
the risk of empty capacity  
or the lack of plant  
flexibility may require the  
plant to be costed as  
dedicated

## Low volumes

Dedicated  
plant can  
really  
penalize  
novel  
technolog  
y at low  
volumes

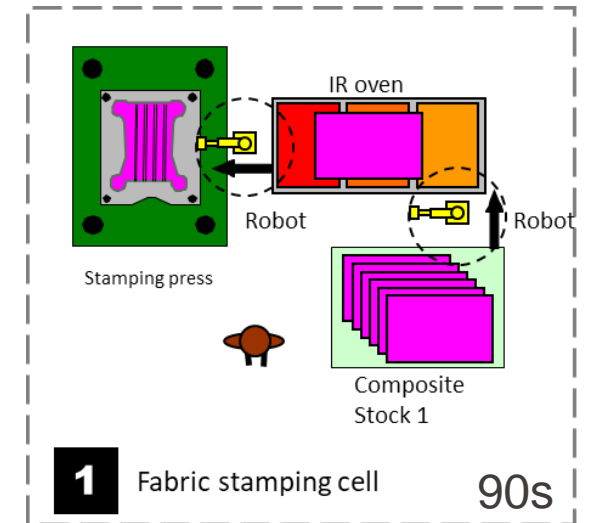
# Cell grouping (and assumptions) within a plant

- Cells can be modelled as:
  - A) Dedicated (amortization over number of parts made)
  - B) Utilization based (amortization over full capacity, cost per minute)



## Adjusted

- Based upon cycle time in each cell
- There will be a bottle neck cell in any process
- A slower cell reduces a faster cell's maximum utilization
- Adjust cell cycle time and % utilization to bottle neck



# Part mass as a key driver in a cost model

## Part mass (bill of materials)

- Often high contribution to overall cost
- Sensitive parameter
- Prototype tooling and physical testing are costly

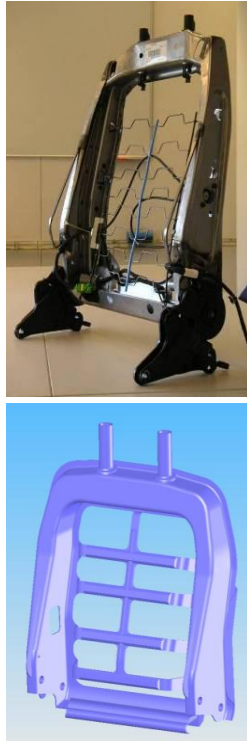
## Virtual prototyping

- Virtual prototyping 1<sup>st</sup> step
- CAD and FEA to give part mass to estimate cost and derive business case
- Digital twin

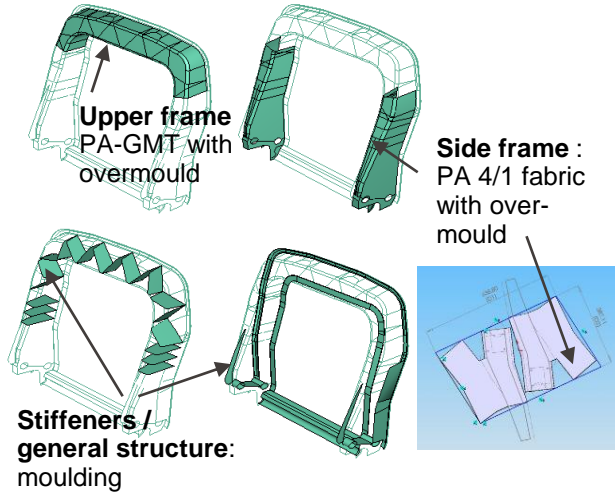
When comparing an incumbent e.g. Steel design

- Check which CTQs (e.g. deflection under load) need to be matched
- Some are a consequence of
  - Manufacturing route (material flow in tool)
  - Material formability
  - Fatigue ...
- To avoid over-design of novel technology (wall thickness)

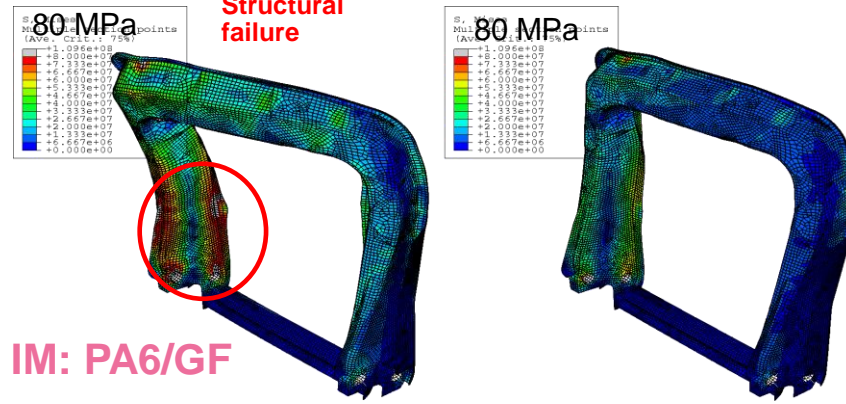
# Application case study – Front seat structure



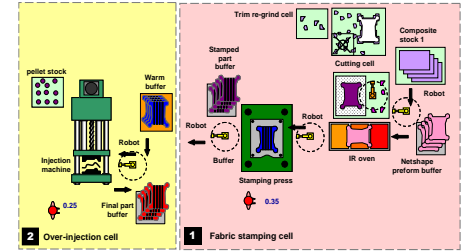
Load case:  
5 kN in upper corner at 80°C



Stress (deformation 5x)

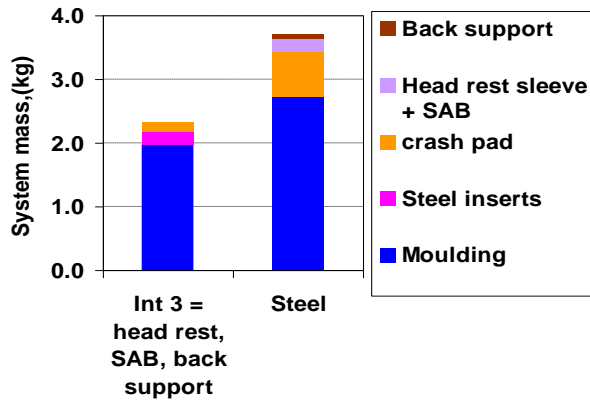


PA6 GF  
+ GMT  
+ fabric

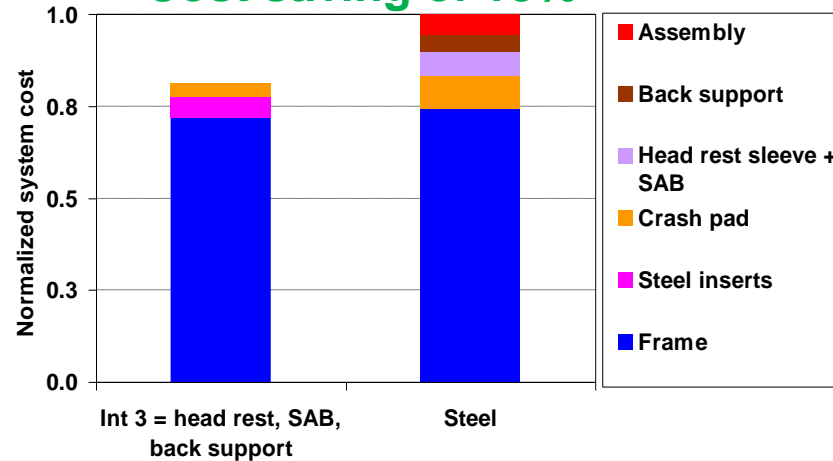


Manufacturing plant  
60s cycle time, 240k/yr

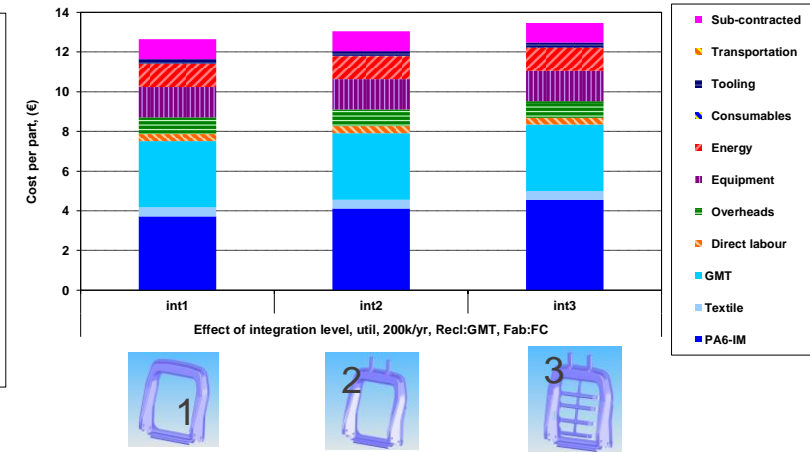
Weight saving of 37%



Cost saving of 18%



Dominance of material costs



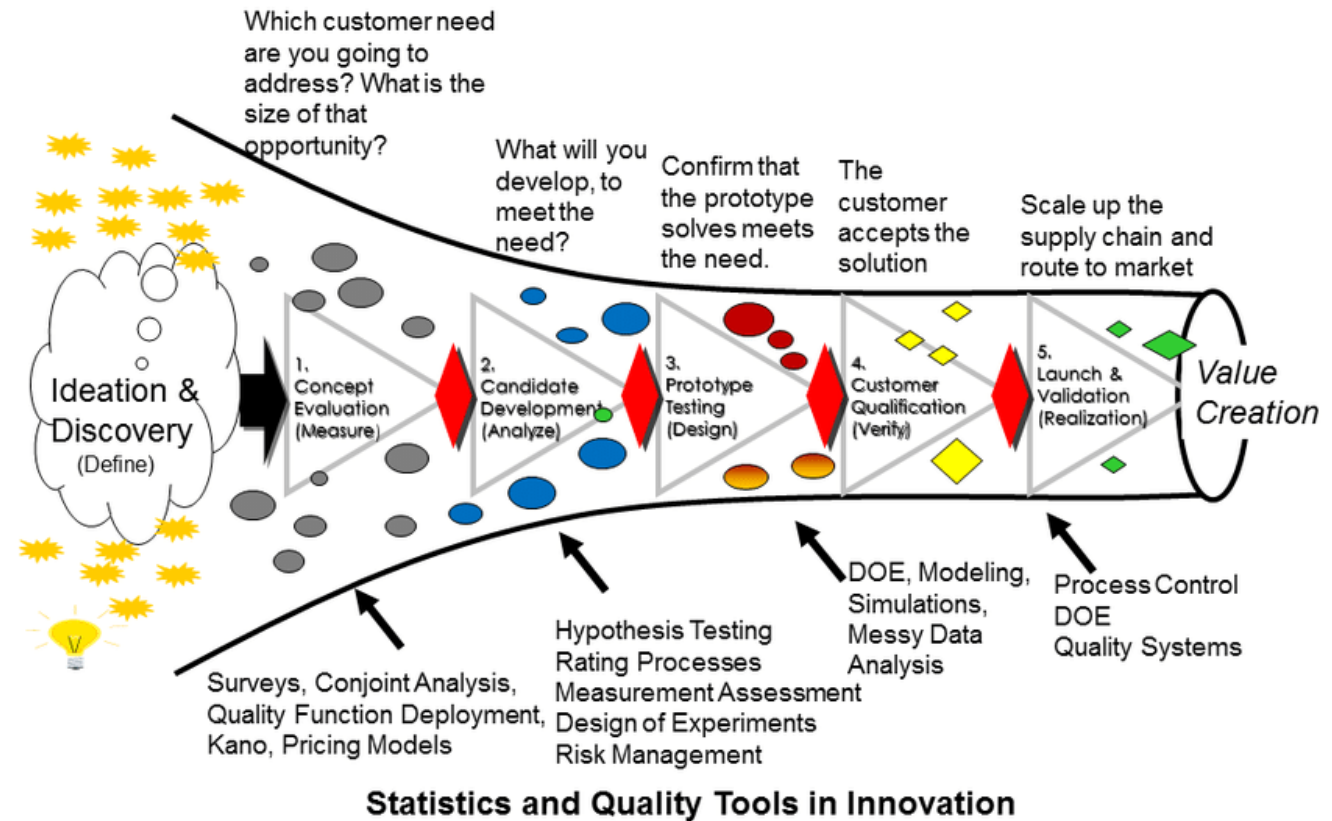
m1 eigen-freq.  
plain to IPPC  
(80°C)  
= 58 to 72 Hz

# BREAK

- Cost modelling approaches
- Technical cost modelling deep dive
- Cost modelling and technology strategy
- Wrap up
- Annex: A simple cost tool

# Sustainability, cost, investment, and business models

- Strategy through the process
- Speaking business language
- Understanding cost, CAPEX, customers, markets
- Will your idea make money?
- At what risk?
- What do your customers think?
- Is it sustainable / LCA?
- Quantify value proposition
- Avoid valley of death ...



[https://en.wikipedia.org/wiki/File:The\\_Cambridge\\_Business\\_Model\\_Innovation\\_Process.png](https://en.wikipedia.org/wiki/File:The_Cambridge_Business_Model_Innovation_Process.png)

[https://www.researchgate.net/publication/283562104\\_Statisticians\\_as\\_innovation\\_leaders/figures?lo=1](https://www.researchgate.net/publication/283562104_Statisticians_as_innovation_leaders/figures?lo=1)

# Finance challenge in scaling sustainable product innovation?

Funding type

Academic/  
industrial  
"Ideas"

Research grants

Spin-off  
venture

Development Grants (\$50k)

Angel investors  
Corporate R&D budget (\$50-500k)

Early stage venture capital (\$500k-22M)

Venture capital (\$2-50M)

IPO, M&A (\$25M)

Corporate challenges

Winning "Ideas"

Moderately successful

Net cash flow  
Revenue growth  
Expenditure

Stage of venture development (TRL)

Basic research<sub>1-2</sub>

Working Prototype<sub>4-5</sub>

Proof of concept<sub>2-3</sub>

Engineering prototypes<sub>5-6</sub>

Target market<sub>4-5</sub>

Supplier contracts<sub>6-7</sub>

Production Prototypes<sub>7-8</sub>

Product introduction<sub>8-9</sub>

First revenue<sub>9</sub>

Failures

Cash flow: "Valley of death"



Technology Readiness Level

Time (years)

2

3

4

5

6

7

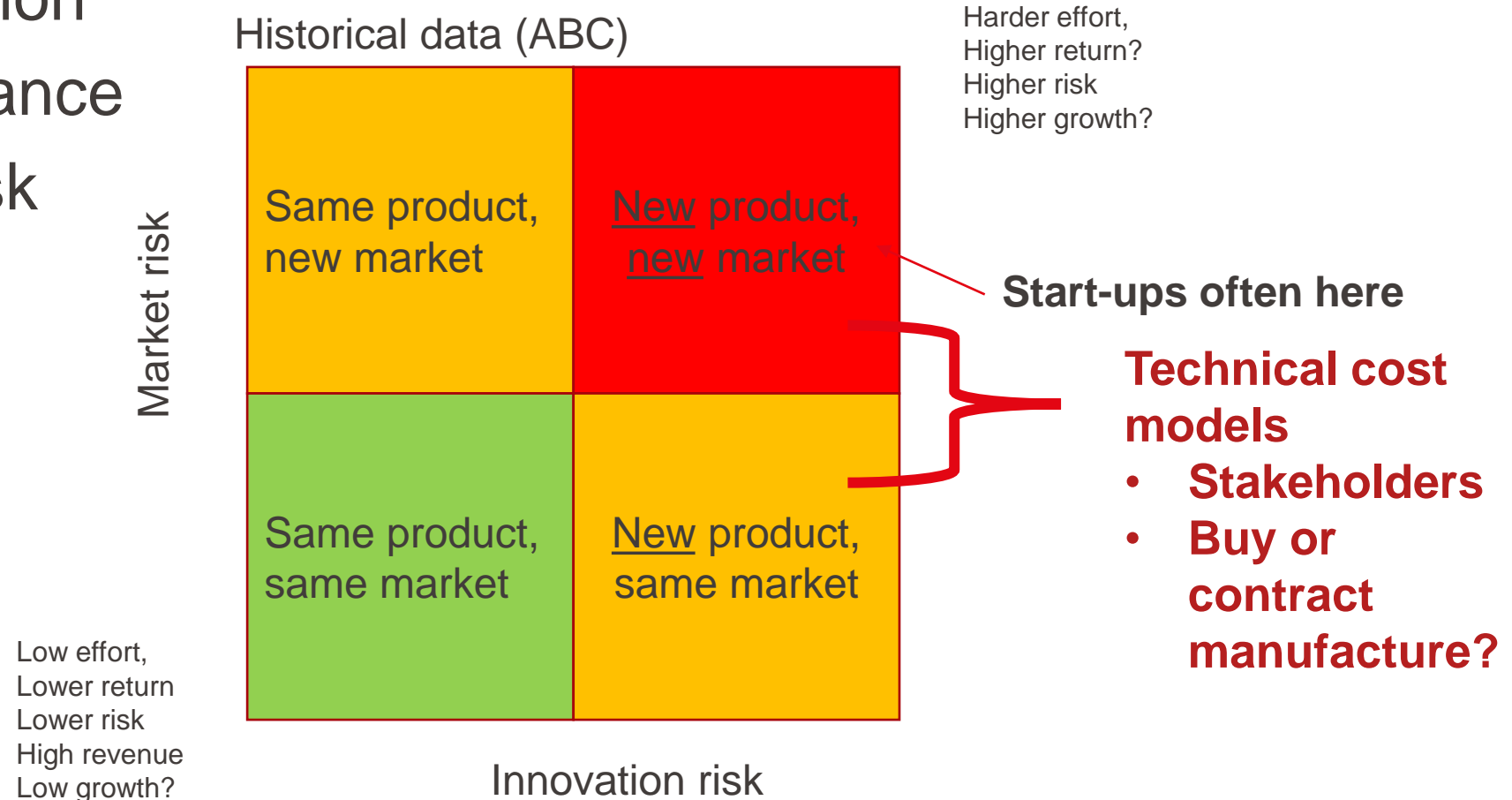
8

9

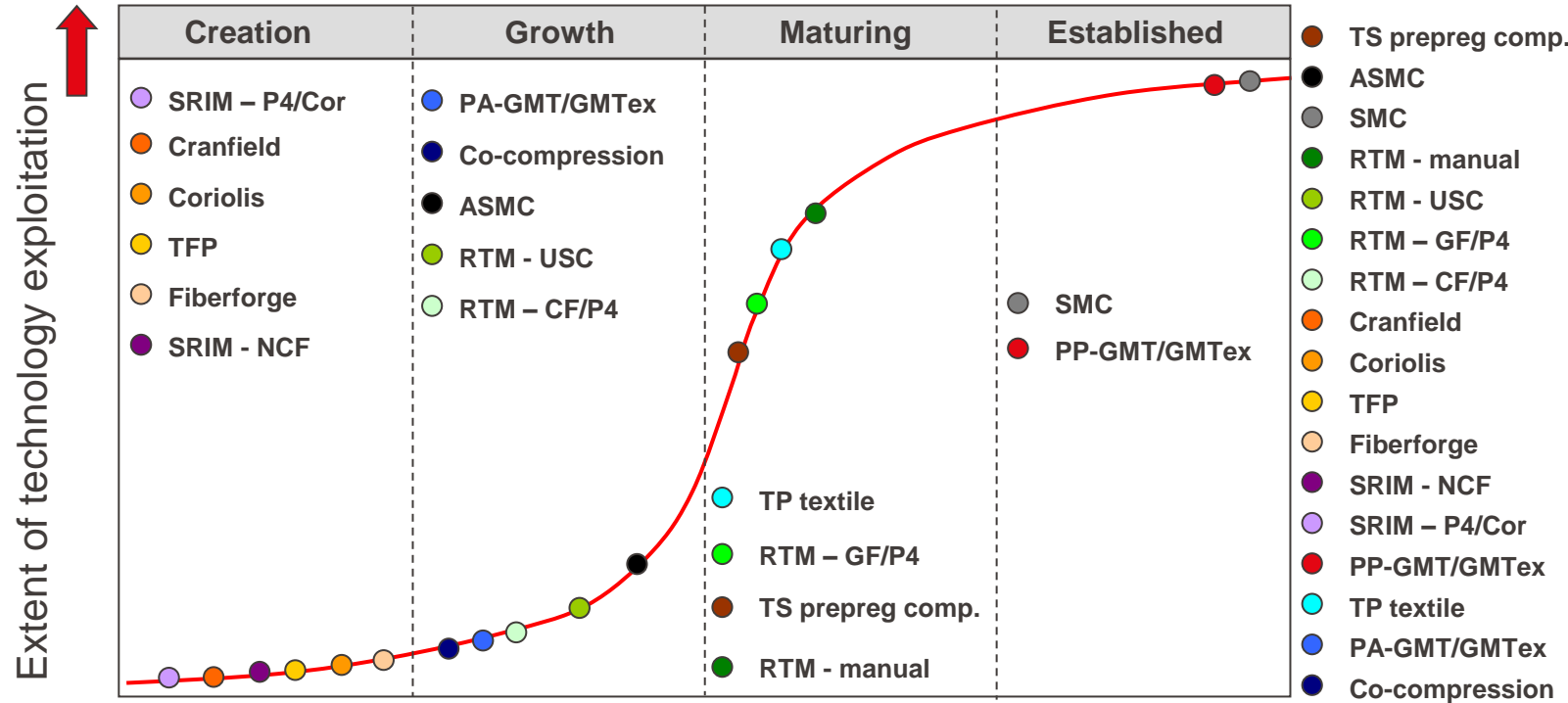
5 (consumer)  
10 (automotive)  
15 (aerospace)

