

GIANCE
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Analysis of energy consumption in the production of graphene material and its impact on the environmental footprint

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GRAPHENE FLAGSHIP

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Core competences

Fraunhofer Institute for Chemical Technology ICT



Explosives technology, safety and security

- Development of propellants and explosives
- Synthesis, processing and manufacturing methods
- Performance measurement and characterization
- Modeling and simulation
- Stability and aging behavior
- Explosives detection



Polymer engineering

- Material and formulation development
- Processing technologies
- Component development and service life analyses
- Lightweight construction and composites
- Recycling and sustainability concepts



Chemical processes

- Non-fossil chemistry
- Electrochemistry
- Chemistry with hazard potential
- Continuous and microprocess engineering
- On-line process analytics
- Process and operational safety of chemical plants



Energy and drive systems

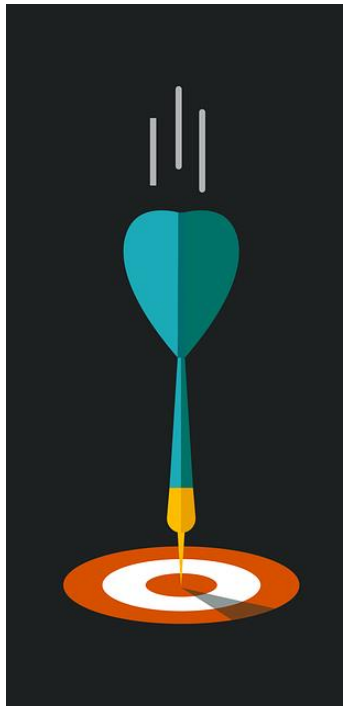
- Drive systems for mobility
- Alternative fuels and energy sources
- Batteries, fuel cells and electrolysis systems
- Thermal storage devices
- Battery and hydrogen safety

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Goals

GOAL OF THIS STUDY:

Comparison of the energy consumption and its impact on the environmental footprint of different technology routes to produce graphene and reduced graphene oxide



FOR WHAT?

- Performance of Life Cycle Assessment (LCA) of the new GIANCE solutions in comparison with the reference solutions
- Specific database are required

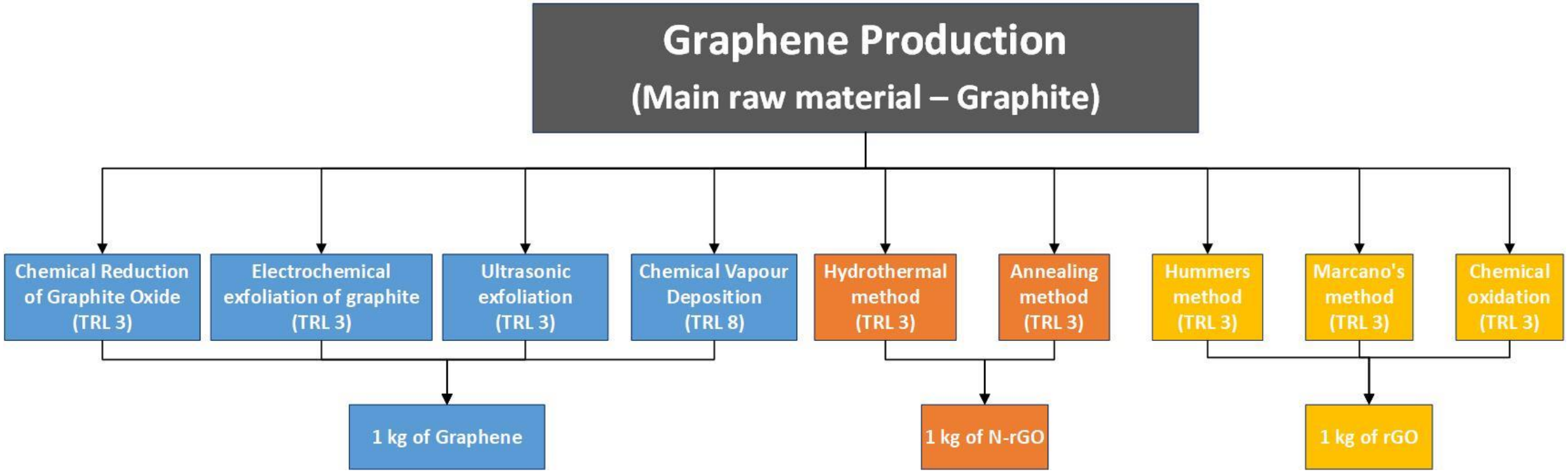
CHALLENGE:

