PLASTIC CHALLENGE
Hackathon 2021

Visualization tools for sustainable material selection – Application to bioplastics

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EU GREEN WEEK 2021 PARTNER EVENT

ZERO POLLUTION #EUGreenWeek
for healthier people and planet

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Agenda

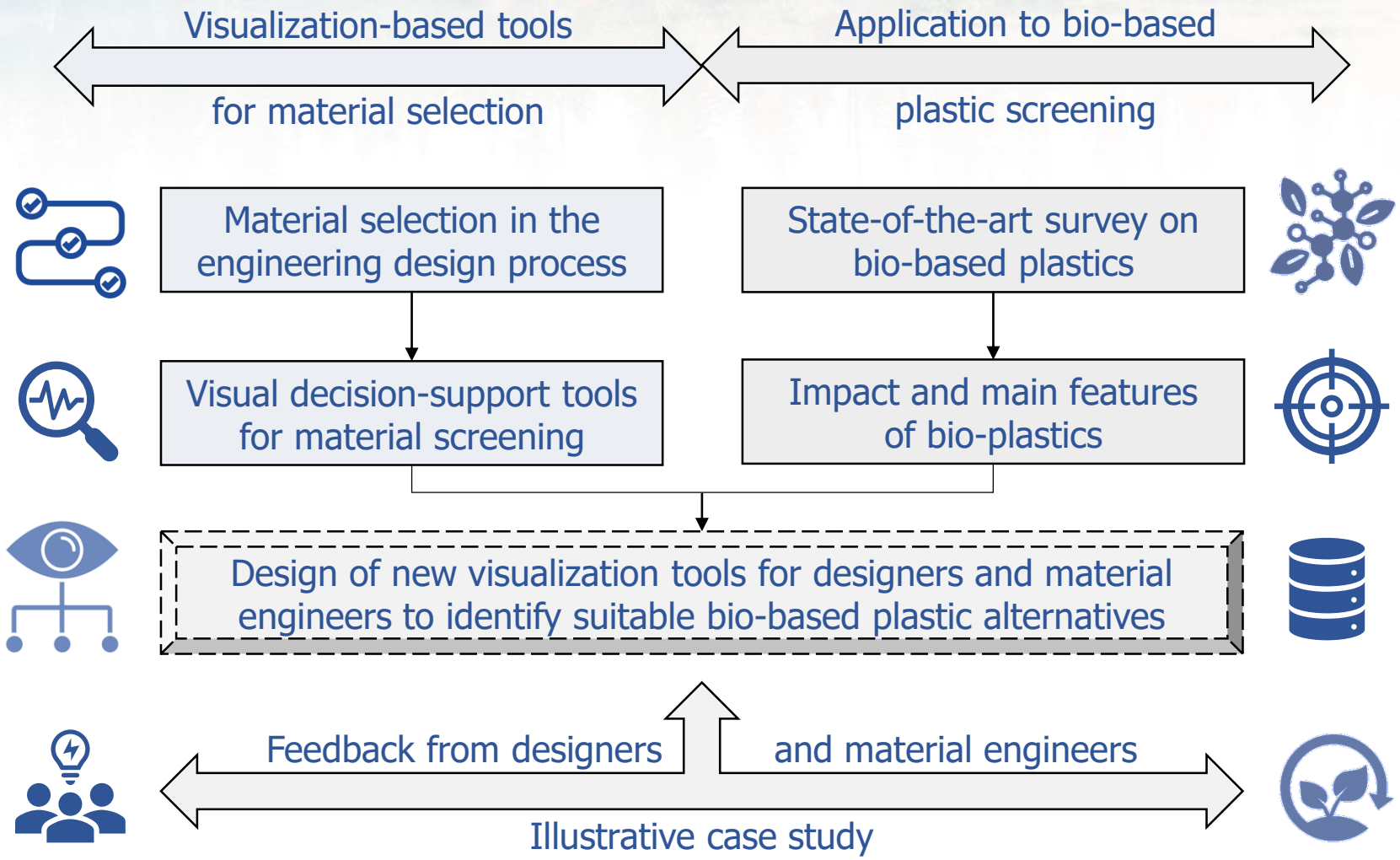
01 **Motivations**
Purposes of new sustainable materials

02 **Design process**
Existing tools for materials selection

03 **Environmental impacts**
Sustainable materials as greener alternatives

04 **Design of new/updated tools**
Prototype of integrated tools for material and design engineers

Graphical Outline



Motivations and Research Question (RQ)

New advanced and sustainable materials are being developed:

- to face issues like petroleum-based plastic pollution;
- to improve mechanical properties, profitability, etc

→ RQ: How to facilitate and ensure the selection of greener materials by design engineers during the (re)design and development process of products?

Integrated visualization-based tools can effectively support designers and material engineers in the screening and selection of sustainable alternatives during the early design stage.