# Innovation and risk

- Knowing the effect of your idea on the company and its markets
- Value proposition
- Cost, performance
- investment, risk



# Risk assessment: cost models do not eliminate Risk!



## Birth of the technology

- Very high technical risk
- Never used to make vehicles
- At research level
- Potentially used in other industries

## Trendsetting Key technologies

- Used by leading manufacturers in the automotive industry
- High technology risk

## Maturing technologies

- Leading suppliers using and applying the technology
- Controlled technical risk has become key to success

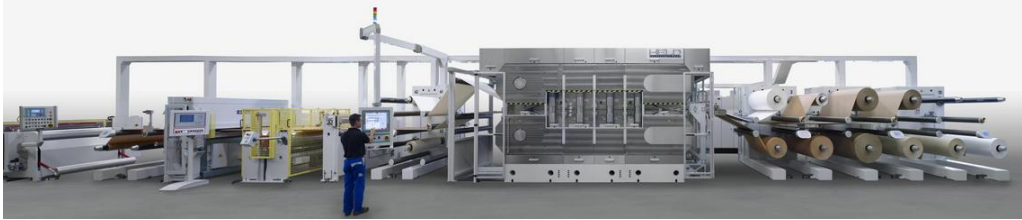
## Standard technologies

- Used by all players in the industry
- Minimal technical risk
- Technology does not make a difference

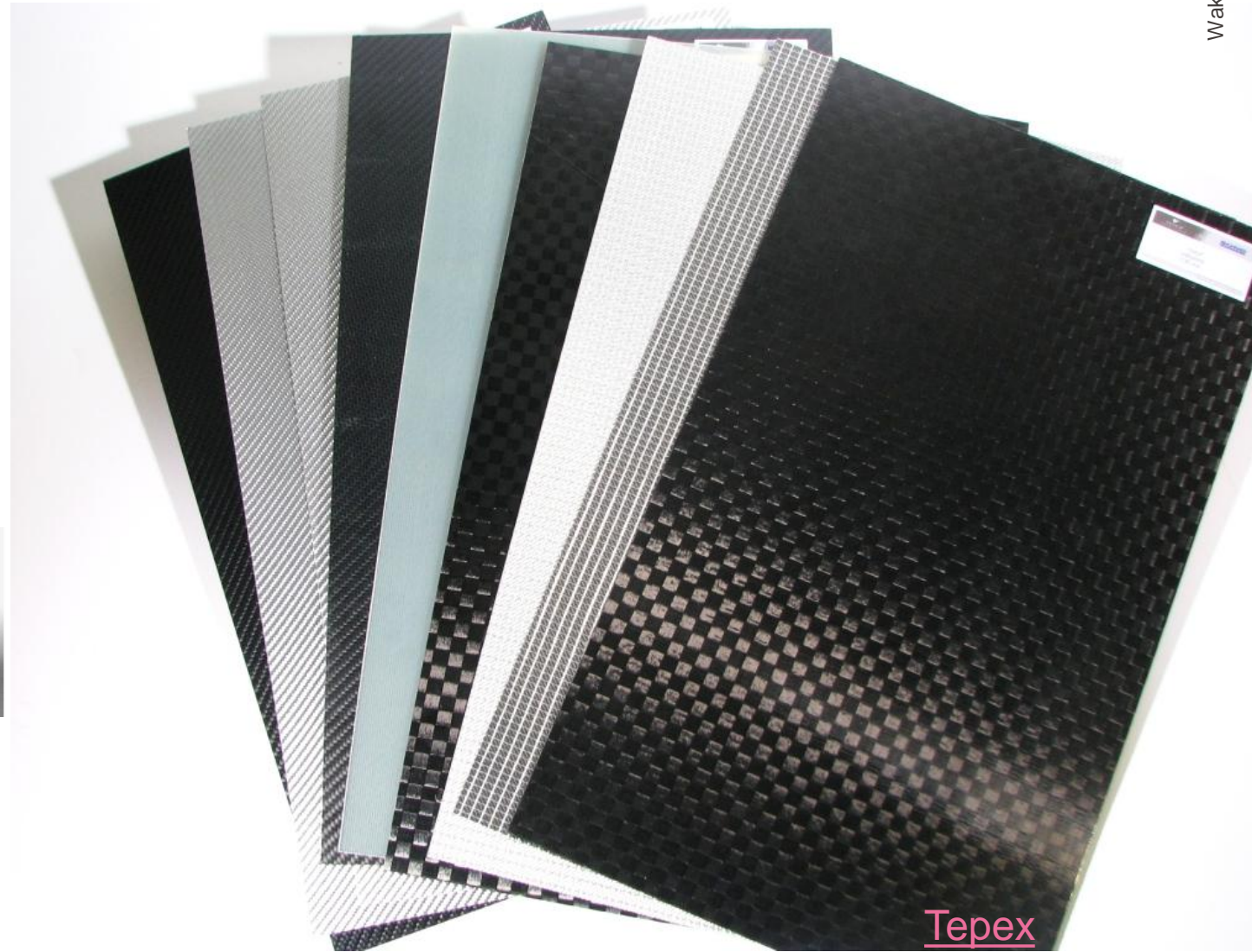
- Where is your idea vs. established processes?
- e.g. steel stamping
- Might be comparing birth phase to standard technologies

# How to build up operation scale with reduced risk?

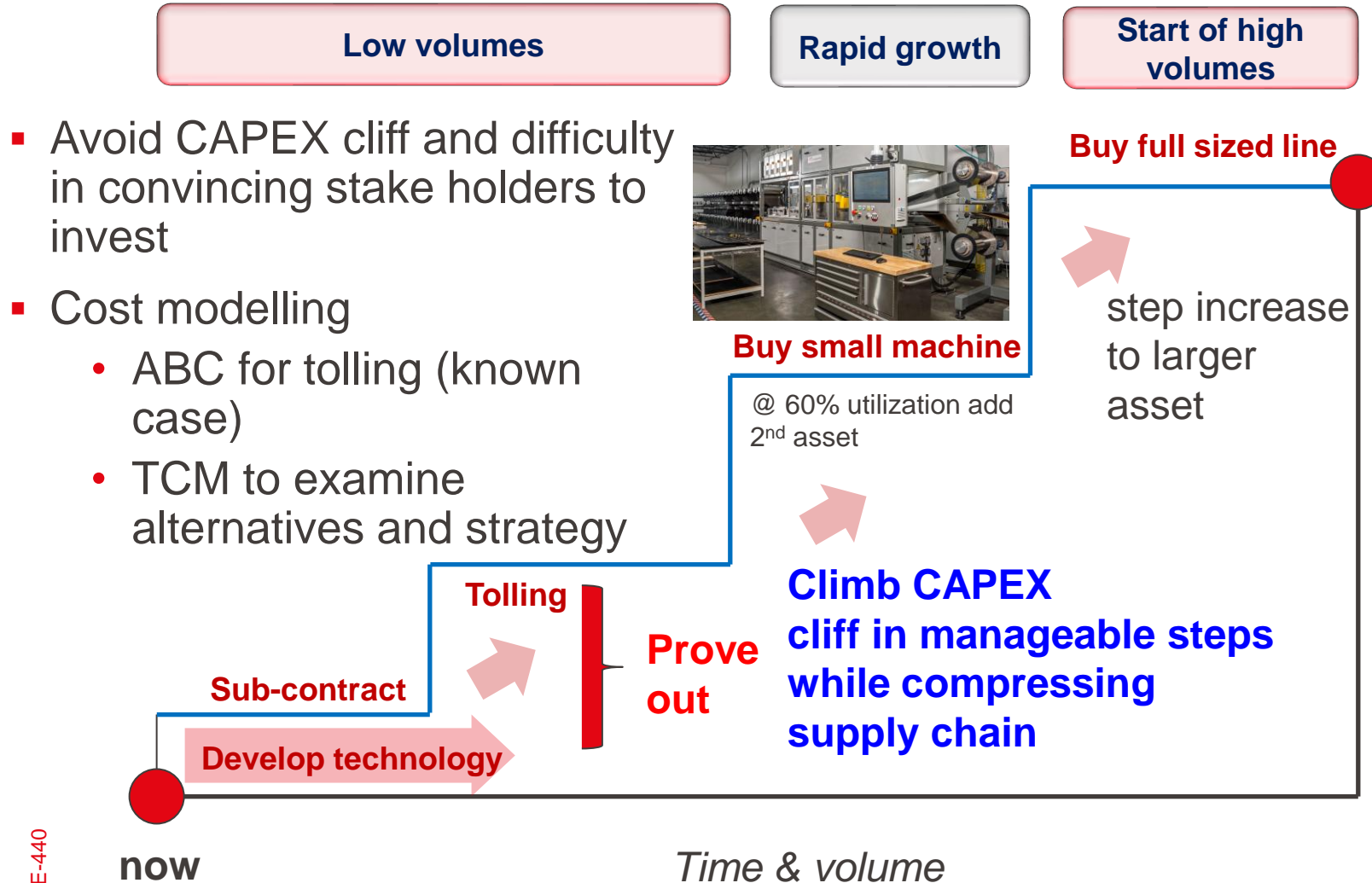
- Thermoplastic composite sheet
- Early revenue justifies more CAPEX!



[Isobare Doppelbandpresse \(Held Technologie\)](#)



# Strategy to minimize CAPEX exposure (risk)

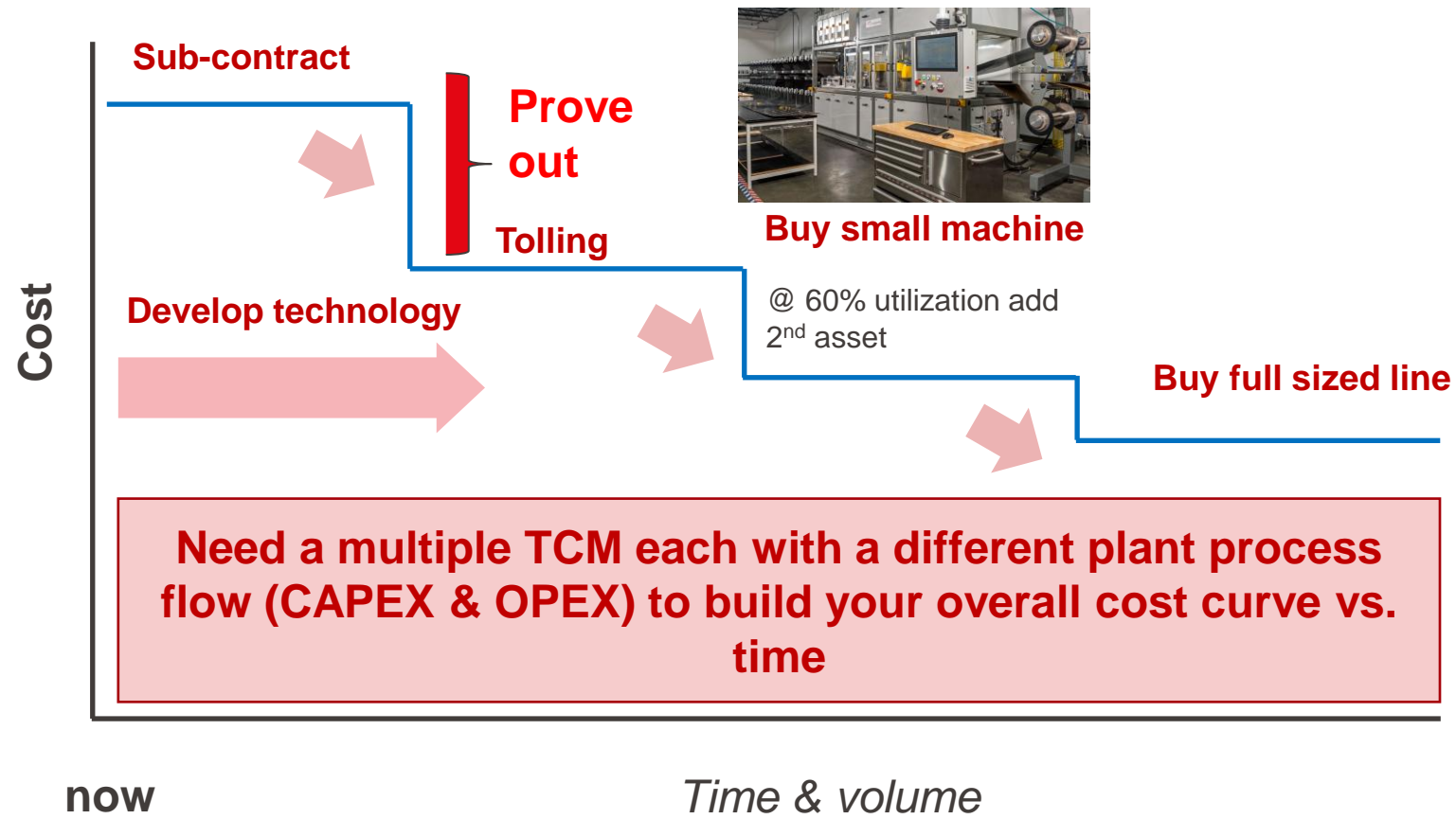


**CAPEX cliff**

- Don't forget open innovation ...
- M&A of SME to bring in capacity, capability, immediate revenue vs. high internal development costs and delayed time to market

**SAME PRODUCT vs. time (customer's eyes)**

# Cost versus time



- CAPEX scaled stepwise
- Reduce financial exposure
- Test market
- Reduce risk
- Compress supply chain
- Final cost 4x lower

# How to model increasing production volumes

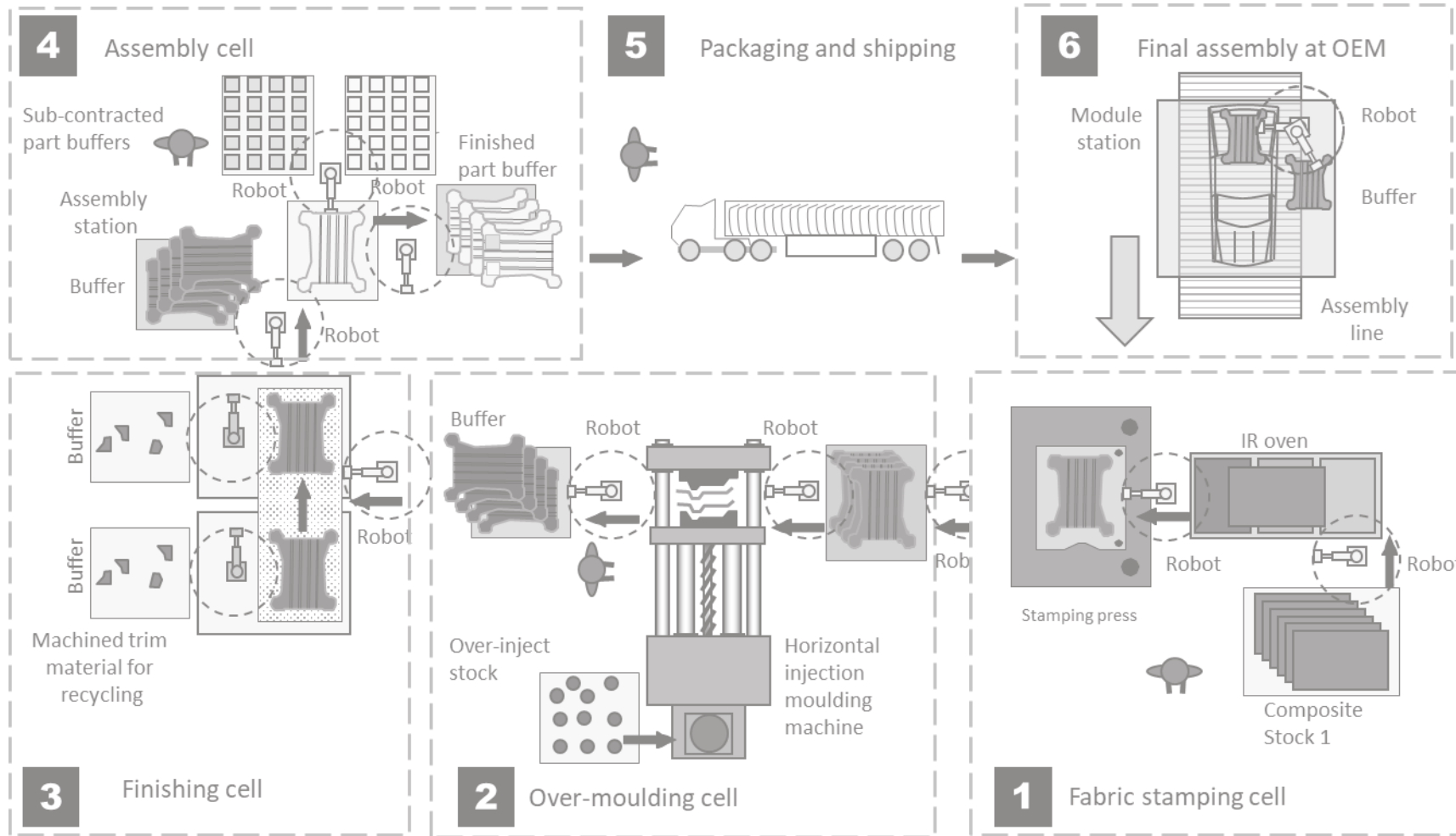
- Need to define:
  - Plant A: lower volumes
    - Add extra shifts
    - Lower CAPEX, lower risk at low volumes, potentially higher costs
  - Plant B: medium volumes
    - Extra shifts added but need to duplicate a machine in bottleneck cell
  - Plant C: high volumes
    - Add parallel cells, higher through-put machines, doubling of tool sets
    - Higher CAPEX, higher risk at low volumes, lower costs at higher volumes

This mean building up a master curve from the three models

If you use option C for low volumes your CAPEX will be very high and under utilized (especially dedicated) physical assets are highly unattractive.