- Lack of data of graphene processes

➢ **Development of Life Cycle Inventories (LCIs) of the graphene production**

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Processes to produce graphene and reduced graphene oxide



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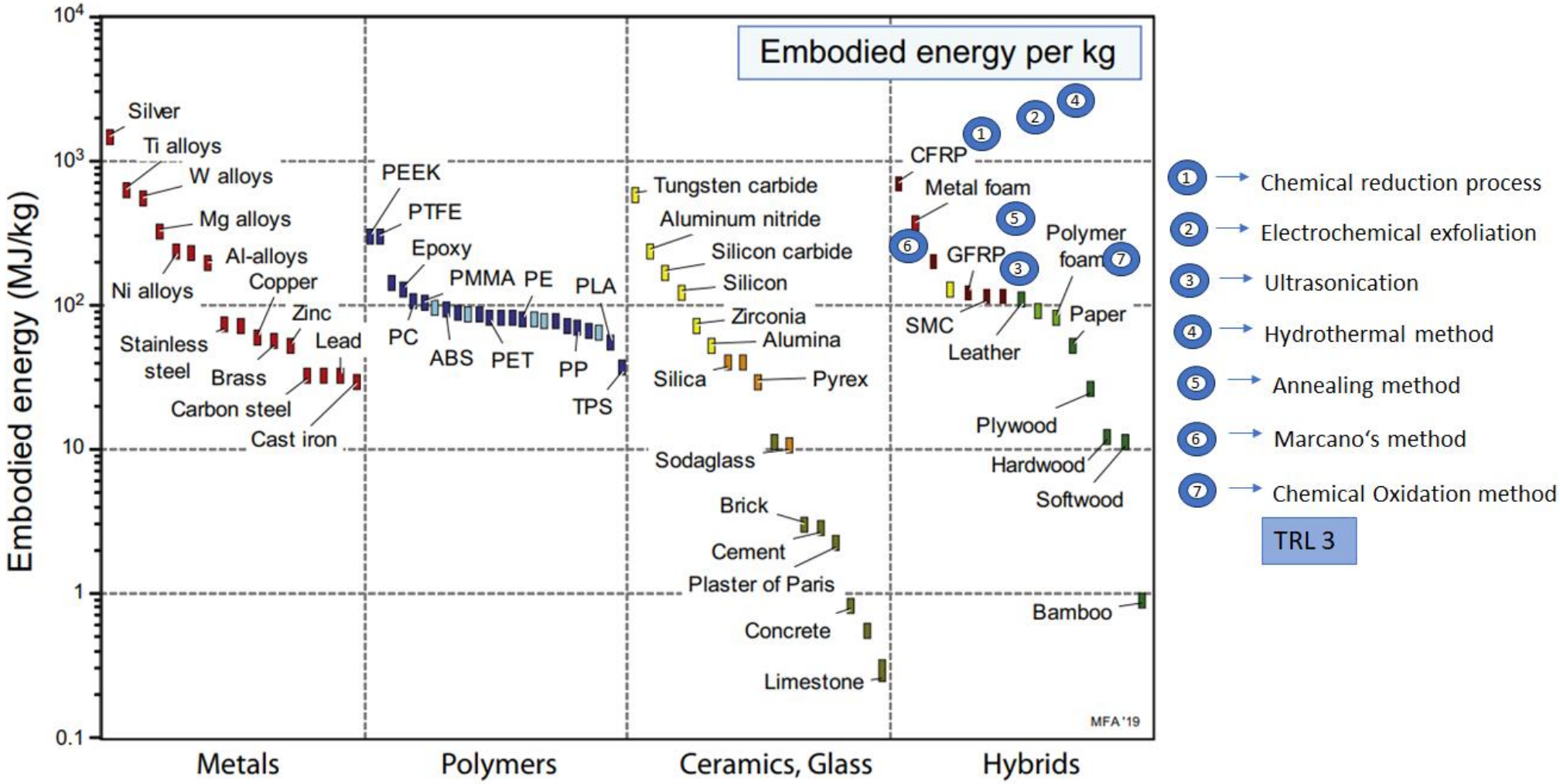
Electricity consumption based on literature