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Requirements and Expected Outcome

To provide a practical, clear, and user-friendly tool/visual/chart/table/infographic to:

- Make informed-decision in sustainable materials selection
- Educate design engineers on sustainable materials alternatives
- With a lightweight and intuitive interface

So that design engineers can understand simply:

- what bio-based materials are more or less sustainable, compared to conventional materials
- what are the possible greener material substitutes in the early design stages

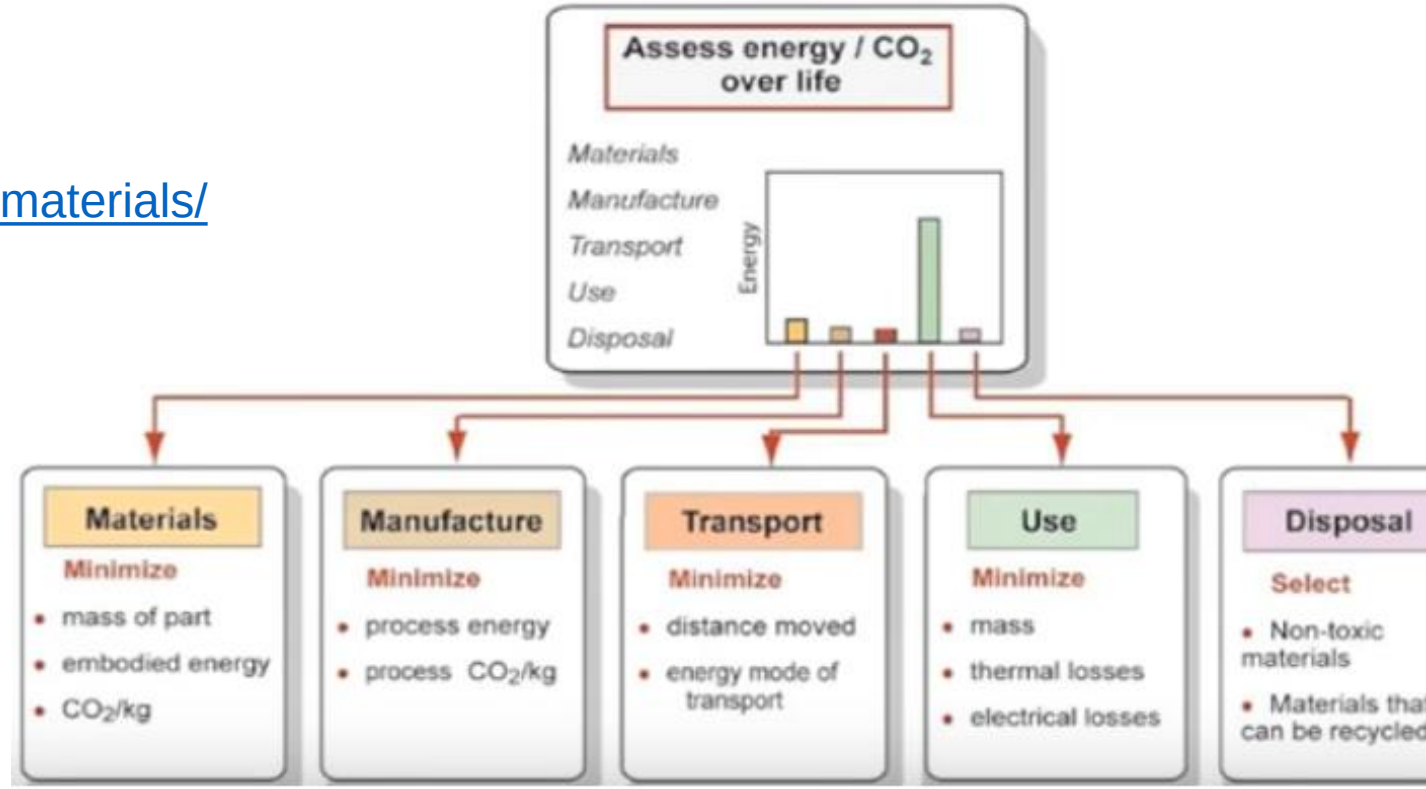
Sustainable Materials

- An ideal sustainable material:
  - is abundant and/or rapidly renewable
  - can be harvested in a sustainable fashion
  - is resource-cheap (requires minimal energy or other material to produce)
  - is chemically safe and healthy
  - has many lives (via recycling, reuse, or composting)
  - is socially benevolent
  - is financially affordable
  - meets relevant laws and labels
  - functions well (doesn't break or wear prematurely, etc.)
  - greens the whole system, not just itself

Materials selection is key to sustainable design strategies throughout the product lifecycle

https://venturewell.org/tools_for_design/greener-materials/

Materials selection is one of the main phases of the product design process and can have a significant impact on the overall lifecycle of products



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Inspiration Sources

Sustainability visualization-based tools

Commendable design attributes
Ramanujan et al. (2017)

Environmental impact of bio-based plastics

In comparison with conventional plastics: PE, PP, PVC, PS, PET, PUR

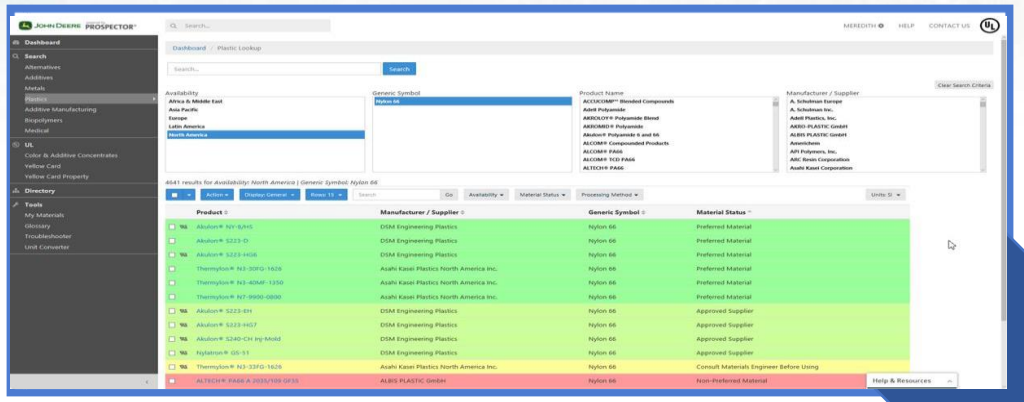
Multi-criteria Decision Analysis

Supporting the selection of engineering materials in product design

Technical substitution for bio-based plastics

Substitution potentials for main fossil-based plastics (Spierling et al. 2018)