# How to model increasing production volumes

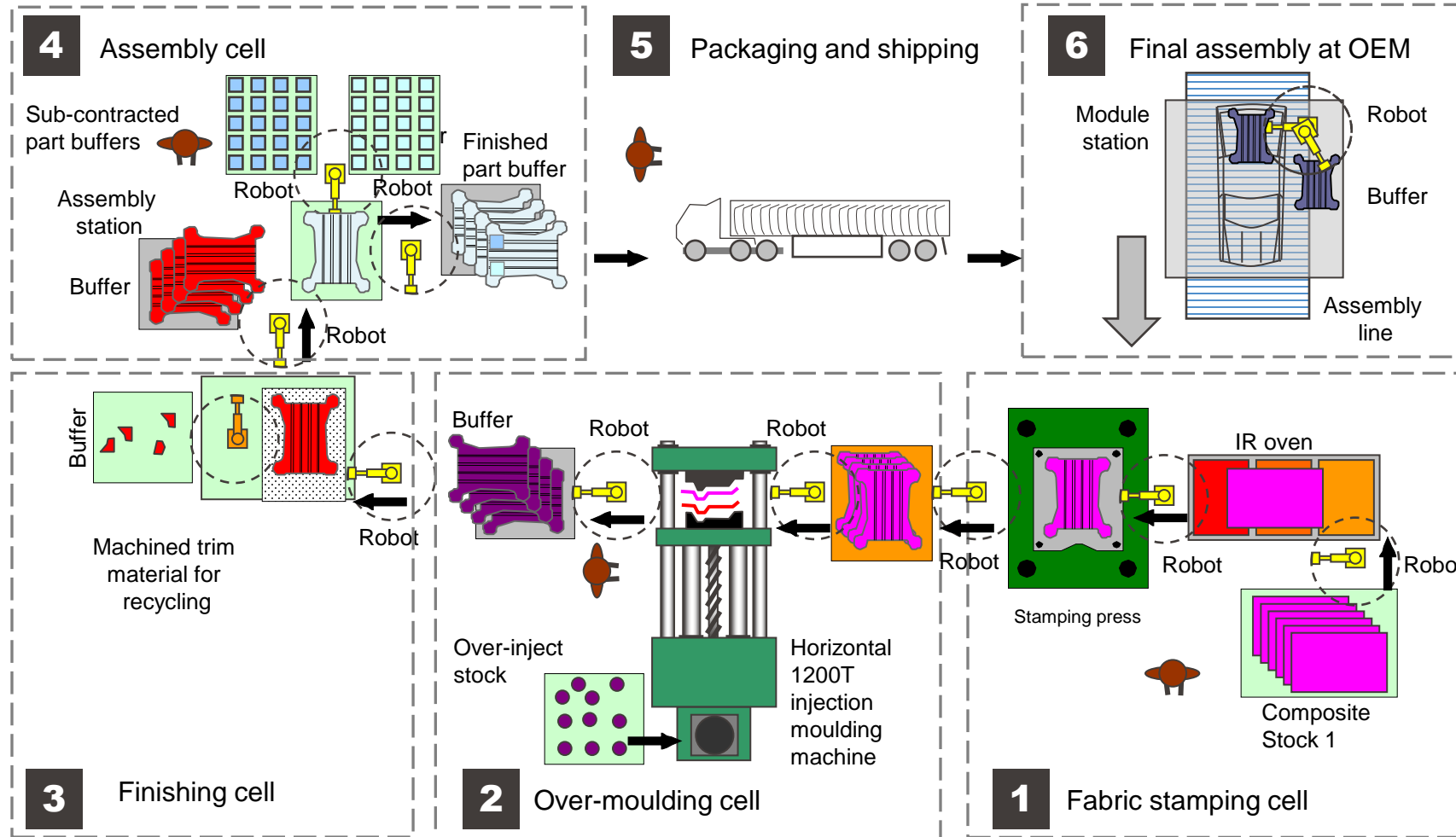
■ Start-up



**Toll manufacturing / contract manufacturing: only invest in the most unique areas (or not at all)**

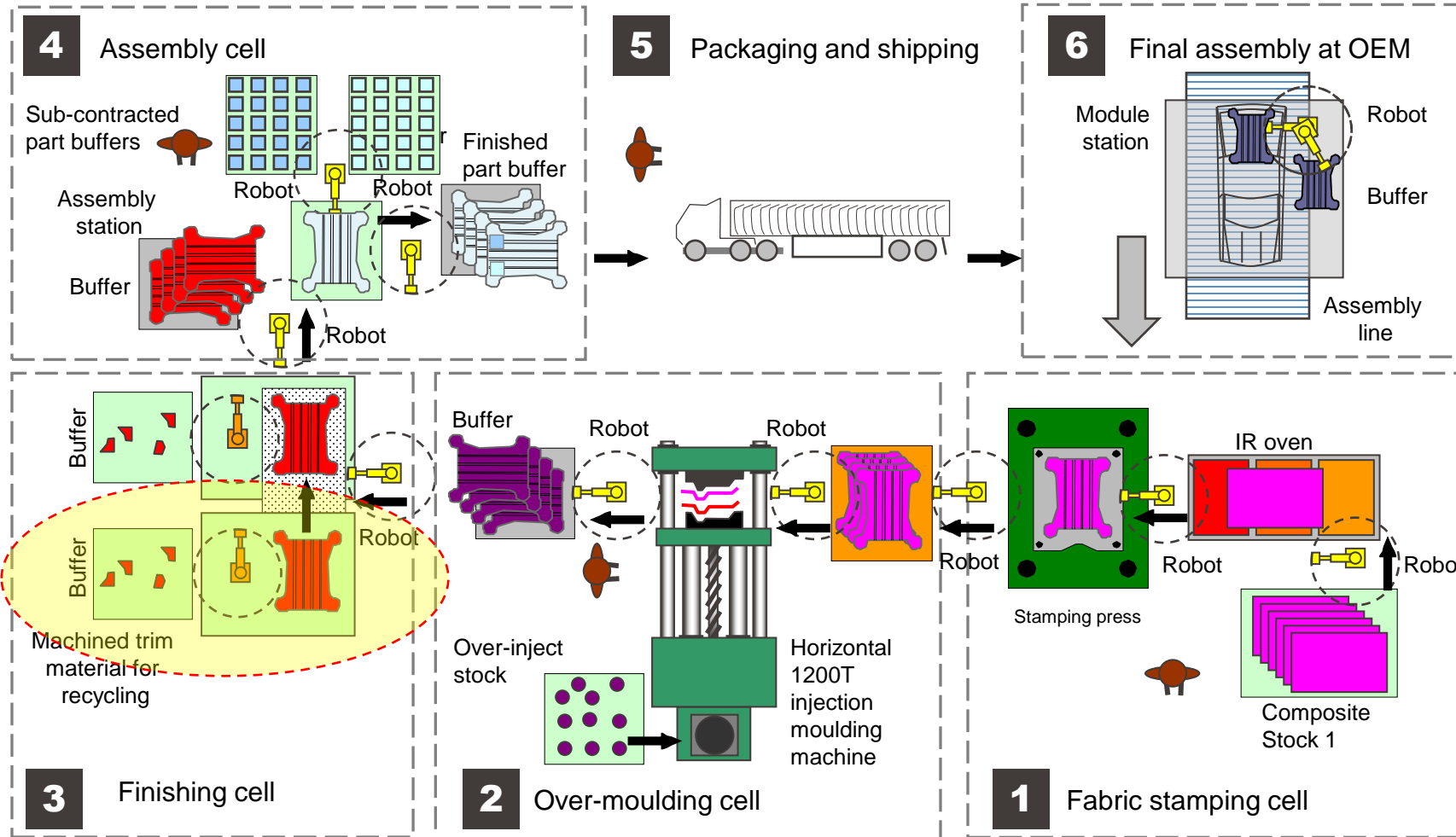
# How to model increasing production volumes

■ Low volume



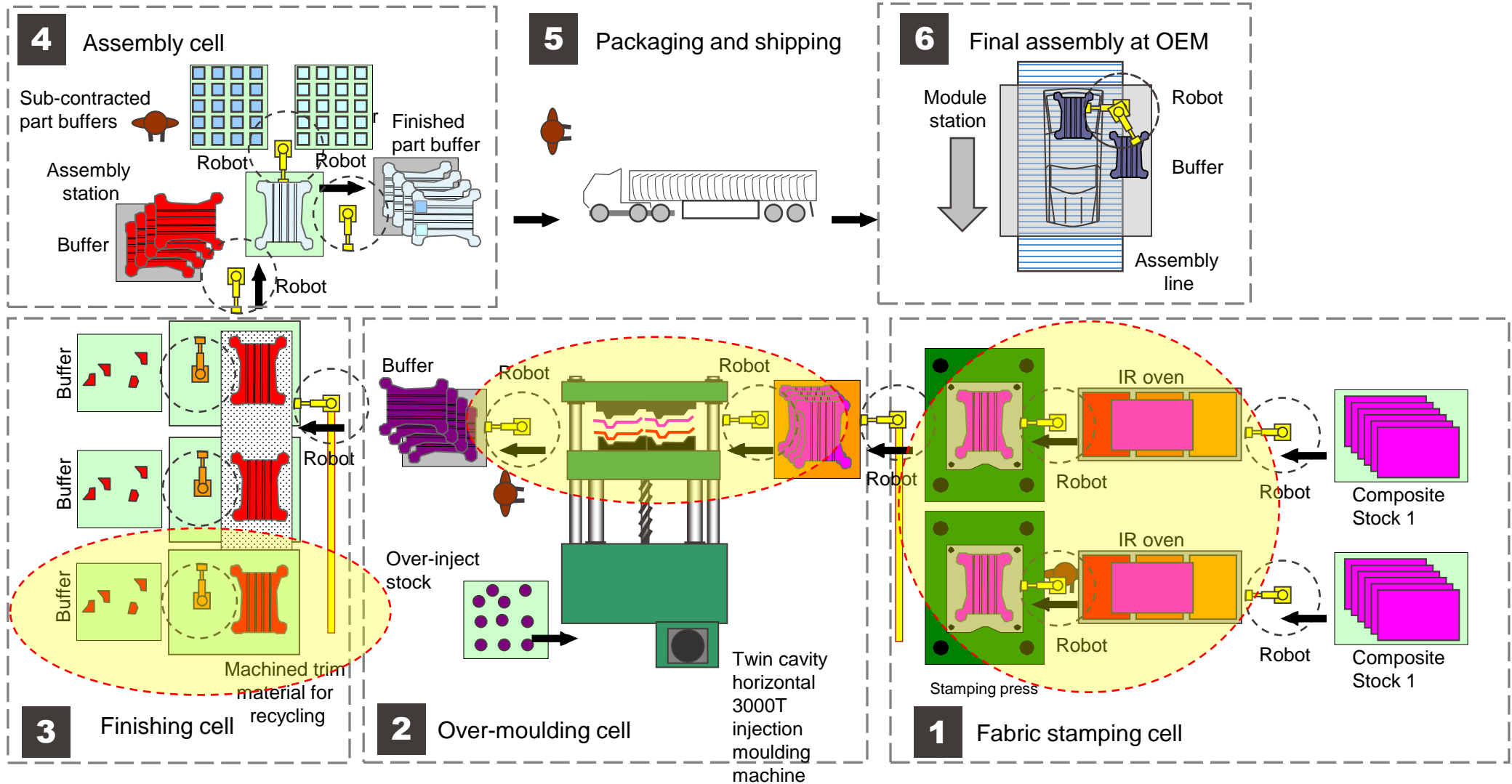
# How to model increasing production volumes

■ Medium



# How to model increasing production volumes

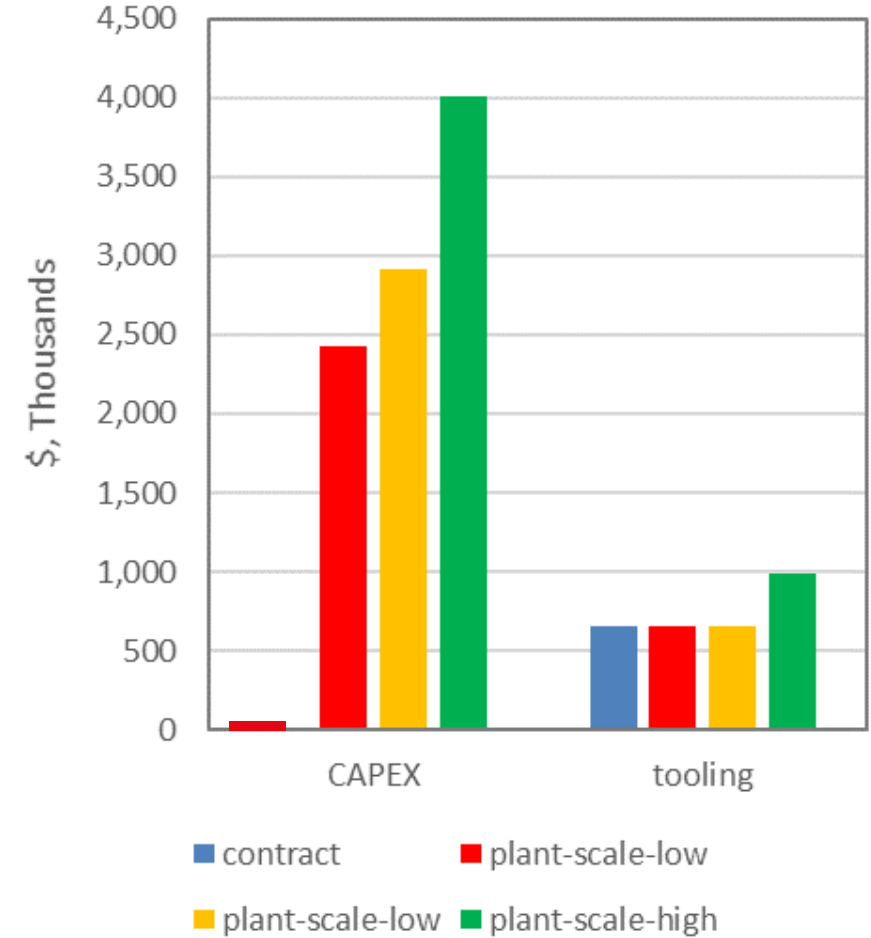
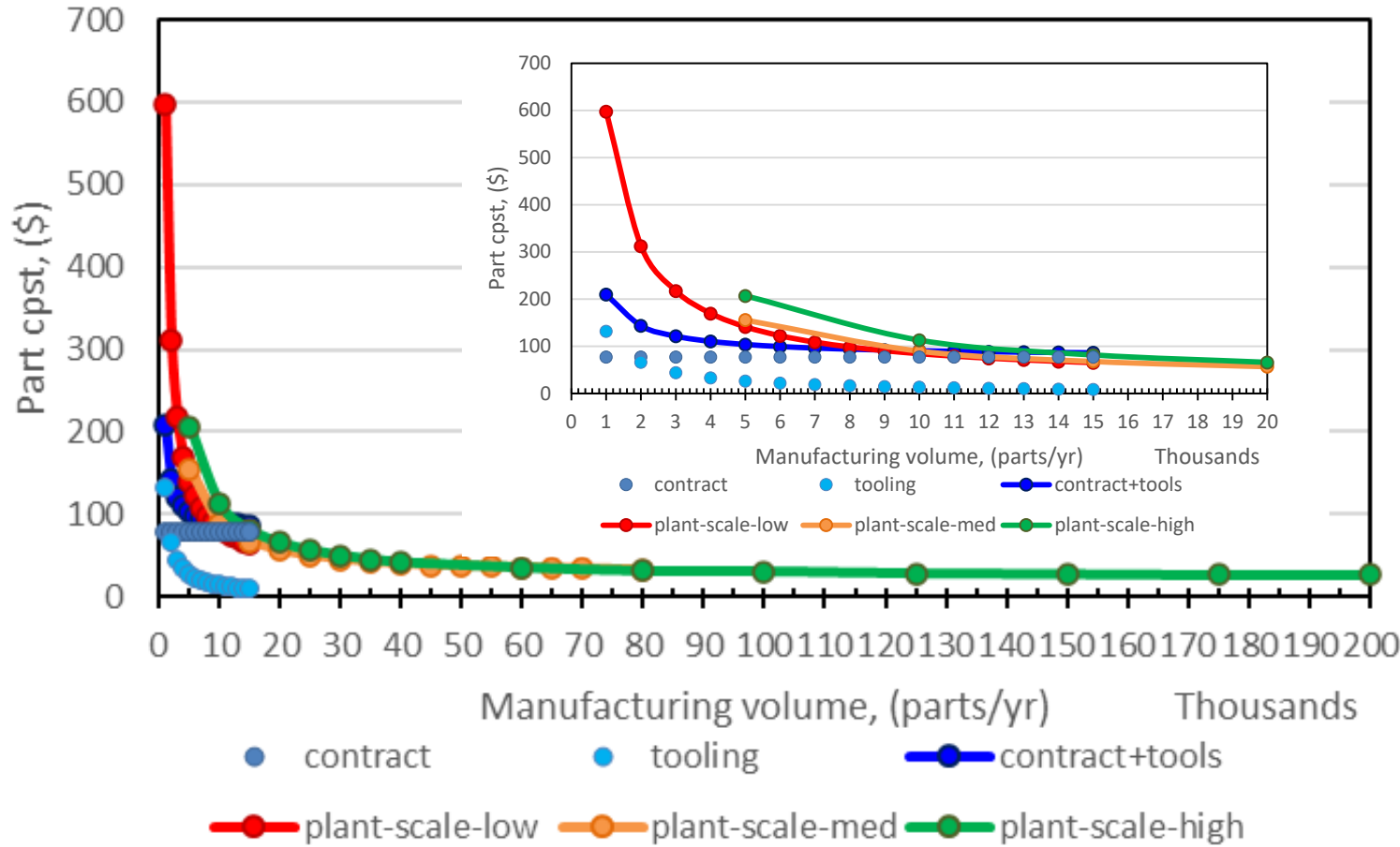
■ High