Processes	Chemical reduction of graphite oxide	Electrochemical exfoliation of graphite	Ultrasonic Exfoliation	Hydrothermal method	Annealing method	Marcano's Method	Chemical oxidation and thermal reduction
Largest contribution to impacts	Heat required during chemical reduction and the substantial energy demand of hydrazine production	High voltage and current are required for the electrochemical reactions	Pre-treatment, Microwave expansion, and Ultrasonic exfoliation processes	stirring, heating, centrifugalizing, and drying	stirring, heating, and evaporating ethanol	heating, stirring, centrifugation, and vacuum drying	Temperature and time required for the oxidation process
Electricity consumption	1100 MJ/kg	1850 MJ/kg	284 MJ/kg	2387 MJ/kg	503 MJ/kg	315 MJ/kg	297 MJ/kg

Sources:
L. Serrano-Luján et al., “Environmental impact of the production of graphene oxide and reduced graphene oxide,” 2019.
M. Cossutta, J. McKechnie, and S. J. Pickering, “A comparative LCA of different graphene production routes,” 2017.
A. D. Ampah, E. Pagone, and K. Salonitis, “Life Cycle Assessment of Graphene as Heating Element,” 2019.
X. Ge, J. Lu, L. Ma, and J. Ma, “Life Cycle Assessment of Different Nitrogen-Doped Reduced Graphene Oxide Production Routes within Early Research,” 2021.
R. Arvidsson, D. Kushnir, B. A. Sandén, and S. Molander, “Prospective life cycle assessment of graphene production by ultrasonication and chemical reduction,” 2014.

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Embodied energies of materials per unit mass