Existing Software

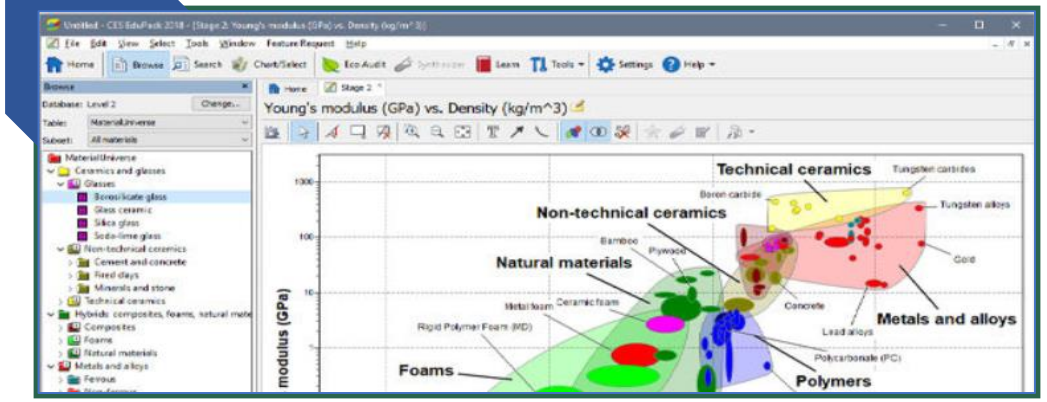


Prospector

- Table-based
- Extensive material database
- Lack of information related to environmental sustainability

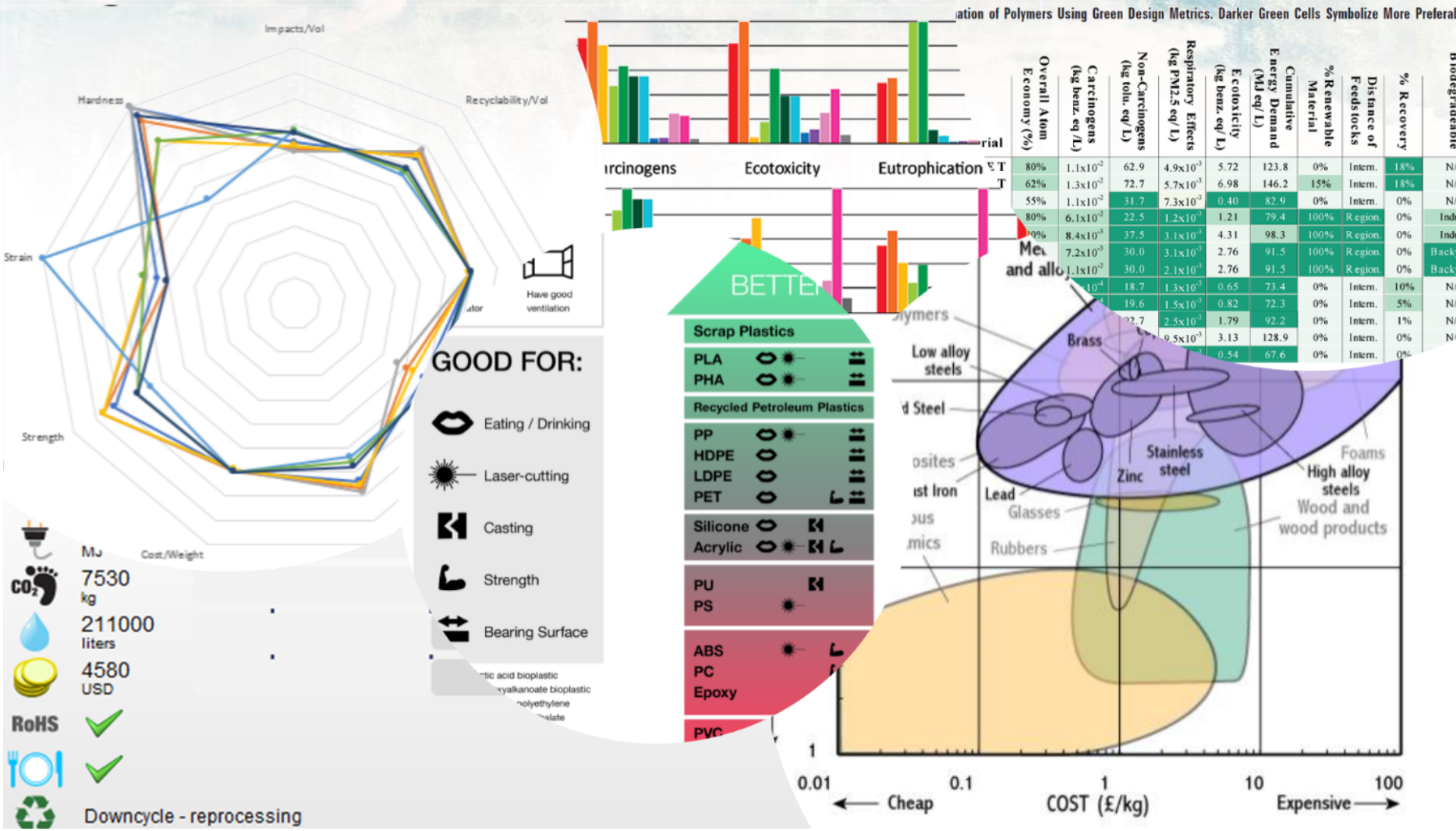
Granta Selector

- Ashby chart
- Comprehensive database/info
- Lack of environmental impact considerations for bio-based plastics