# Master curve (from dedicated cells)

■ Cost

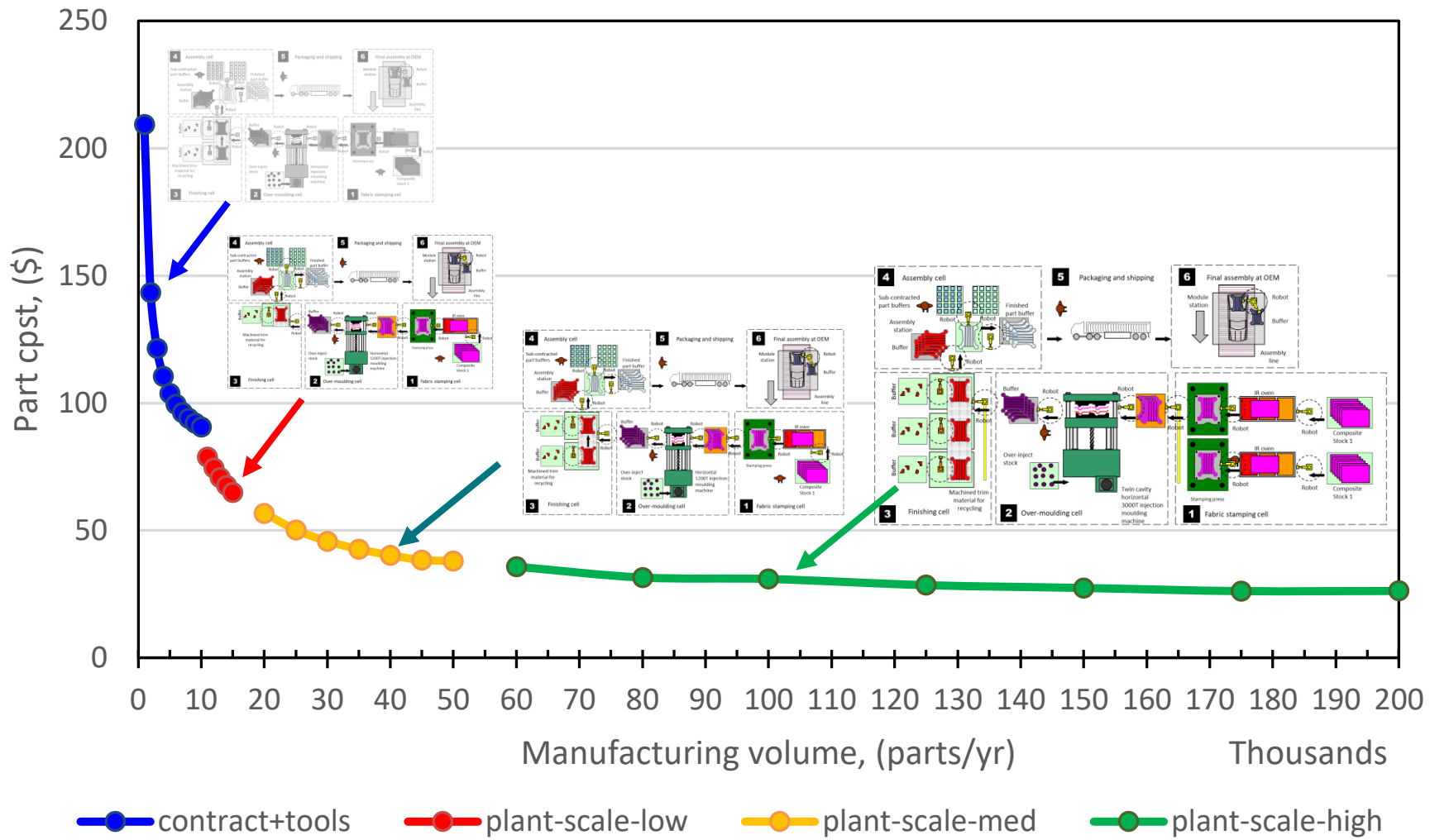
■ CAPEX



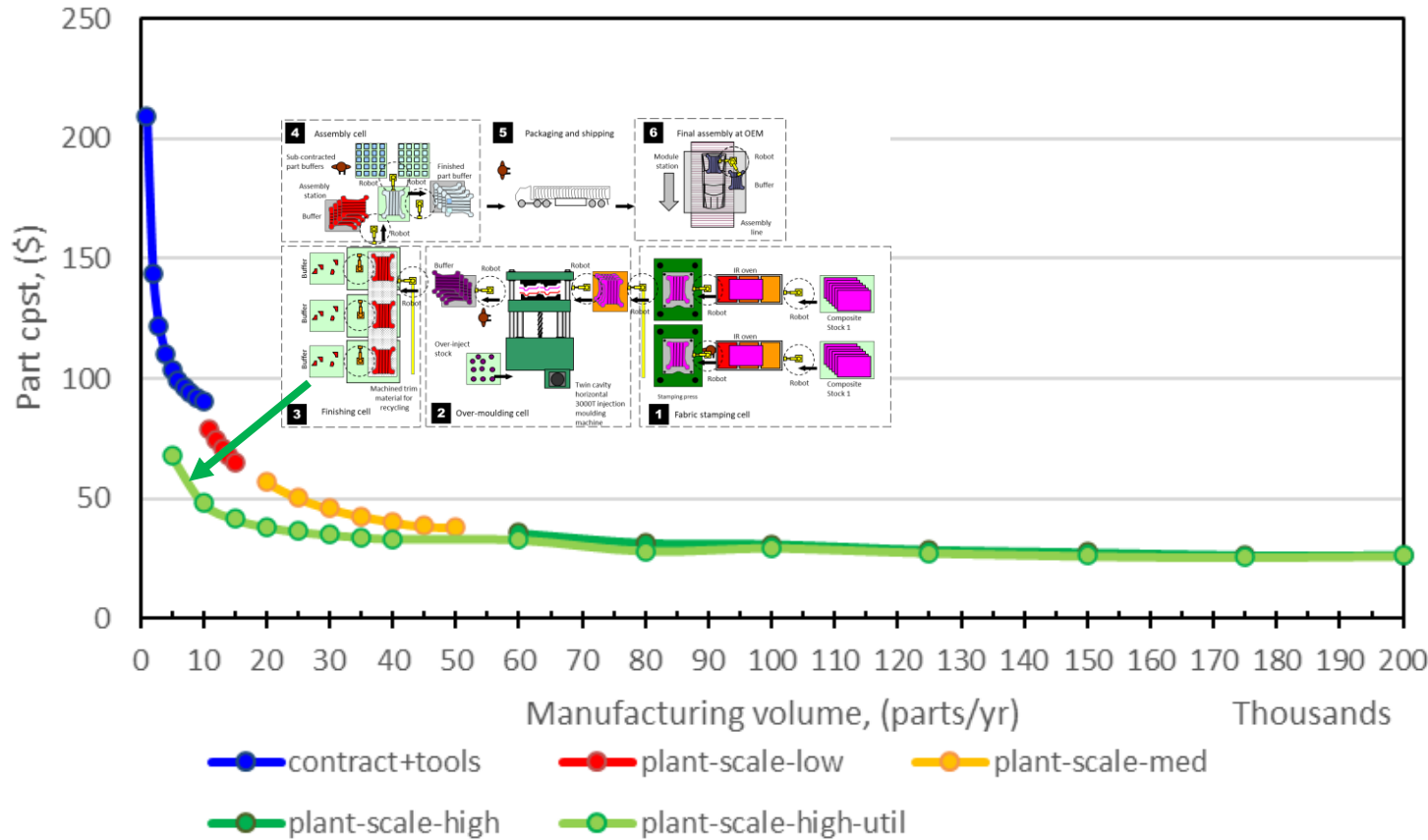
■ MSE-44

Contract price 2.5x fully utilized cost at 200k/yr (incl. tooling)

# Master curve (from dedicated cells)



# High volume utilized



- Caution using the “best-case” fully utilized model at low volume
- Don’t invest in ultimate case if your plant cannot have e.g. >60% utilization
- Stepwise scale up (case-by-case)
- CAPEX is key to attractive business financials (NPV)
- Cost models do not show breakeven / cross overs with business financial modeling but are key to build good business models

Need to model NPV / IRR / ROI / disc. Payback period etc USING cost model data to make true master curve

# Definition of a Value Proposition

The compelling promise and desired set of product deliverables and experiences that an offering makes to a defined target audience that outweighs its total perceived cost while being differentiated from available alternatives and supported by reasons to believe.



Source: Mohan Sawhney  
Kellogg School of Management

- **Specific to: i) customer and ii) an application (not a material or process)**
- **Quantified benefits (\$ basis)**
- **Needs to be compelling enough for upfront engineering investment**
- **In automotive light-weighting**
  - **Functional performance, System mass and cost**
- **Drive value-in-use pricing**

# Costing in-kind and non-in-kind incumbents



Non-in-kind incumbent  
(steel stamping)



## Proposal



- In-kind incumbent  
(another composite process)



## OEM approaches to costing targets

- Use buy in price (need to know manufacturing volume & if / how tooling is amortized)
- Use internal COM data, which may or may not include plant / tooling amortization
- May give a cost “target”, which may or may not be the same as the real price or cost
- OEM contact person, if not a costing person, may not understand the basis of the number they supply to us

# Using a cost model to feed a business model

- Convert cost vs. volume into cost vs. time
- Track (CAPEX and OPEX) directly from cost model
- Use in financial models
  - Pricing
  - Market growth
  - Revenue predictions
- Care to model SARD correctly
- Better to model SARD with detailed personnel costs (R&D, marketing etc) specifically vs. time
- Avoid “Valley of death”, Revenue is critical

# Gross margin approaches

## ■ Cost plus

- Apply a fixed gross margin e.g. 40% to the total operating cost
- Commodity approach
- When lacking a strongly defined value proposition
- Weak understanding of customer needs / poor customer intimacy
- Lack of product differentiation

## ■ Value in use pricing

- Examine the benefits of your product to the customer to meet their needs in monetary terms (quantified)
- Compare with in-kind and non-in-kind incumbents
- Probe willingness to pay
- Margin is built upon product specific value proposition

# Implementation of light weight materials

## Selection factors (steel vs. Al vs. TPC vs. XYZ)

Weight saving

Cost position

CAPEX intensity  
(OEMs / Tiers /  
Material suppliers)

LCA (one of many  
important issues  
to understand and  
position)



Engineering  
investment  
Acceptable risk

Trusted design  
and modeling  
tools

Design space  
needed /  
functional  
integration

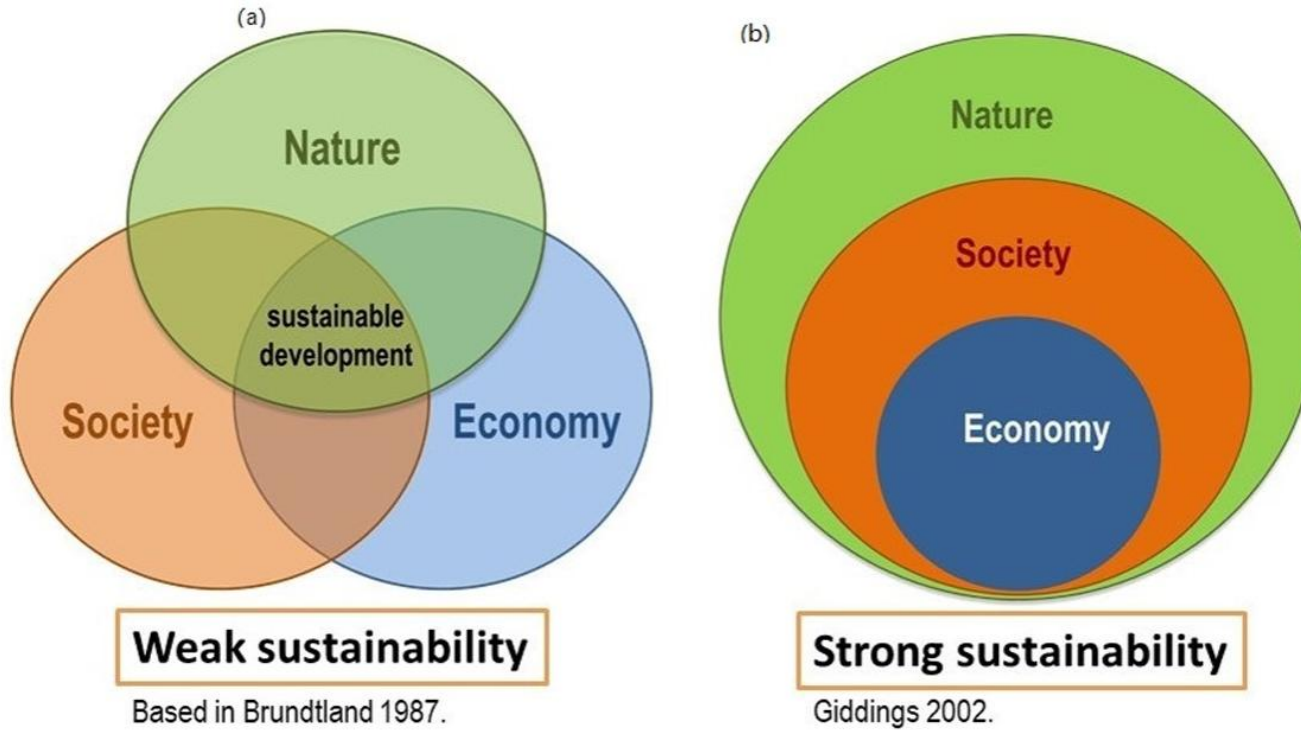
Transition from a  
linear to a circular  
economic model

Good financials  
NPV, ROI, GM

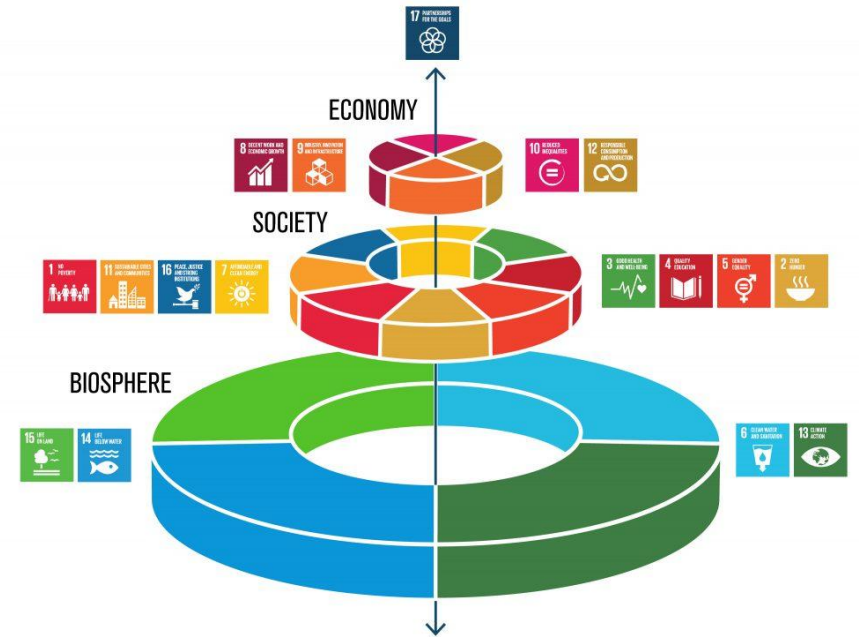
Robust  
manufacturing:  
equipped and  
able supply chain

Stable materials  
supply (multi-  
source)

NetPositive  
companies



**Figure 1.** Graphic representations of weak and strong sustainability: (a) Weak sustainability, or sustainable development, presents the environmental, social, and economic themes with equal weighting and seeks to balance them. This image was developed based on the Brundtland Report and was widely disseminated. (b) Strong sustainability, with a focus on systems, presents the three themes as nested and confers different sizes and weightings to them. This model was presented by Giddings in 2002.



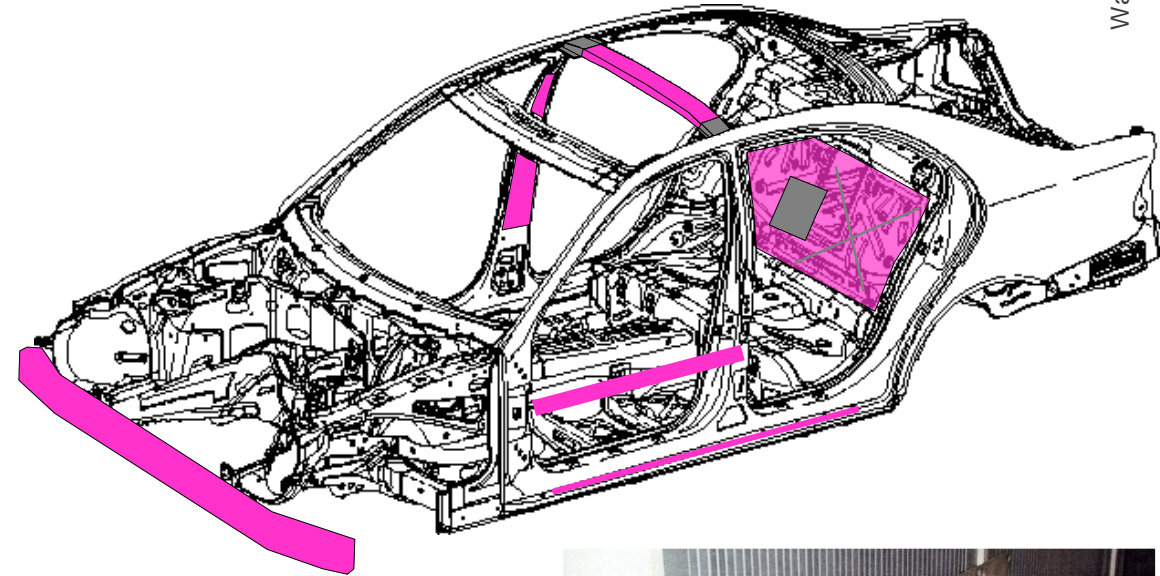
[The Doughnut economy and circularity in business models – Best For The World](#)

Functional unit:

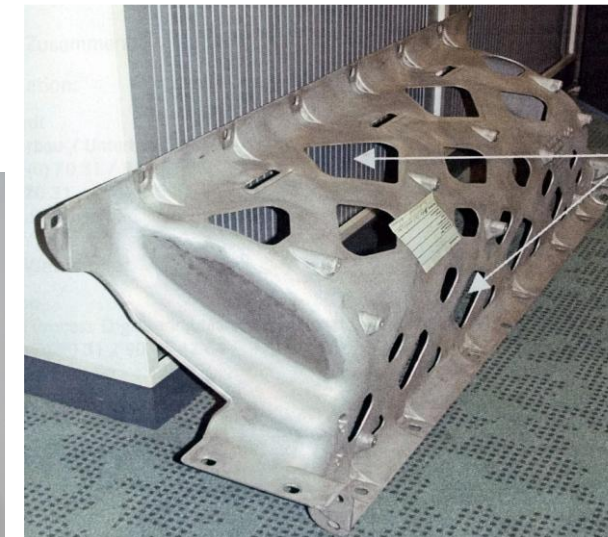
## Curved structural panel

- typical of BIW, rear bulkhead
  - does not need to pass through E-coat process (but could)
  - temperature capability if needed
  - magnesium benchmark
  - detailed sensitivity studies
- Rear Structural Bulkhead
 

• Steel	5.8kg
• Magnesium	2.2kg
• SMC	2.5kg
• GF/PA GMT	2.4kg
• GF NCF/HP-RTM	2.3kg
• CF NCF/HP-RTM	1.8kg (1.2kg)

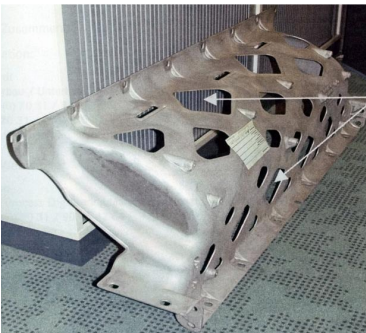
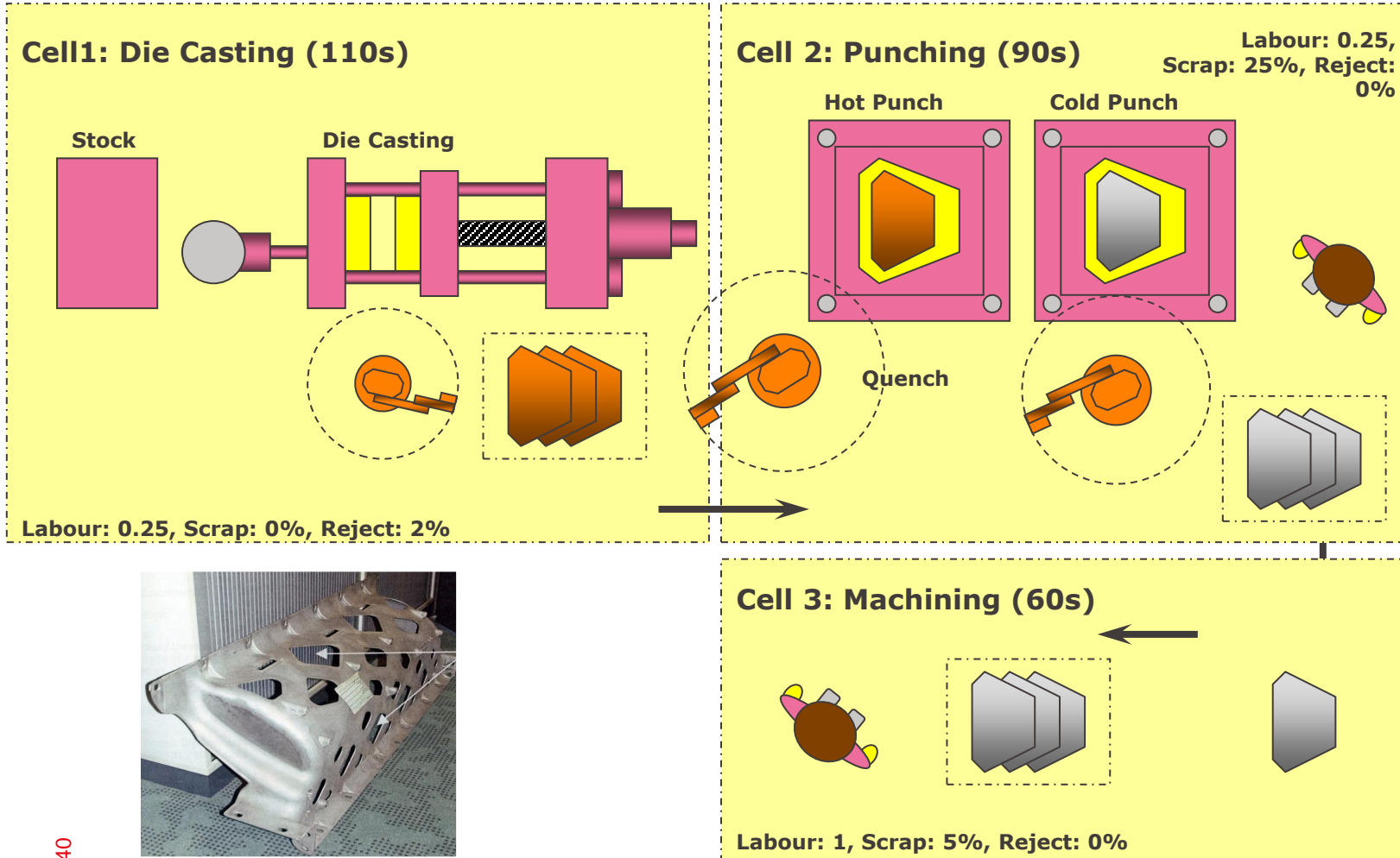