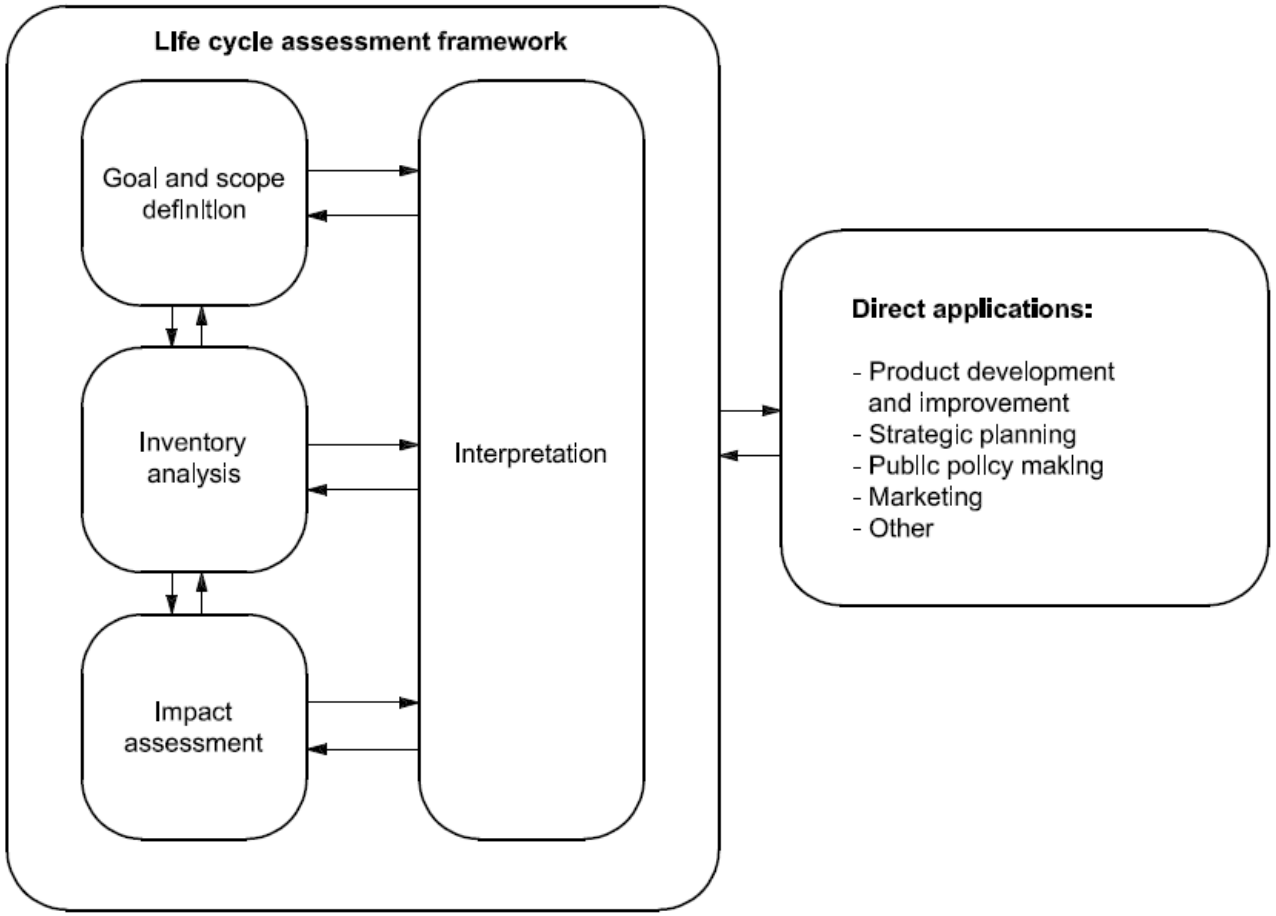


Source: based on „Materials and the Environment: Eco-Informed Material Choice", 3rd Edition, 2020

Embodied energy is the sum of all the energy required to produce any goods or services, considered as if that energy were incorporated or 'embodied' in the product itself.

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LCA tool (ISO 14040:2006)

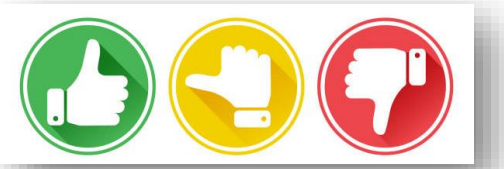


Source: ISO 14040:2006 **Figure 1 — Stages of an LCA**

LCA can assist in:

- identifying opportunities to improve the environmental performance of products at various points in their life cycle;
- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or **process design or redesign**);