Common Visualization-based Tools

- ✓ Ashby diagram
- ✓ Scatter plot
- ✓ Bar chart
- ✓ Radar chart
- ✓ Arrow
- ✓ Table
- ✓ Textual sheet
- ✓ …



ation of Polymers Using Green Design Metrics. Darker Green Cells Symbolize More Preferal

Overall Atom Economy (%)	Carcinogens (kg benz. eq/L)	Non-Carcinogens (kg tolu. eq/L)	Respiratory Effects (kg PM2.5 eq/L)	Ecotoxicity (kg benz. eq/L)	Cumulative Energy Demand (MJ eq/L)	%Renewable Material	Distance of Feedstocks	% Recovery	Biodegradeable
80%	$1.1x10^{-2}$	62.9	$4.9x10^{-3}$	5.72	123.8	0%	Intern.	18%	N
62%	$1.3x10^{-2}$	72.7	$5.7x10^{-3}$	6.98	146.2	15%	Intern.	18%	N
55%	$1.1x10^{-2}$	31.7	$7.3x10^{-3}$	0.40	82.9	0%	Intern.	0%	N
80%	$6.1x10^{-2}$	22.5	$1.2x10^{-1}$	1.21	79.4	100%	Region.	0%	Ind
0%	$8.4x10^{-3}$	37.5	$3.1x10^{-3}$	4.31	98.3	100%	Region.	0%	Ind
	$7.2x10^{-3}$	30.0	$3.1x10^{-3}$	2.76	91.5	100%	Region.	0%	Back
	$1.1x10^{-2}$	30.0	$2.1x10^{-3}$	2.76	91.5	100%	Region.	0%	Back
	10^{-4}	18.7	$1.3x10^{-2}$	0.65	73.4	0%	Intern.	10%	N
		19.6	$1.5x10^{-3}$	0.82	72.3	0%	Intern.	5%	N
		92.7	$2.5x10^{-2}$	1.79	92.2	0%	Intern.	1%	N
			$9.5x10^{-3}$	3.13	128.9	0%	Intern.	0%	N
				0.54	67.6	0%	Intern.	0%	

Survey and Focus Group

Sample of questions asked:

i. Is this tool relevant or valuable for material selection?

ii. How would you assess the design and user-friendliness of this tool, and what could be improved?

iii. Which combination of the tools presented would you find useful?

iv. Would you find added value to a web-based app of such visual tools?

Insights on what designers and material engineers value most

- The “Green Arrow” for plastics: helpful to provide a quick material suggestion on sustainable materials that share the same “good for” labels.
- But also lightweight, user-friendly, highly visual web-based tools or Ashby-like diagram.

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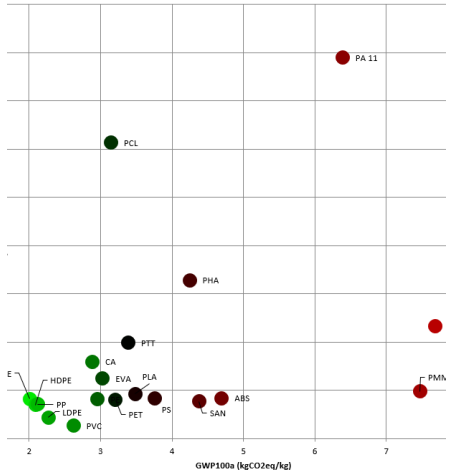
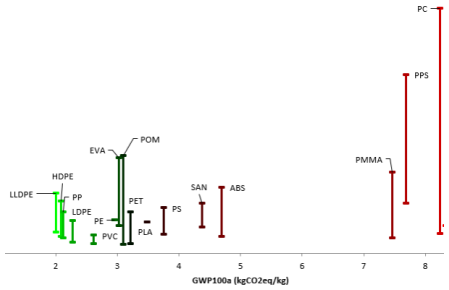
Prototyping of S-Material Selection/Visualization Tools