## Aluminum?

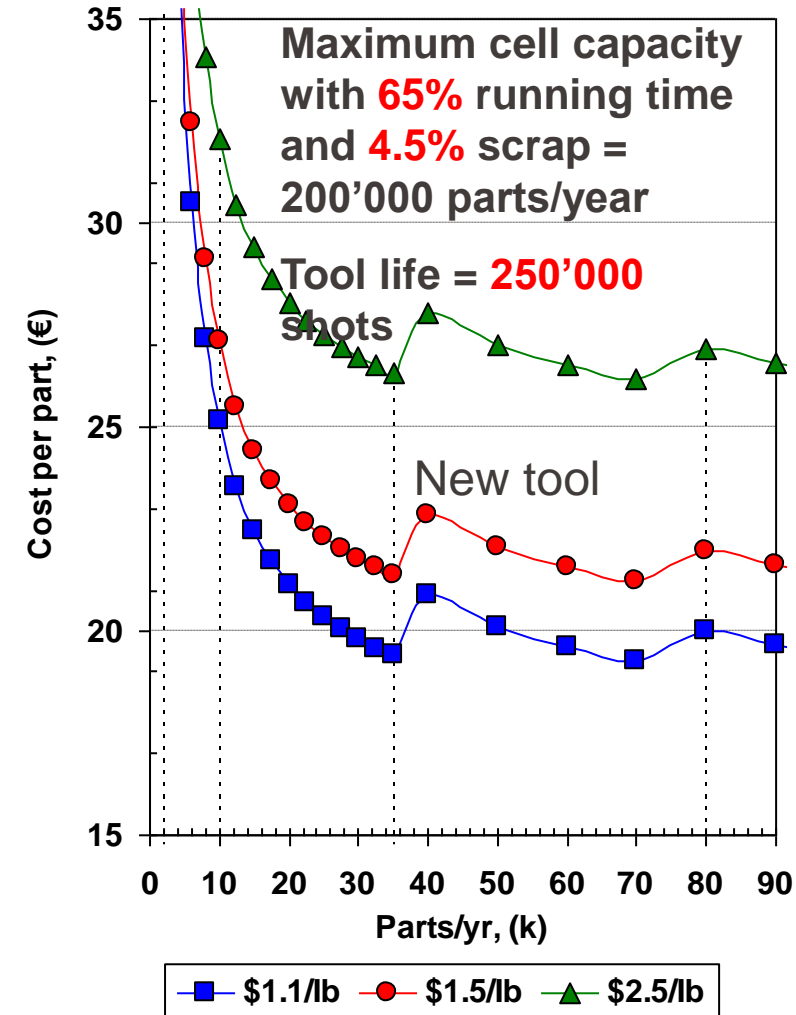


[Assessing the life cycle costs and environmental performance of lightweight materials in automobile applications - ScienceDirect](#)

# Magnesium Die Casting

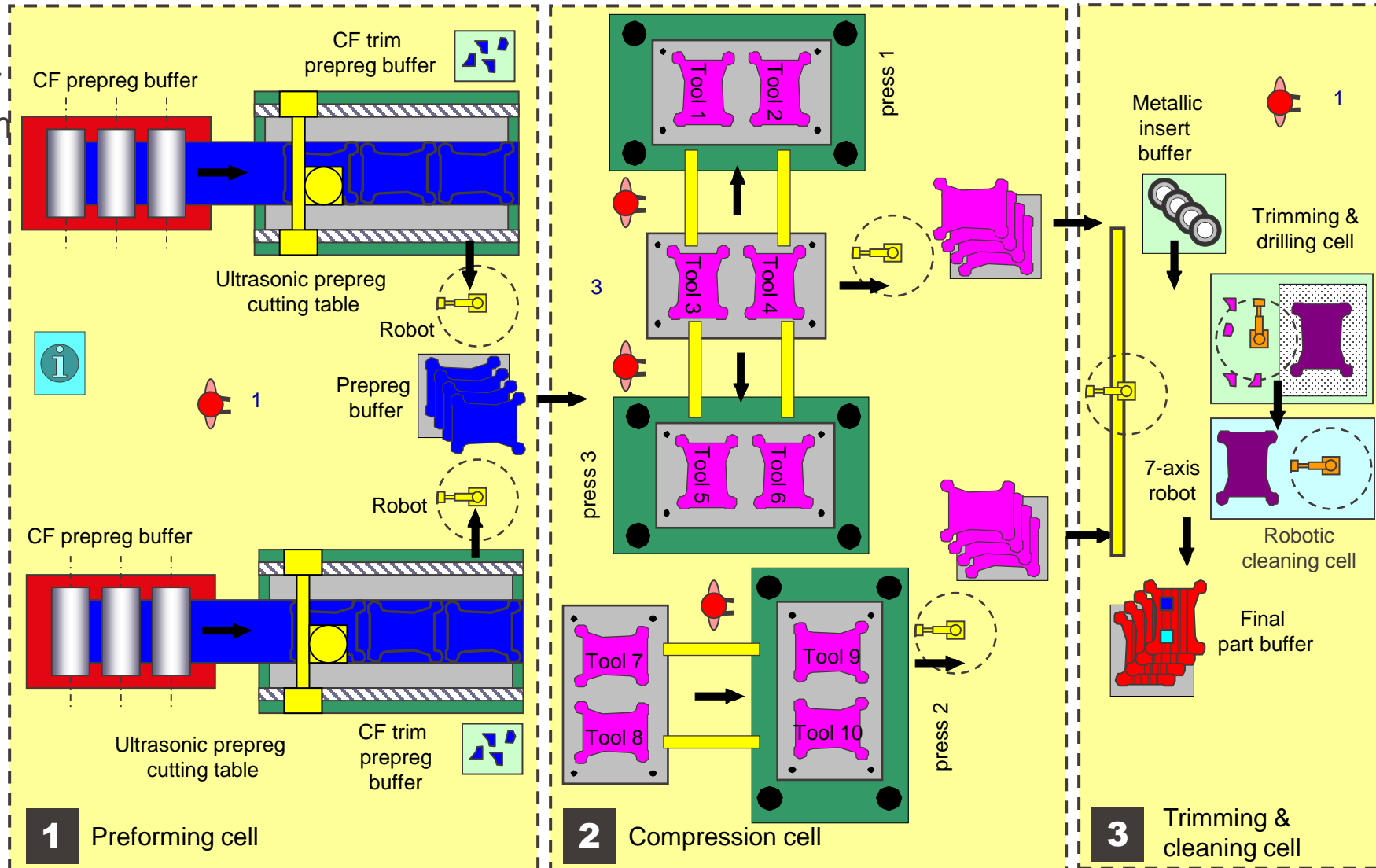


MSE-440



# CF/epoxy prepreg compression (1 example)

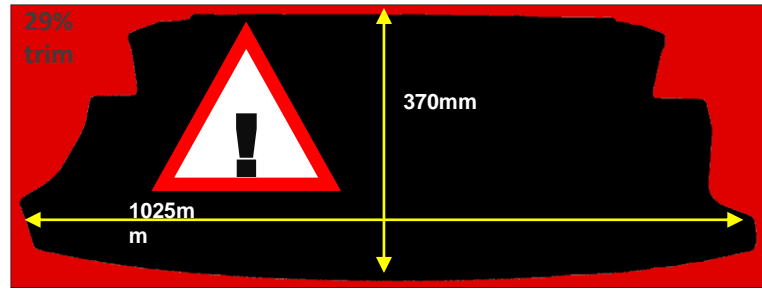
- Cure time reduced over 15 years from 10 min to 1min30s
- Today less plant and CAPEX needed (reaction kinetics)
- Now used in BMW 7 series
- 67s with 4 cavities



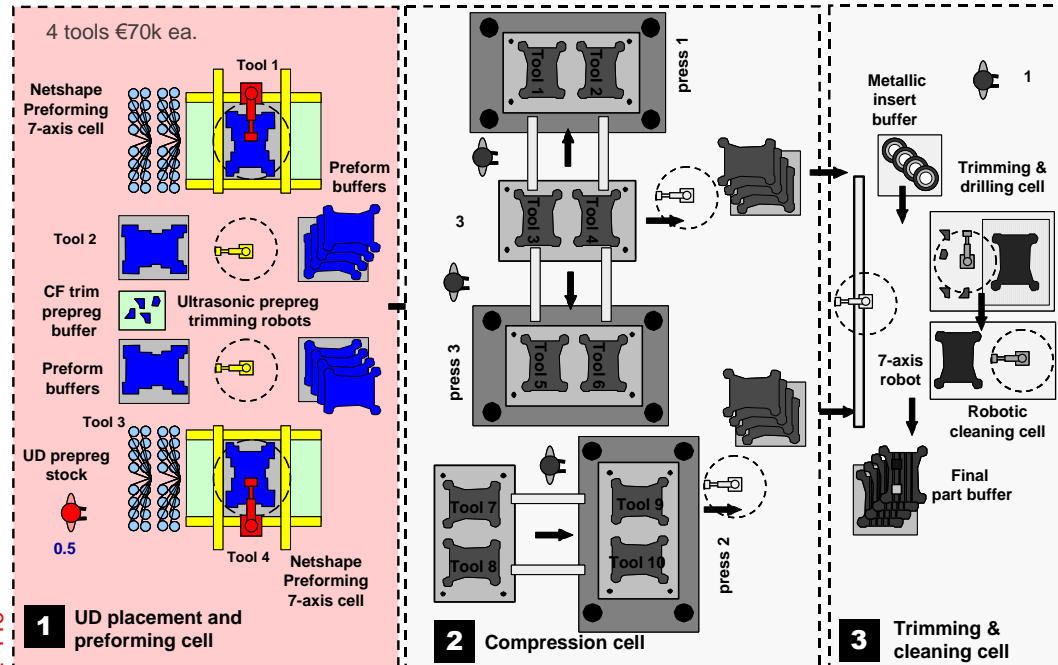
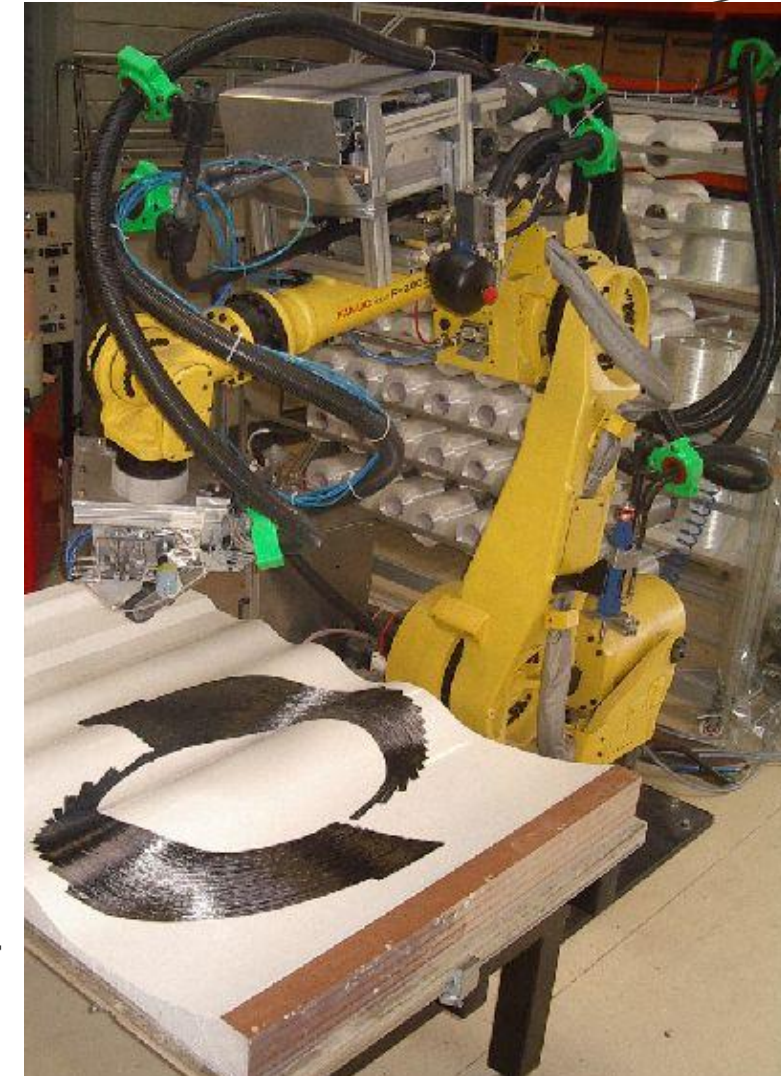
Key issue was high amount of carbon fiber trim

# State of the art – reduce trim fractions

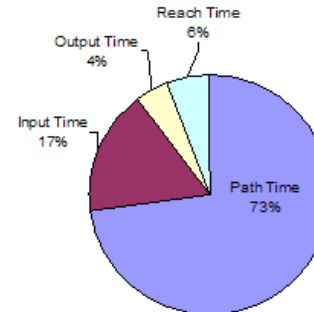
- 6 axis robot & external 7 axis
- up to 30 yarns placed simultaneously
- machine cost = €700k, €1M with 7<sup>th</sup> axis
- UD CF/epoxy prepreg
- trim = 5% (bulkhead) / reject rate = 2%
- **cell maximum capacity**
  - 1 shift = 22k/yr, 2 shift = 45k/yr, 3 shift = 68k/yr



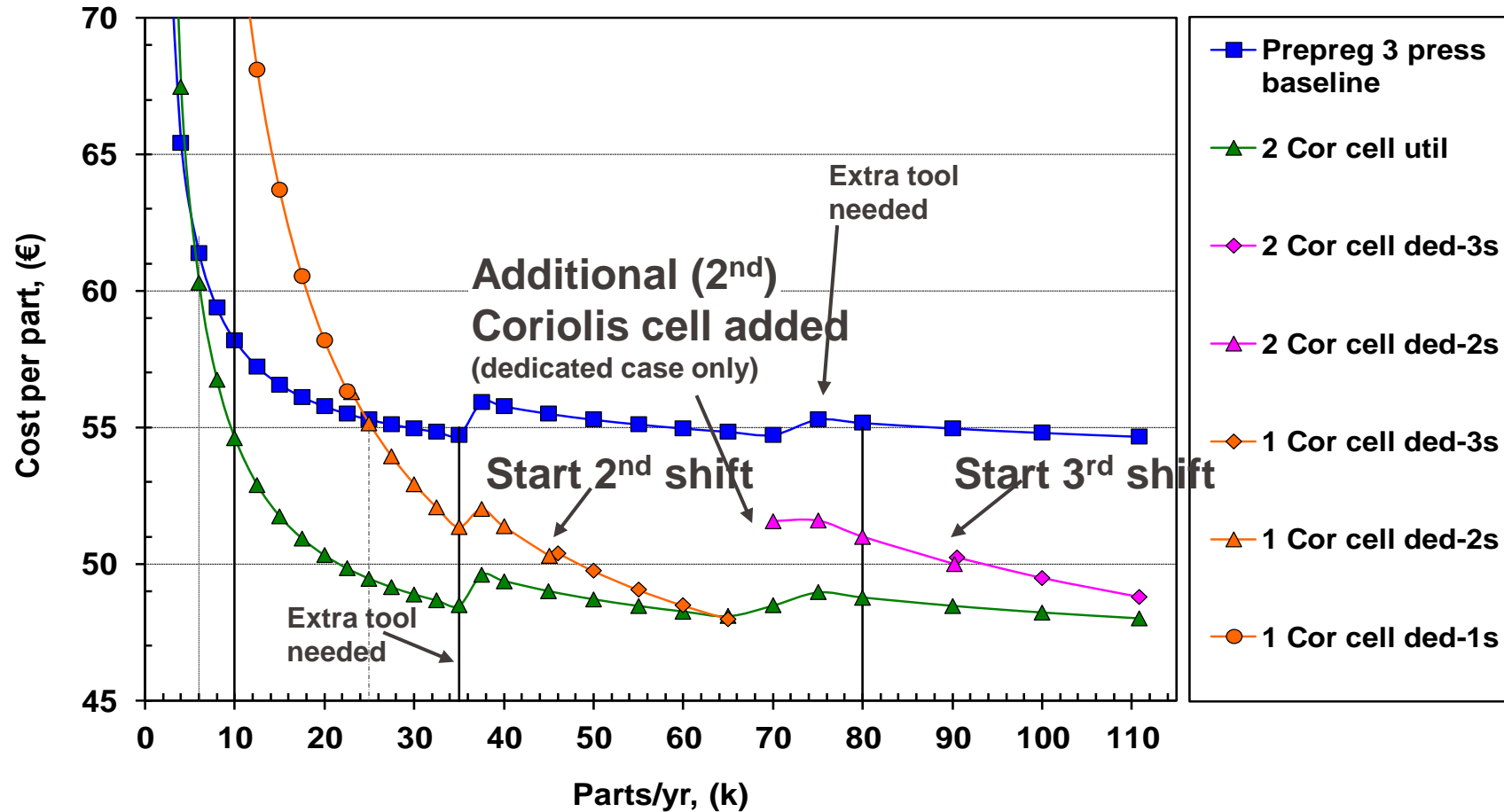
Key area to address in composite manufacturing process development