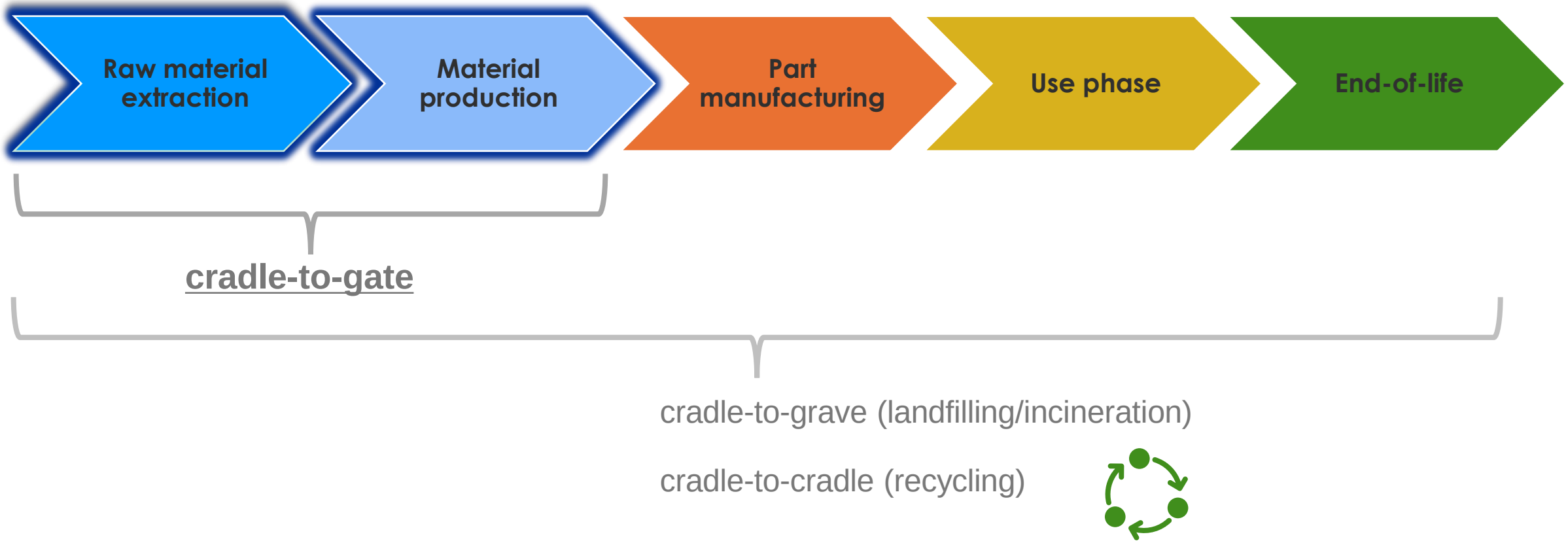


- the selection of relevant indicators of environmental performance, and marketing.

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LCA modelling



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Environmental indicators



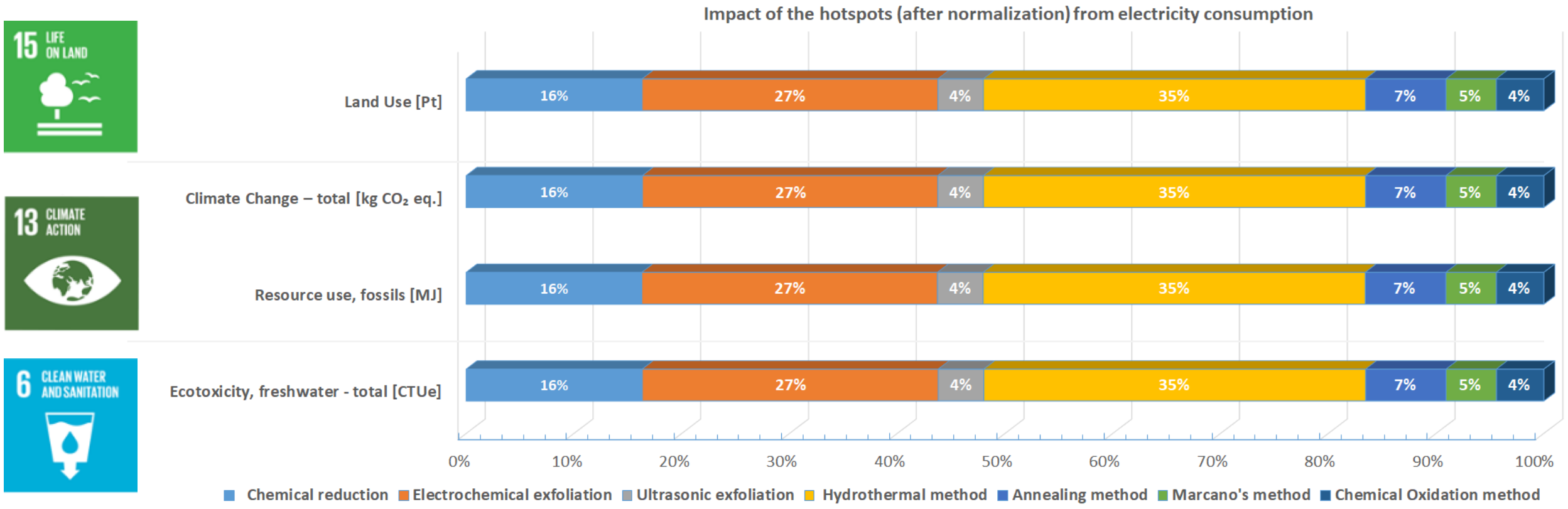
Environmental Footprint (EF 3.1) indicators

European Platform on LCA | EPLCA (europa.eu)

➢ **To verify the key environmental hotspots of each process to produce graphene**

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Identified hotspots



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Conclusions

Life Cycle Inventories of the graphene production were developed

Impact on the environmental footprint of energy consumption in the production of graphene material was assessed

Support GIANCE partners during the design phase (order of magnitude of the environmental impact and identification of the hotspots)

Next steps within GIANCE: continue to develop the LCA database and assess the environmental impact of use cases to support partners in ensuring the environmental benefits of next-generation graphene materials.

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Thanks for listening!

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