Ashby-like chart

Env and eco info

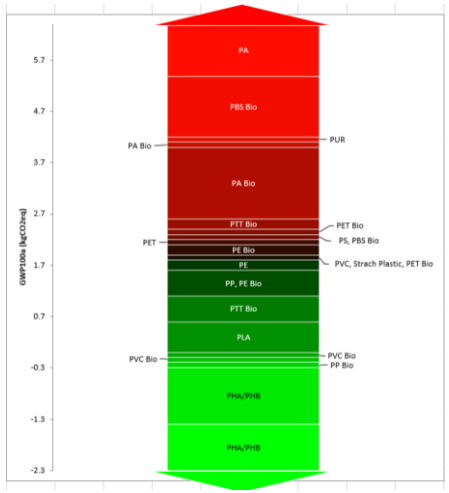
Bio-based plastics



Ashby-like chart II

Price range/uncertainty

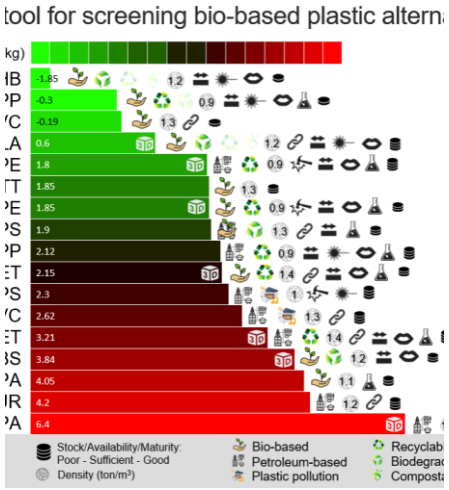
Bio-based plastics



Updated 1D arrow

Env ranking (GWP)