CORIOLIS composites



# CF/epoxy prepreg compression – netshape approach

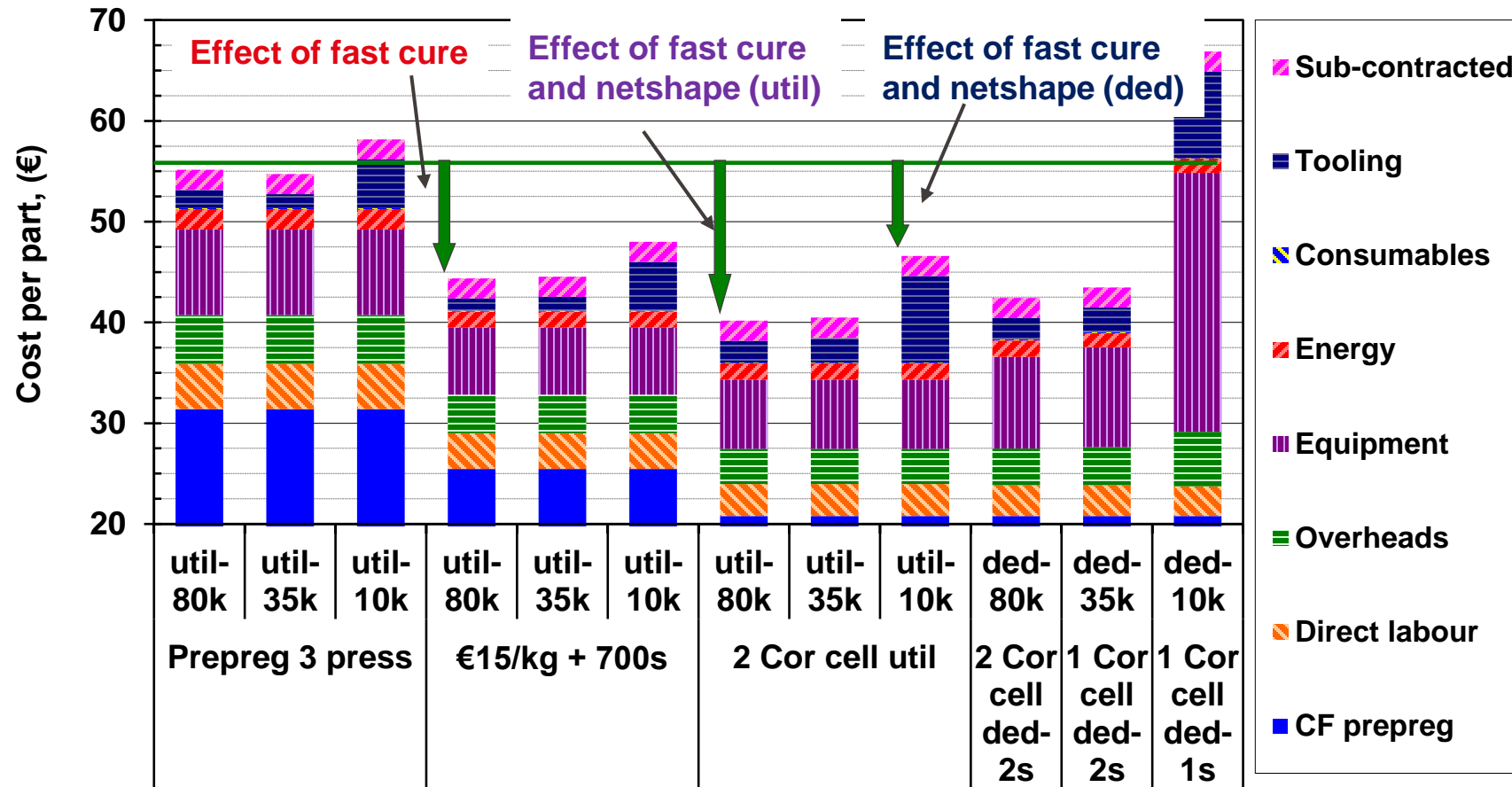


Changing plant diagram (1 cell to 2 cells) in this chart for dedicated cell approach

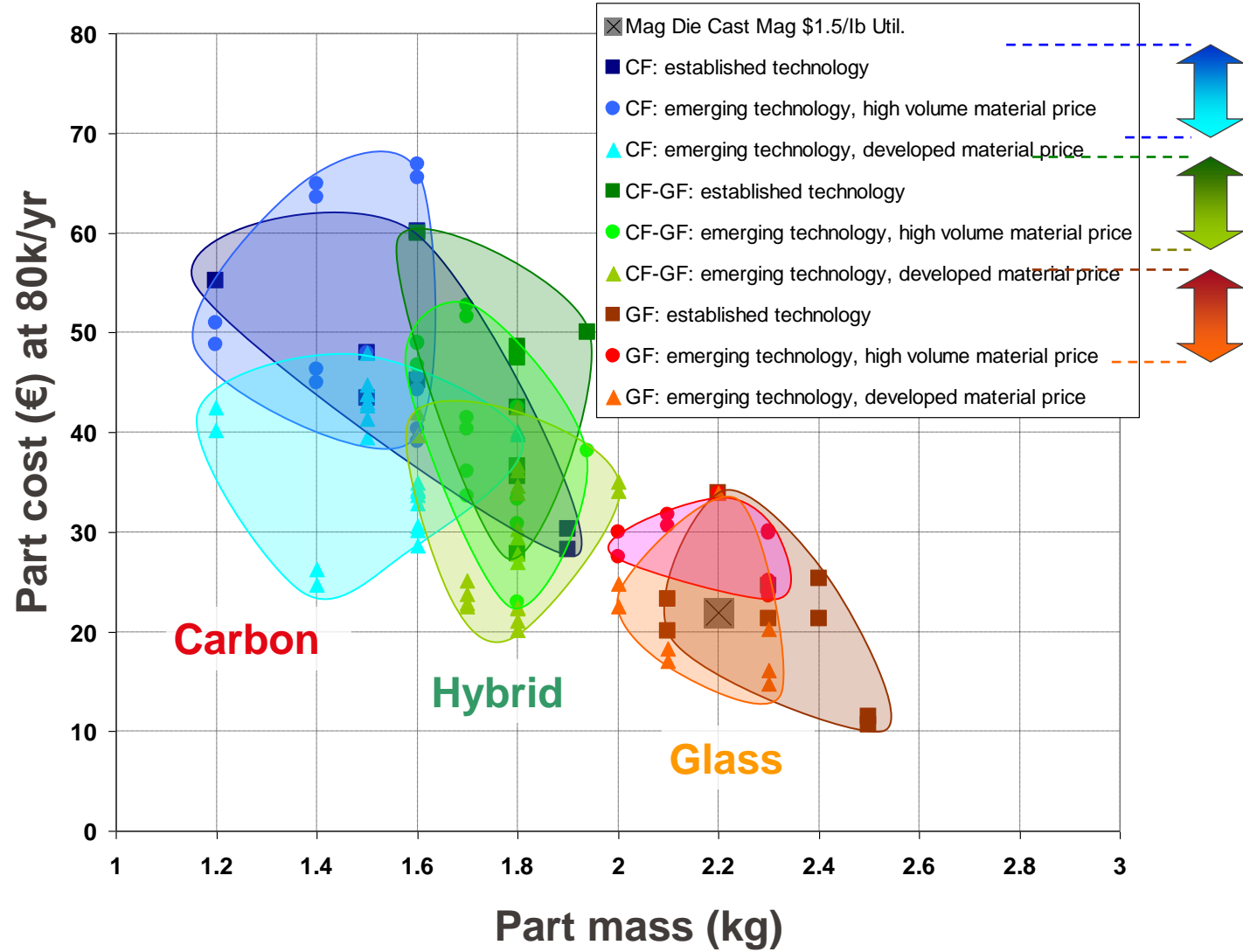
# CF prepreg compression – netshape & fast cure

Hypothetical assumption: cure cycle reduced from 900s to 700s (compared also for textile approach)

COMBINED with Coriolis system and prepreg cost reduction from €18.5/kg to €15/kg

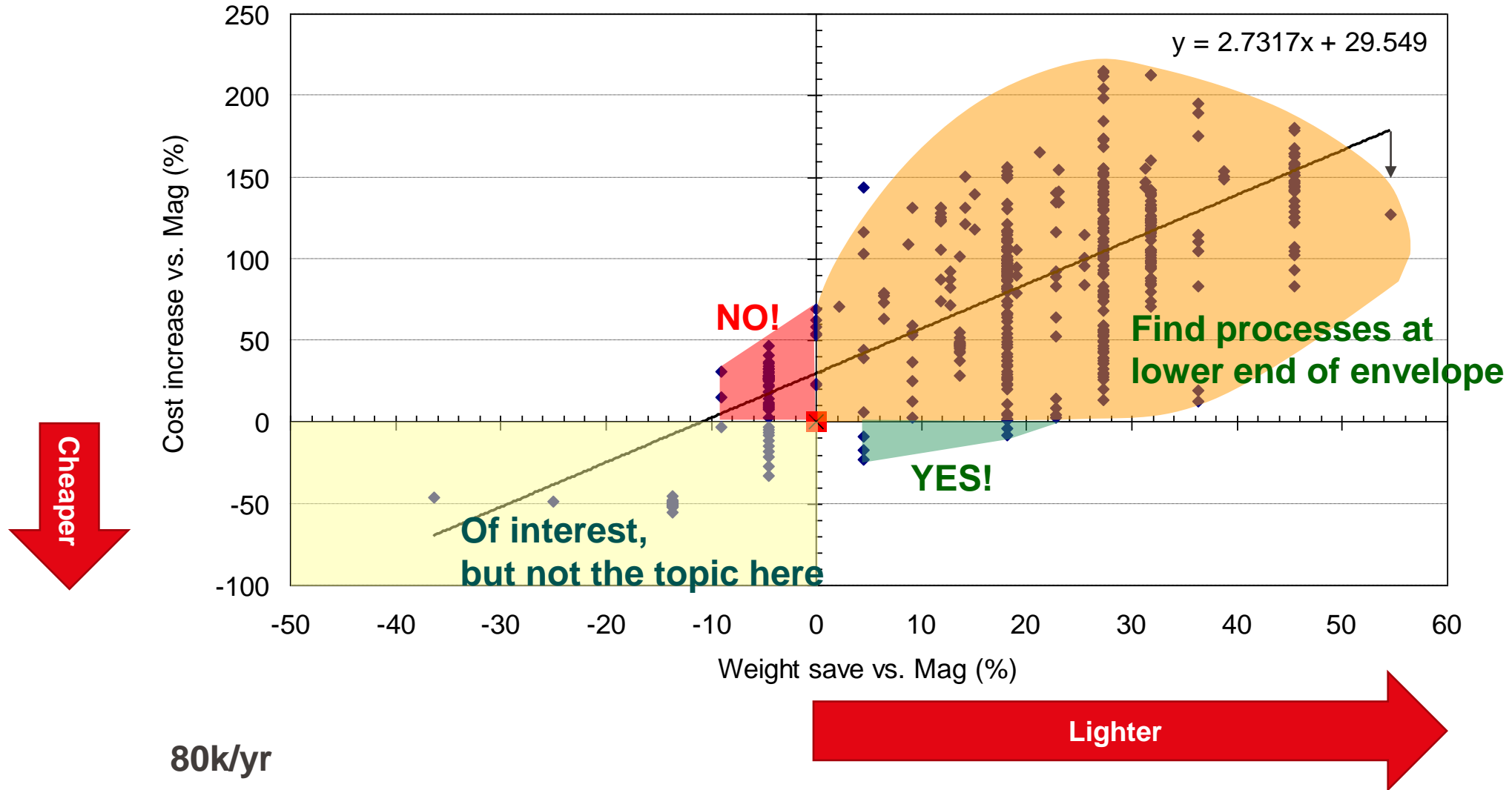


# Cost vs. mass map – selected case

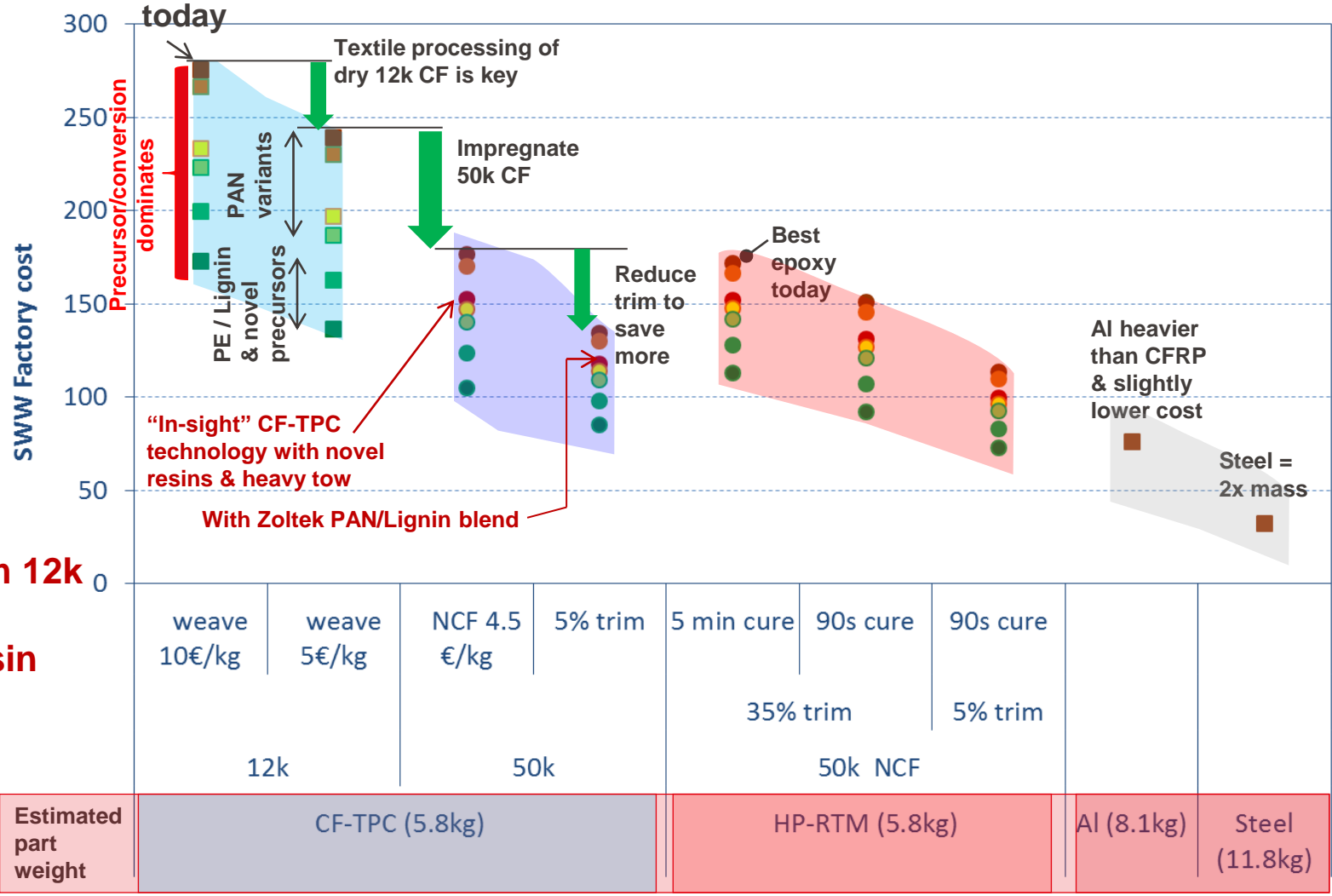


80k/yr

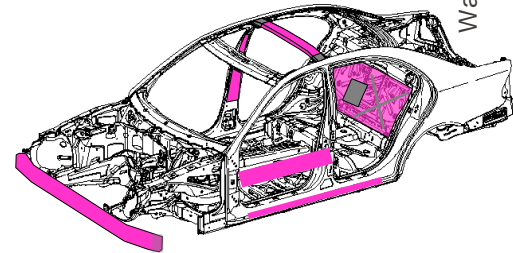
# Cost increase vs. weight saving



# Reducing cost of automotive structures



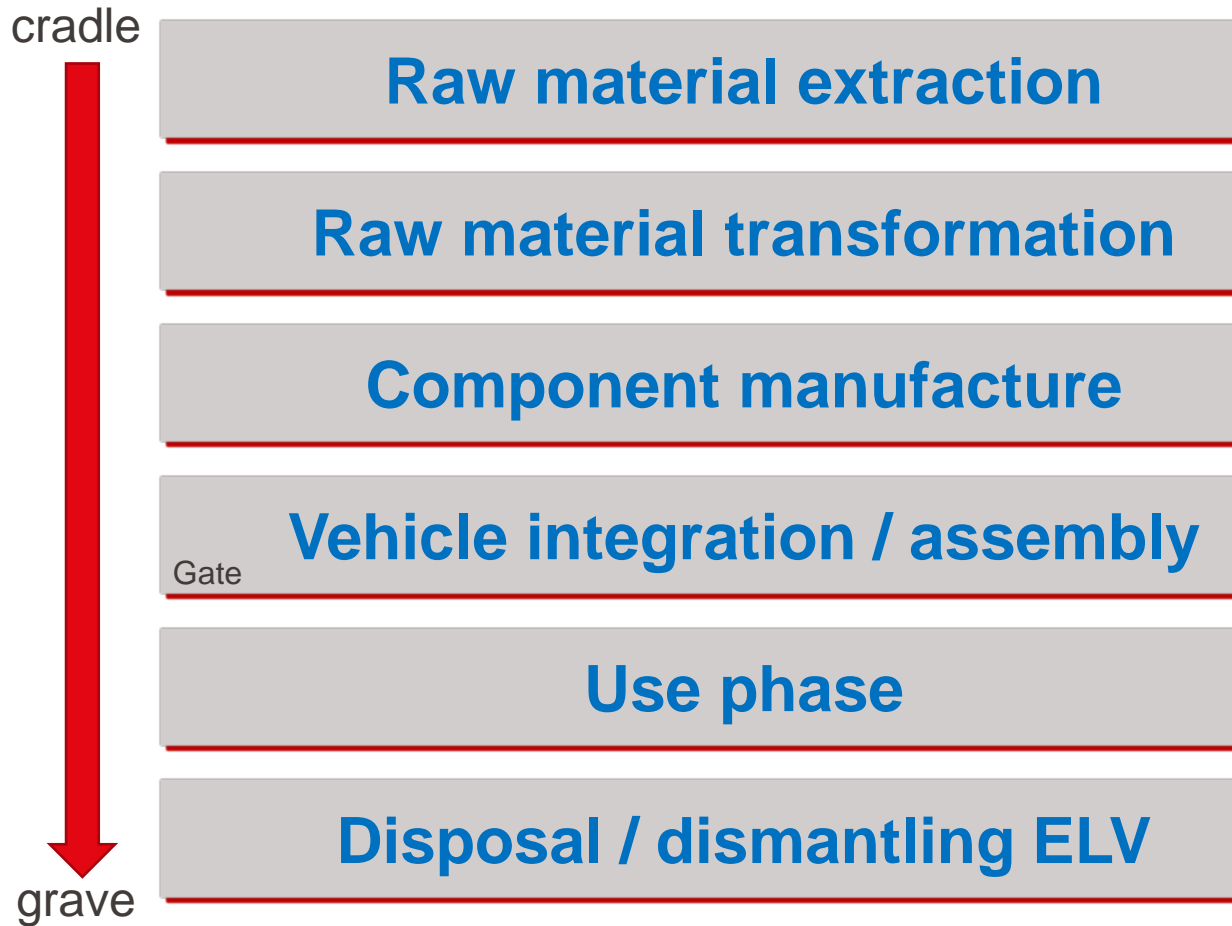
- Transition from 12k to 50k tow
- Enabled by resin and textile technology
- Reduce trim



Future developments will place both TS and TP composites at cost parity with Al at lower weight