Bio-based plastics

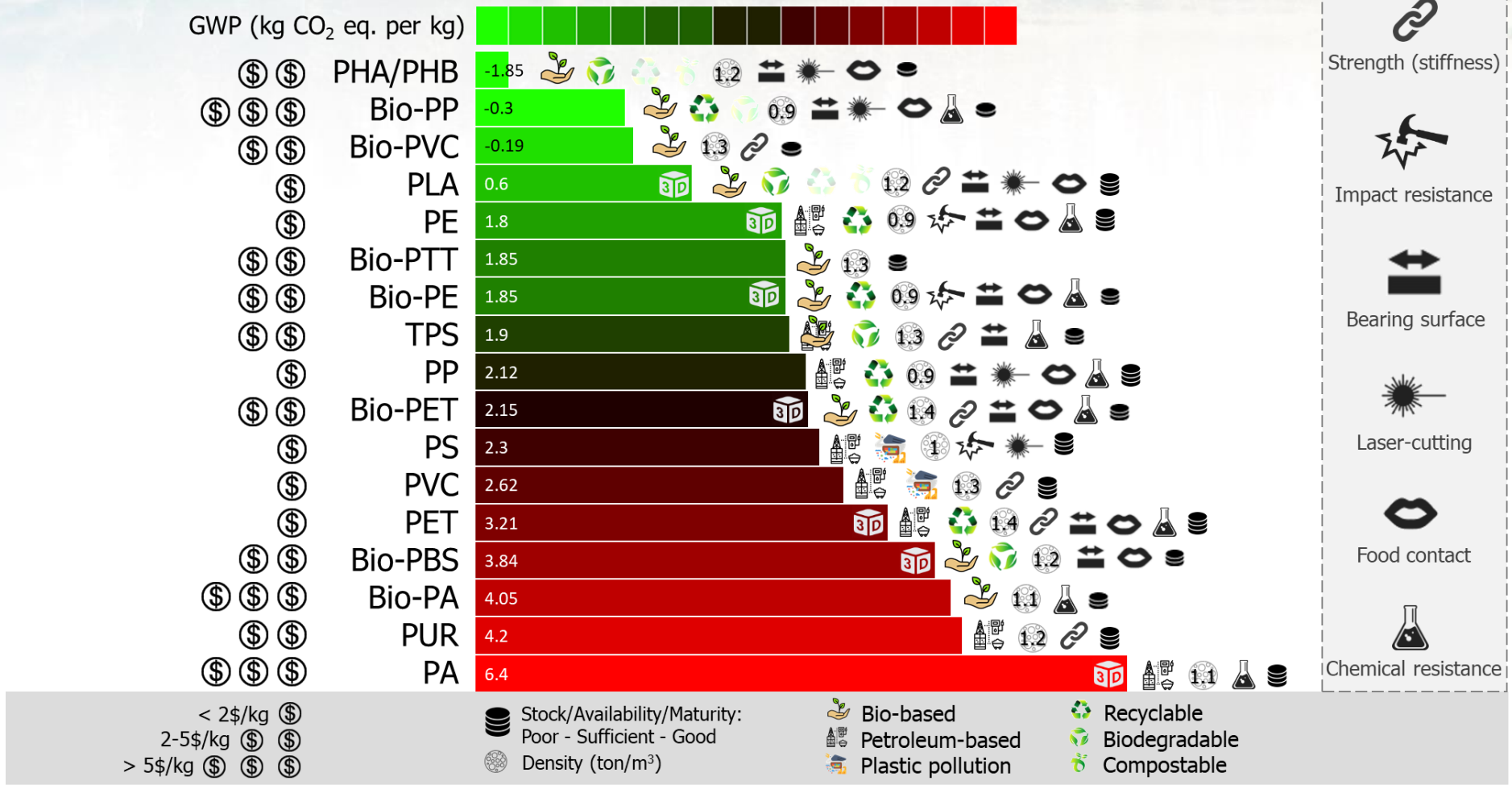


Combined/Hybrid

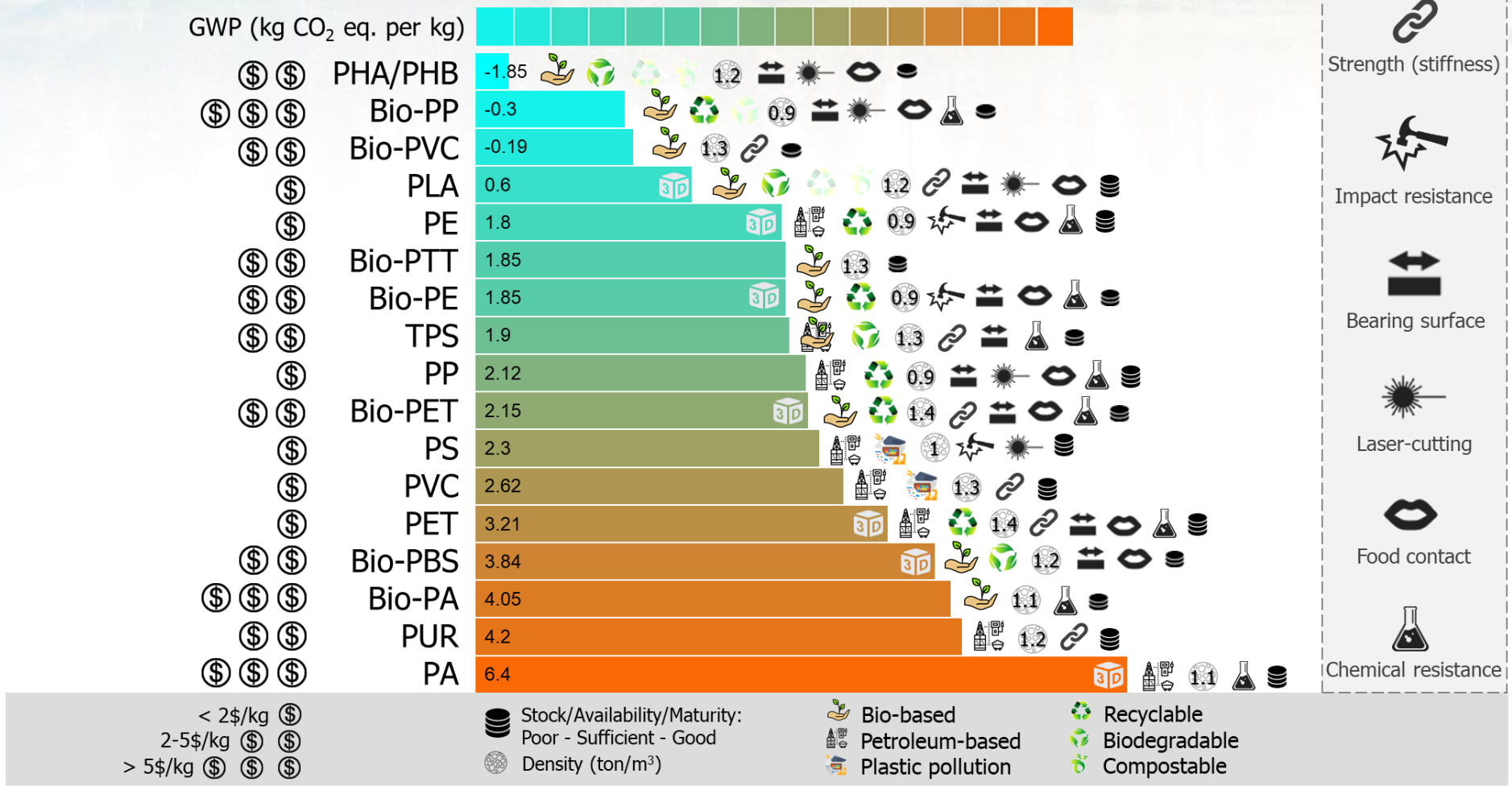
Ranking, multi dim

Bio-based plastics

Visualization tool for screening bio-based plastic alternatives



Visualization tool for screening bio-based plastic alternatives



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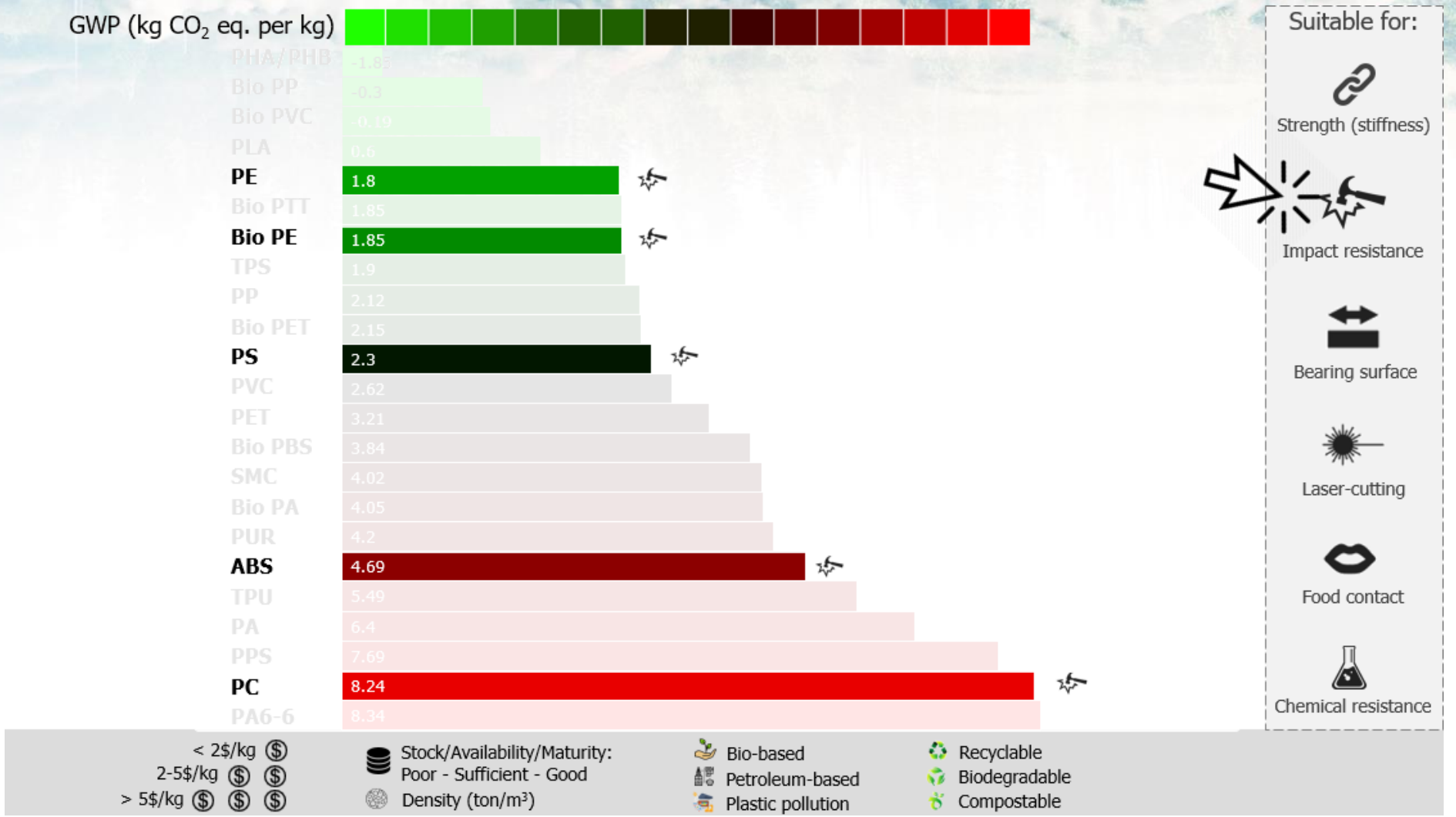
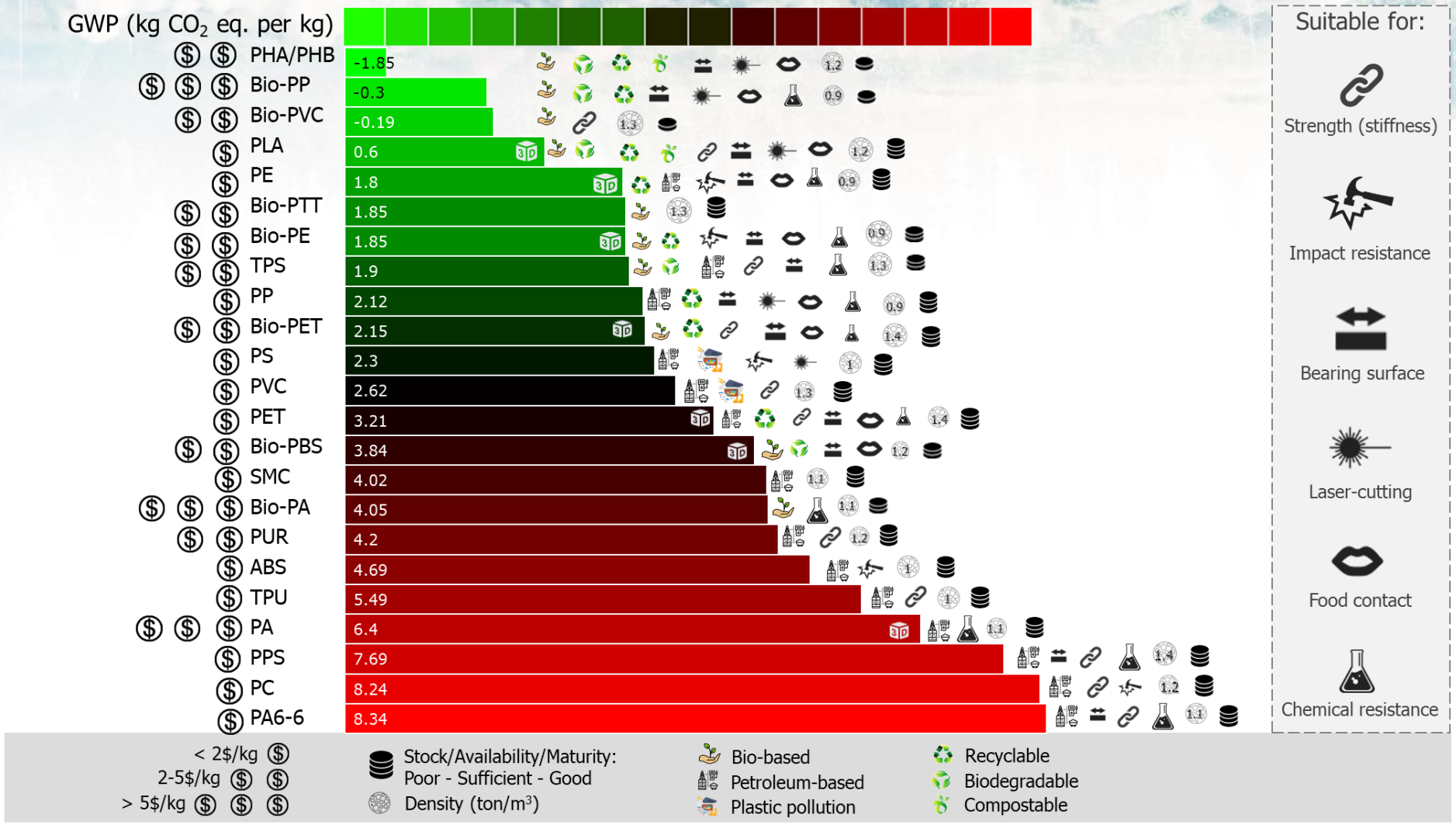