# LCA system boundaries: define scope

## Life Cycle Phases

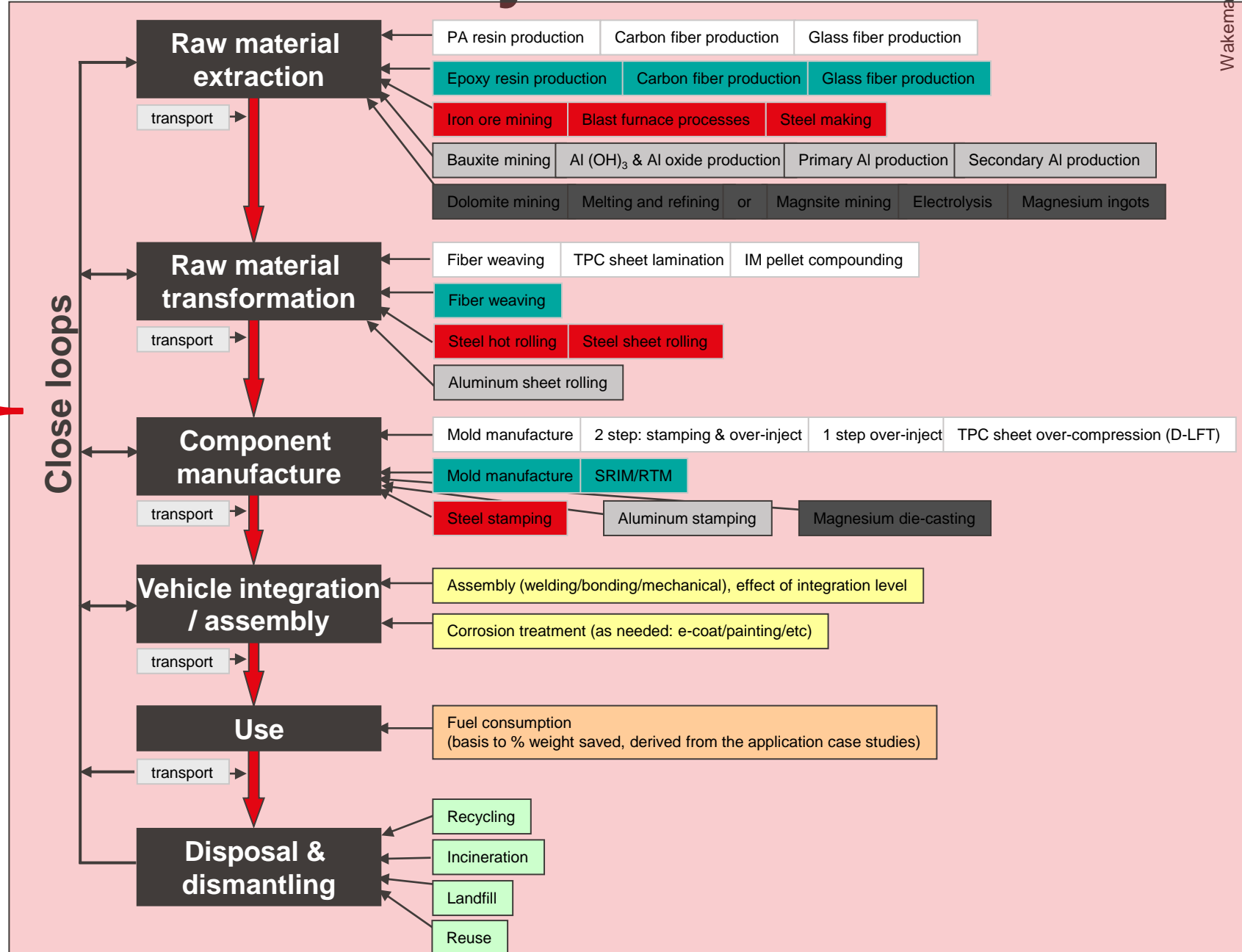


Full system analysis to examine multiple interests and see complete effect

**We need to move from a linear to circular economic model**

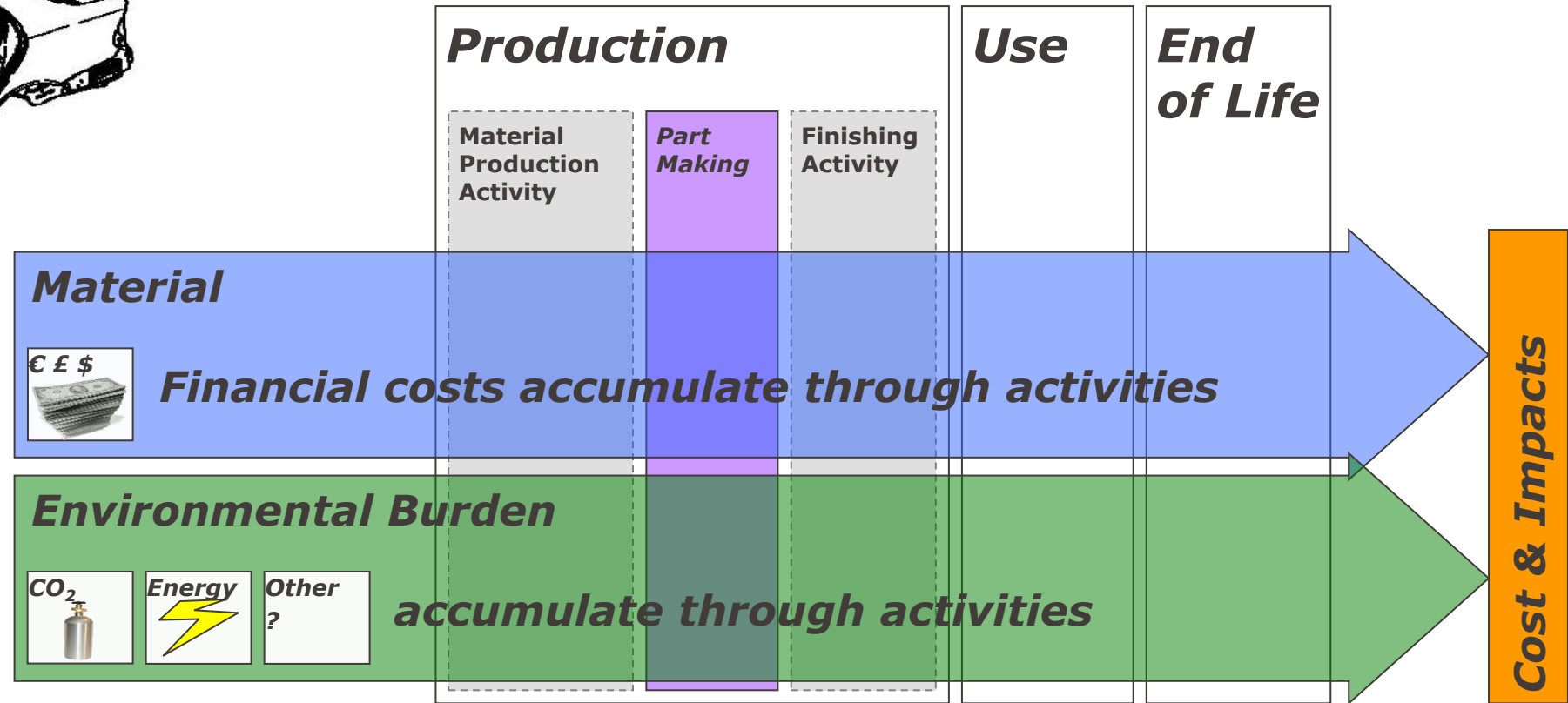
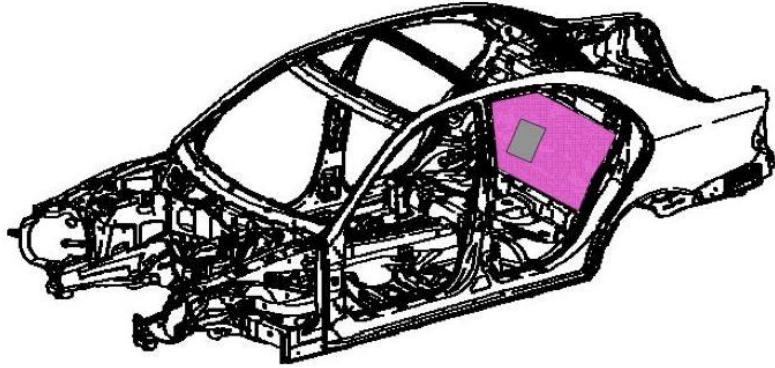
# Example of multi-material LCA system boundaries

- Reuse / Redistribute
- Remanufacture / Refurbish
- Recirculate materials
- Maintain / Prolong
- Regenerate
- Share
- Recycling



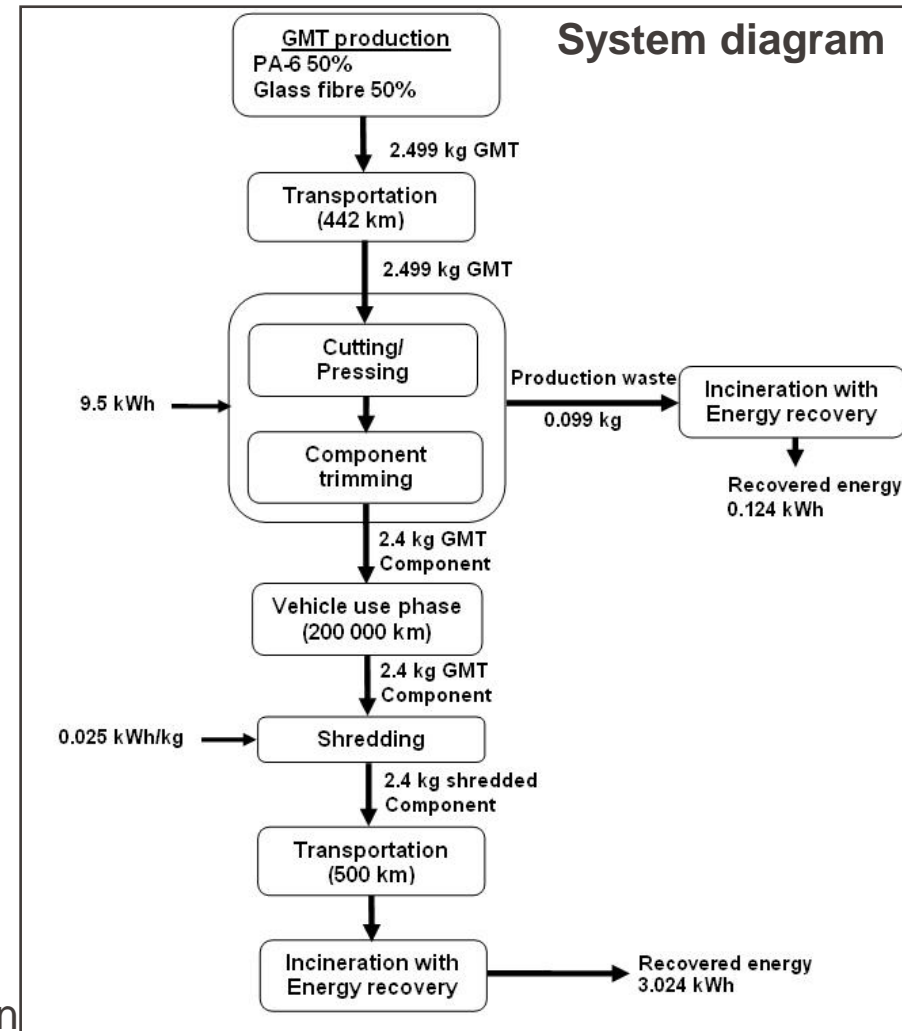
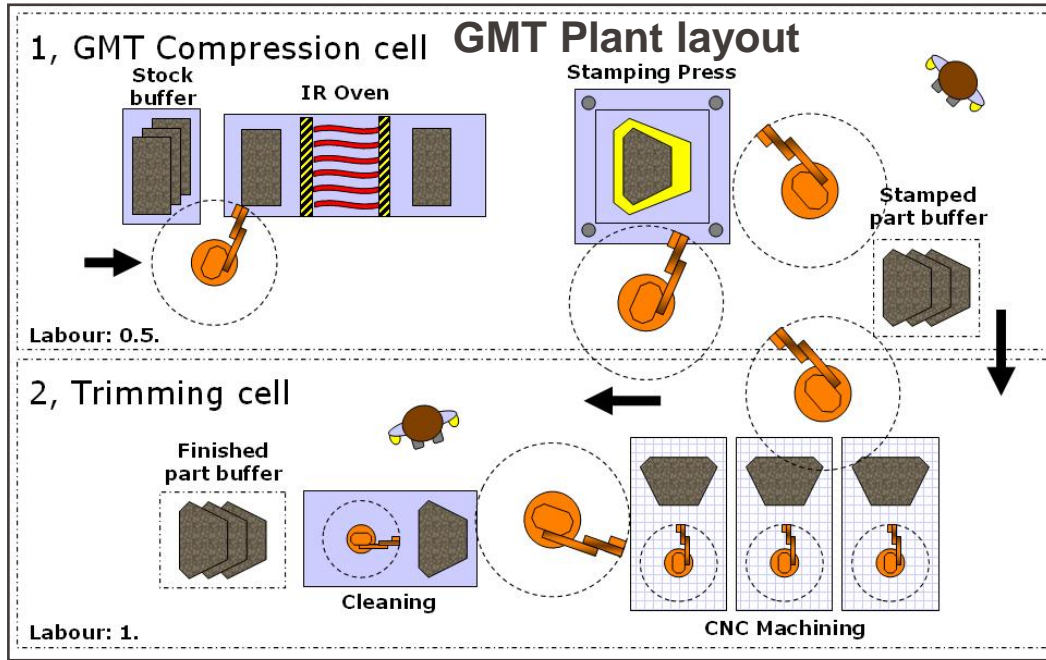
# Coupled cost modelling, LCA, and LCC

- Costs & burdens of each phase are considered
- Accumulated info used for economic and environmental assessment



[Assessing the life cycle costs and environmental performance of lightweight materials in automobile applications - ScienceDirect](#)

# Case study method



- Technical cost model (LPAC)
- Simapro used, with Impact 2002:
  - Human health (DALY)      Disability Adjusted Life Years
  - Ecosystem quality (PDF)      Potentially disappeared fraction
  - Climate change      CO<sub>2</sub> (kg)
  - Resources      MJ

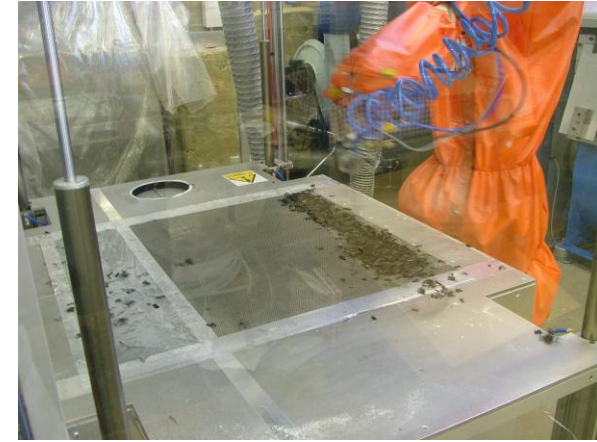
# P4 process and SRIM

A key step made – but needs combining with aligned materials

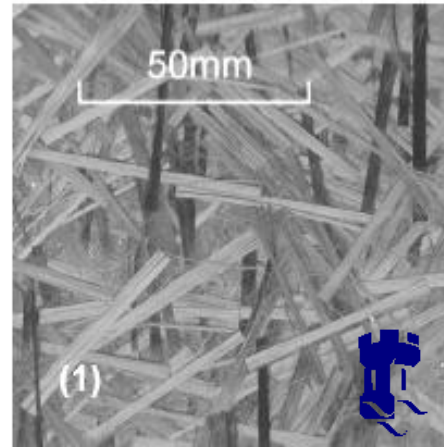


- 2 preforming stations
- preform mass 3.1kg
  - quick tool changes (~10 min)
  - 7-axis robot
  - net-shape preform
  - complex shape capability
  - direct process from roving
  - low scrap (< 3%)
  - high output (4 kg/min)

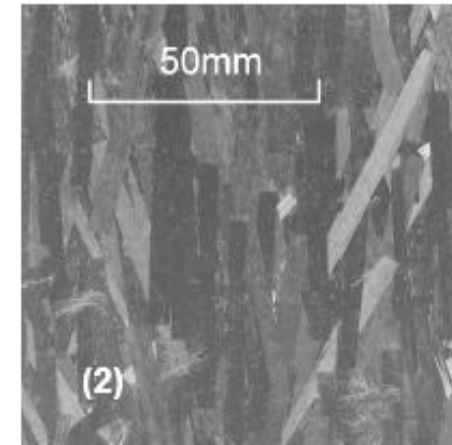
## CARBON FIBER P4



Vanquish with P4 applications



random



aligned

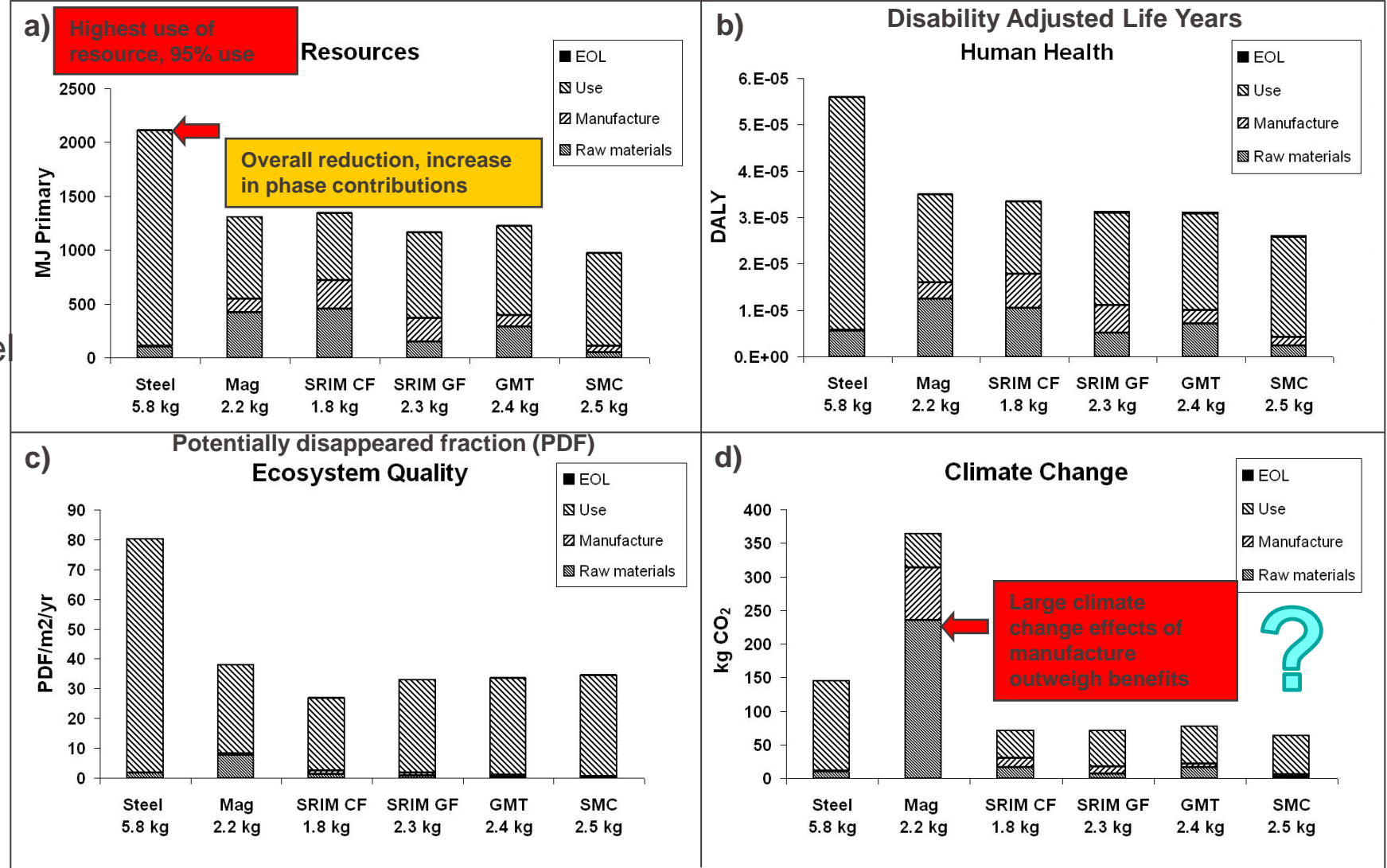
SRIM  
160s to 520s  
cycle time per  
tool depending  
on chemistry