GWP (kg CO_2 eq. per kg)
PHA/PHB -1.85
Bio PP -0.3
Bio PVC -0.19
PLA 0.6
PE 1.8
Bio PTT 1.85
Bio PE 1.85
TPS 1.9
PP 2.12
Bio PET 2.15
PS 2.3
PVC 2.62
PET 3.21
Bio PBS 3.84
SMC 4.02
Bio PA 4.05
PUR 4.2
ABS 4.69
TPU 5.49
PA 6.4
PPS 7.69
PC 8.24
PA6-6 8.34
Suitable for:
Strength (stiffness)
Impact resistance
Bearing surface
Laser-cutting
Food contact
Chemical resistance
< 2$/kg
2-5$/kg
> 5$/kg
Stock/Availability/Maturity:
Poor - Sufficient - Good
Density (ton/m³)
Bio-based
Petroleum-based
Plastic pollution
Recyclable
Biodegradable
Compostable



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Application on agricultural products

Original plastic materials (petroleum-based)	**Mass (kg)**		**Sustainable alternatives (bio-based or recycled plastics)**	**Estimated GWP impact savings (kg CO_2 eq.)**	
	Product 1 Autonomous Lawn Mower	Product 2 Tractor Sprayer		Product 1 Autonomous Lawn Mower	Product 2 Tractor Sprayer
PE	5	480	Bio-PE	- 0.25	- 24
PP	5	60	Bio-PP	12.1	145.2
PVC	0.1	10	Bio-PVC	0.28	28.1
PA	0.1	200	Bio-PA	0.23	470
PUR	2	5	Recycled PUR	4	10
Total	12.2	755	Significance	Manufacturing impact reduced by 10%	More than half a metric ton of CO_2 avoided

Perspectives

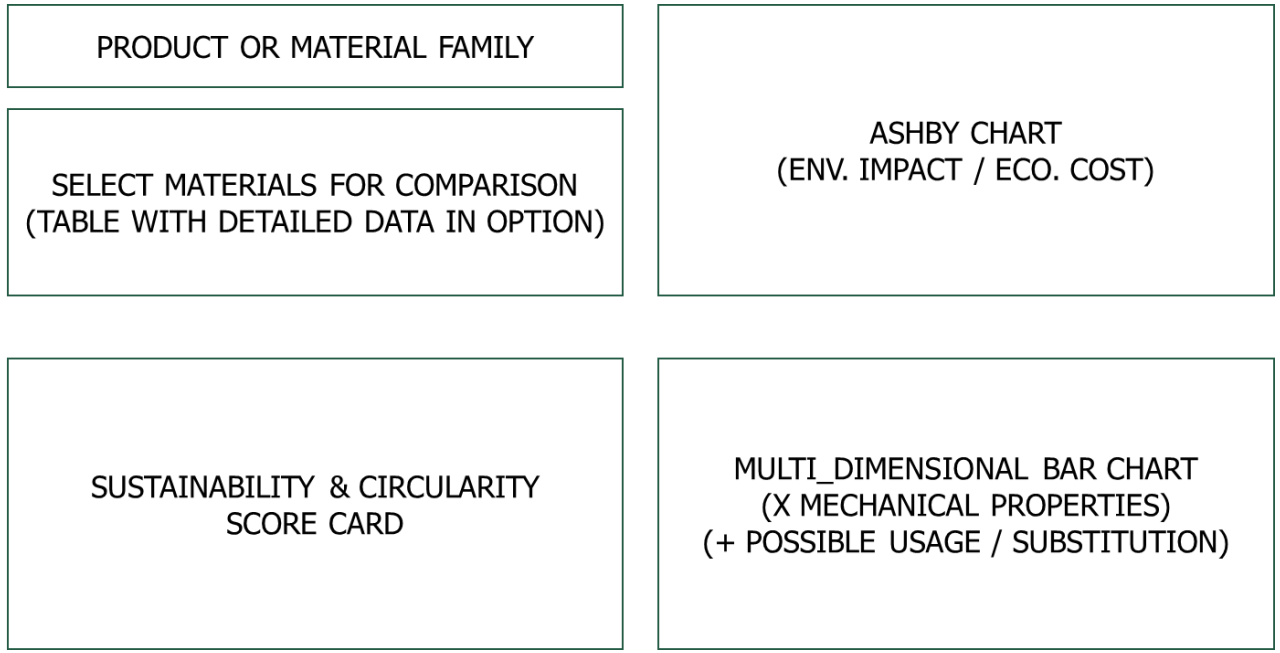
Towards an interactive dashboard

Bio-based plastics in a CE perspective

Further experimentations and workshops

Dissemination and consumer awareness

→ Uptake of bio-based alternatives



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