Random CF (recycled/recovered grades)  
Use primary CF as an aligned material

# Life cycle assessment results

Recovered steel

Potential Disappeared Fraction of Species

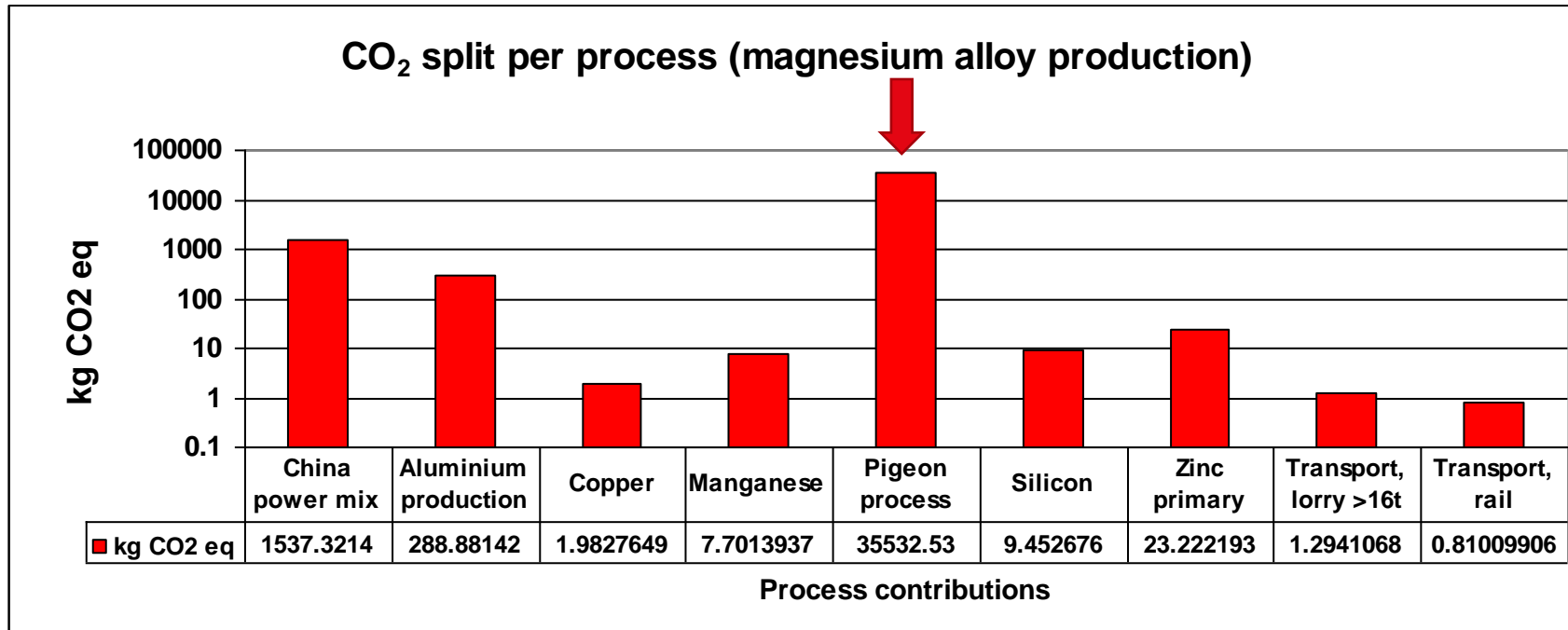


DALYs measure the gap between an ideal situation in which everyone lives to the standard life expectancy in perfect health and the actual situation

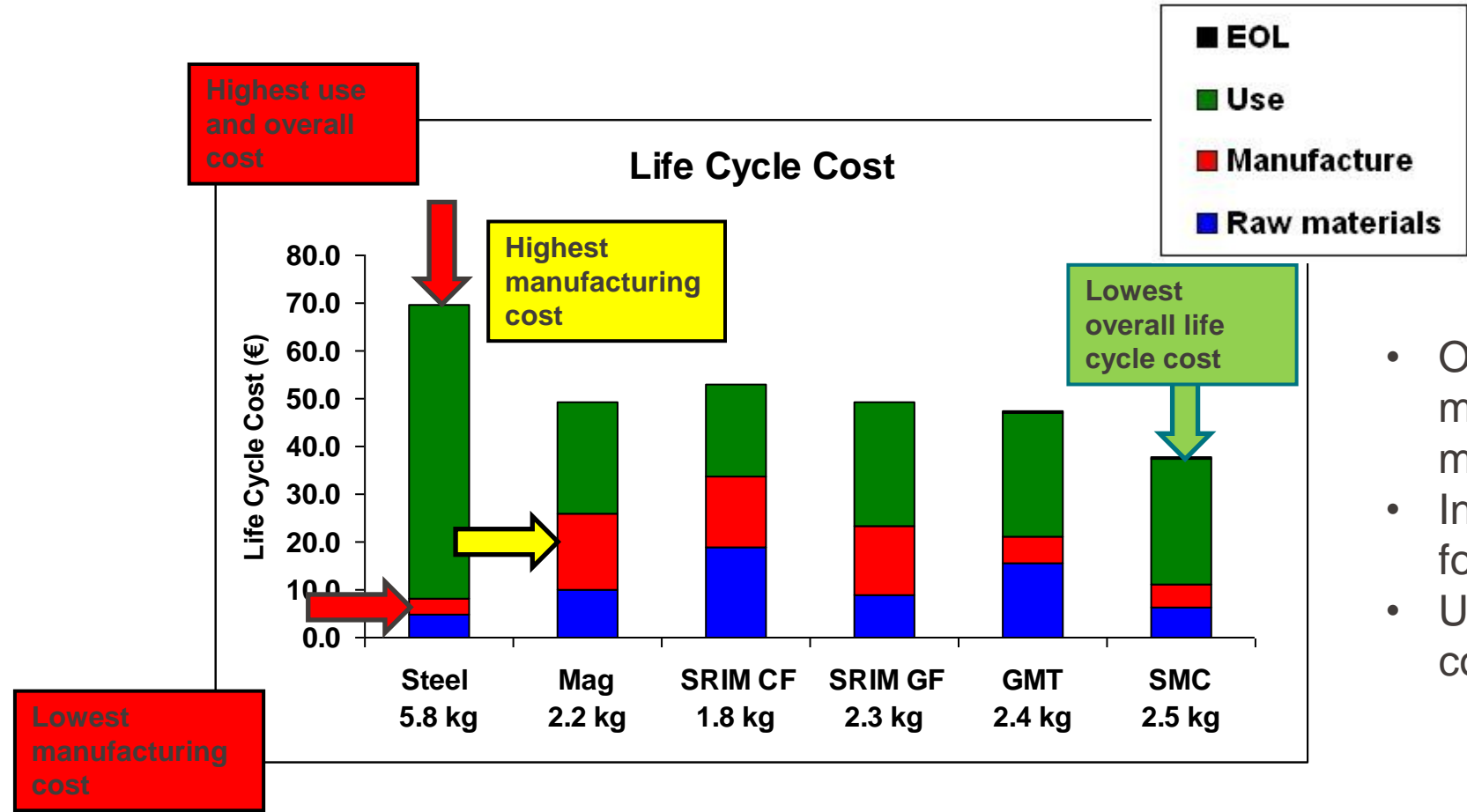
# Magnesium production: needs sensitivity study

- Molten Mg & alloys volatile, oxidize explosively in air
- Require surface protection in casting processes
- Industrial adoption of Sulfur Hexafluoride (SF6) in protective gas mixtures to reduce formation of impurities and improve quality to give cleaner, non-toxic atmospheric workplace
- SF6 applied in low concentrations (most potent greenhouse gas defined under Kyoto Protocol)
  - Atmospheric lifetime 3,200 years, a GWP-100 of 23,900 relative to CO<sub>2</sub> (Norsko Hydro, 1998)

Assumes all SF6 is lost! (not true)

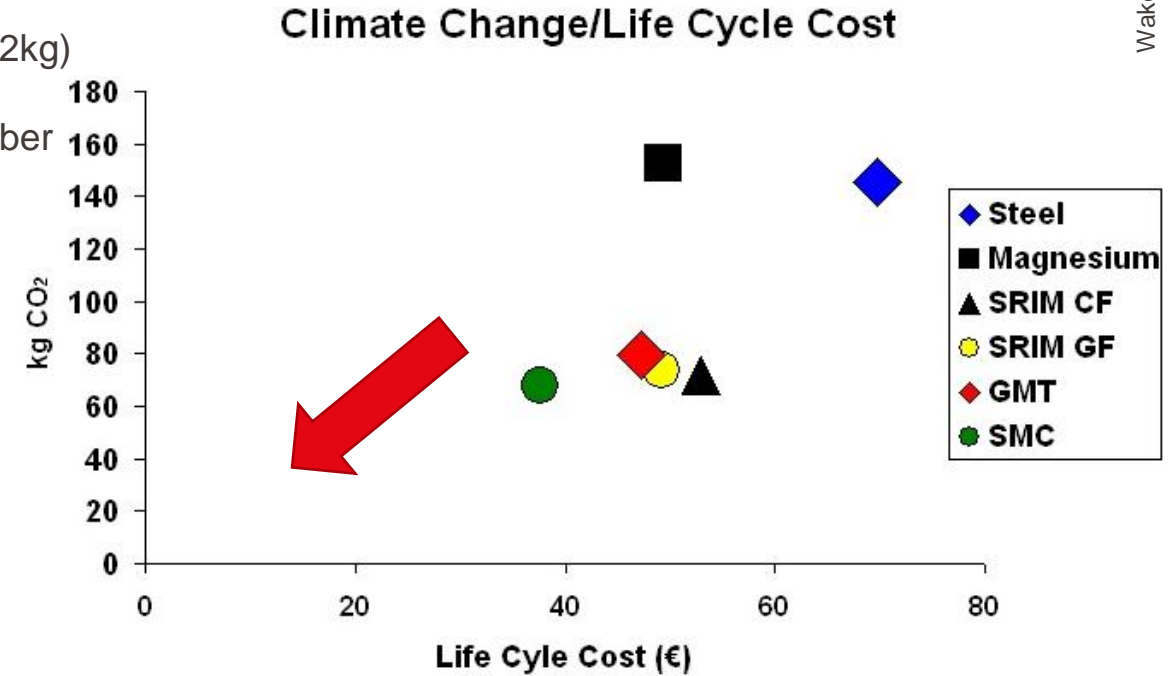
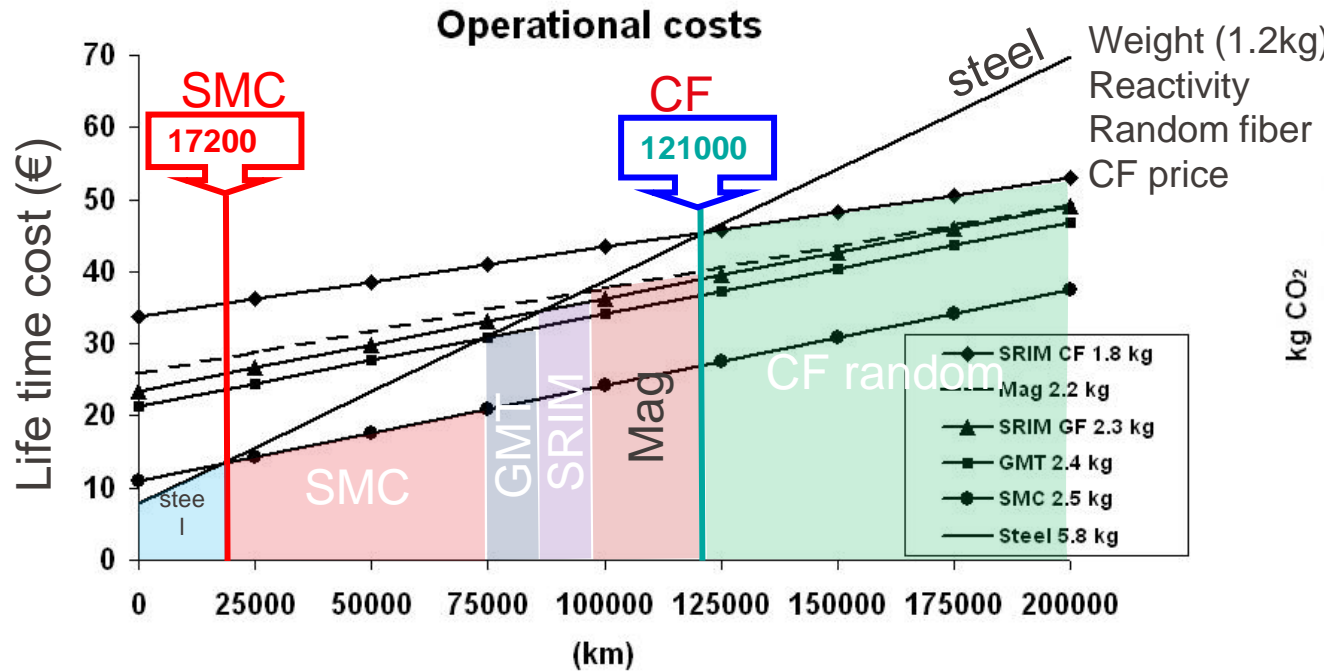


# Life cycle costs per part (200'000 km)



- OEM interested in materials and manufacture
- Innovation allowance for higher cost raws?
- User pays use phase costs

# “Break even” analysis (€), Material ranking



- Composites give cost & impact reductions over life time; but increased manufacturing cost
- SMC comes out well, despite a higher weight and issues of recyclability
- CF: update with faster reacting resins, aligned fibers for lower mass, specific CF LCA data (e.g. 50k tow, wind power, bio-mass PAN, BMW i3)
- Phase shifting was observed for the magnesium scenario: lowered use phase emissions, but higher for manufacture
- Automotive manufacturers need to reduce use phase emissions and to increase recycling at the end of life

# Coupled Cost and Life cycle analysis

- Coupled TCM, LCA, LCC to assess the implementation of composite parts
- Can be further integrated into business financials
- Ideas for further developments
  - low energy cure, alternative fibers, geographic effects, circular economy, ELV, ...
- **Environmental pricing & negative externalities**

- Data quality
  - LCA inventory data for composite materials and processes lacking
  - Can be misleading or historical (not forward looking)

- Collaboration is needed between LCA analysts, materials producers and process engineers to improve the databases (and conclusions!)
- Vision of the whole life cycle is important to build up a strategy



**Design out waste and pollution**



**Keep products and materials in use**



**Regenerate natural systems**

- Cost modelling approaches
- Technical cost modelling deep dive
- Cost modelling and technology strategy
- **Wrap up**
- Annex: A simple cost tool

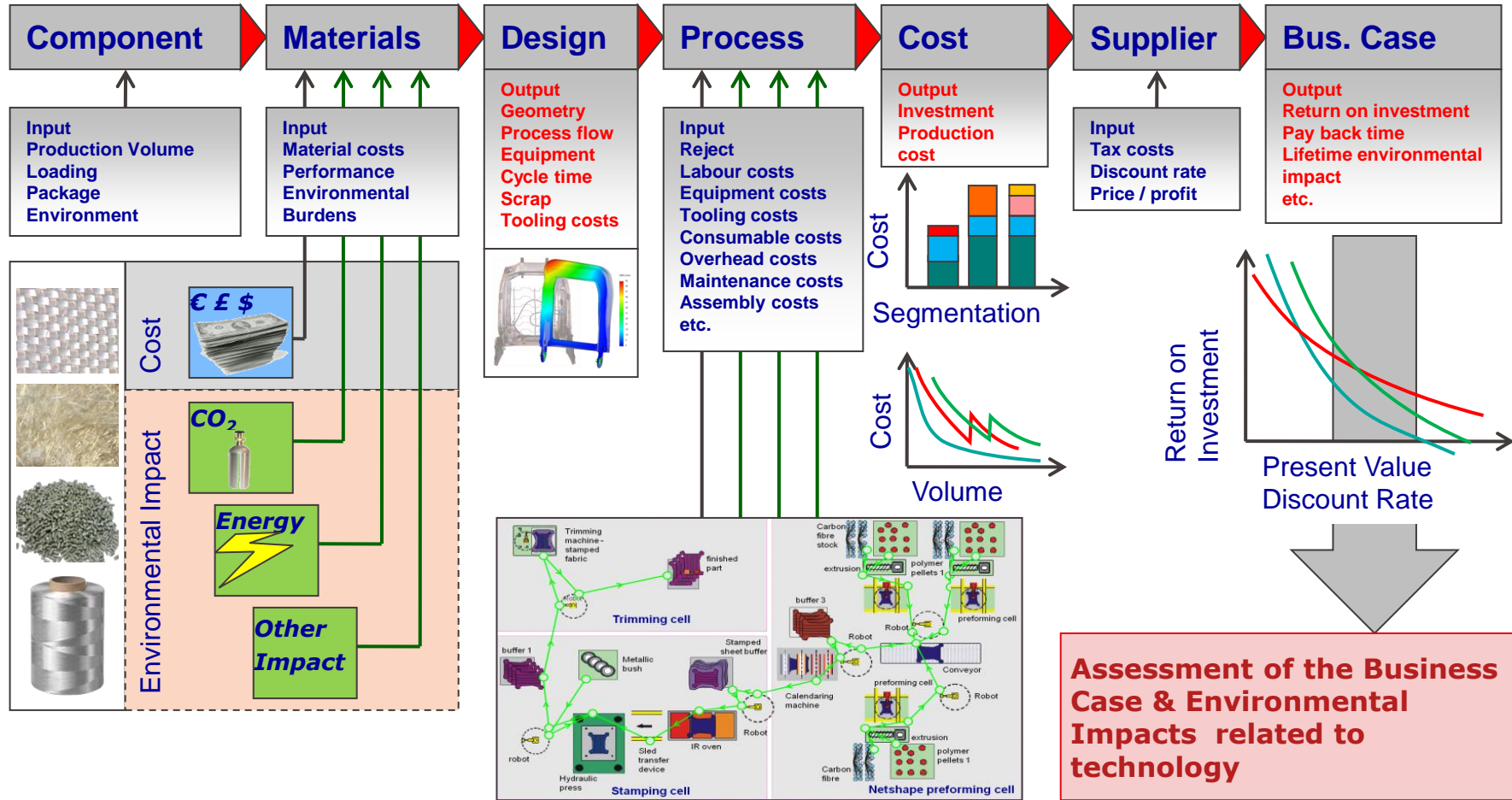
# slido



## How can cost modelling help in a project or initiative?

① Start presenting to display the poll results on this slide.

- Technical, Financial & Environmental Cost Prediction



# Conclusions: cost modelling

## As a tool

- Helps us understand a technology
- Assess early ideas
- Gain support to research proposals / funding
- Develop a value proposition
- Establish a scaling strategy
- Build the business case and financials

## Approach

- Rigorous
- Data driven
- Embed scientific and engineering principles and knowledge

## Aids

- Help innovative ideas move towards industrialization
- Language for communication across functions and with customers

# Financial definitions for engineers

<b>Price</b>	the amount of money given or set as consideration for the sale of a specified thing
<b>Factory cost</b>	the expenses that are incurred by the business to manufacture goods that are intended to be sold to the customers in the normal course of business and includes all <b>cost</b> linked to production like the direct material <b>cost</b> , direct labor <b>cost</b> and other manufacturing overheads.
<b>Fixed</b>	A cost that does not change with an increase or decrease in the amount of goods or services produced or sold. Expenses that have to be paid by a company, independent of any specific business activities
<b>Variable</b>	is a <b>corporate expense that changes in proportion to production output</b> . Variable costs increase or decrease depending on a company's production volume; they rise as production increases and fall as production decreases. Examples: costs of raw materials and packaging.
<b>CAPEX</b>	<b>Capital expenditures</b> (CapEx) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment. CapEx is often used to undertake new projects or investments by a company.
<b>CAWC</b>	cost associated with capital (installation), sometimes $CAPEX + CAWC = 1.5 \text{ to } 2.5x \text{ CAPEX}$ )
<b>OPEX</b>	<b>operating expenditure</b> , ongoing expenses inherent to operation of the asset. Includes items like <b>electricity</b> , salaries, R&D, travel, SG&A (selling, general and administrative expense)

# Financial definitions for engineers

<b>NPV</b>	Net present value: Value in today's money of a future investment: difference between the present value of cash inflows and the present value of cash outflows over a period of time. Used in <u>capital budgeting</u> and investment planning to analyze the profitability of a projected investment or project. Calculation of NPV includes: CAPEX, materials, market growth, pricing, margin vs. time, the <u>time value</u> of money, the <u>discount rate</u> over project duration.
<b>ROI</b>	Return on investment, evaluate investment efficiency or compare a number of different investments. Measures the return on a particular investment, relative to the investment's cost. The benefit (or return) of an investment is divided by the cost of the investment, expressed as a percentage or a ratio.
<b>CAGR</b>	Compound annual growth rate (CAGR) is the <u>rate of return</u> (or market growth) that would be required for an investment to grow from its beginning balance to its ending balance
<b>Gross margin</b>	Gross margin is a company's net sales revenue minus its cost of goods sold (COGS). The sales revenue a company retains after incurring the direct costs associated with producing the goods it sells, and the services it provides.
<b>Corporation tax</b>	A levy placed on a firm's <u>profit</u> by the government. Calculated by deducting expenses, including the <u>(COGS)</u> and depreciation from <u>revenues</u> .
<b>Time to first revenue</b>	When your project receives payment for goods produced, 1st +ve cash flow



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of Advanced Composites**