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Investigating the integration between life cycle thinking, green chemistry principles, and sustainability policies

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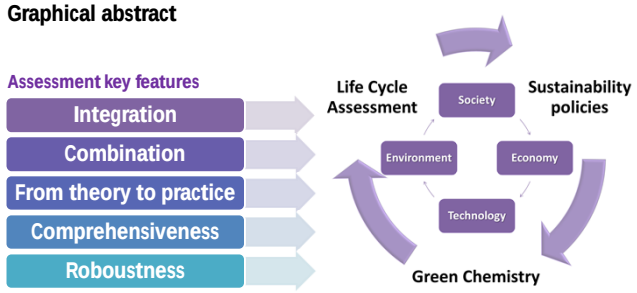
Introduction

International and local industrial policies are moving towards sustainability in the last decades. Reliable methodologies to assess environmental performance are needed. Life Cycle Assessment and Green Chemistry are two theoretical methodologies well established in scientific research for environmental studies in the engineering field, but they are not usually used together. The purpose of the present research is to assess if and how life cycle assessment methodology can be integrated to green chemistry principles and to local and international industrial policies in order to achieve sustainability goals at territorial level.

Method

Literature review is conducted by two leading scientific databases (Scopus and Web of Science) in September 2020, focusing on "Topic" for Web of Science and on "Title, Abstract, Keywords" for Scopus. Keywords introduced are "green chemistry" AND "Life Cycle Assessment or Life Cycle Analysis or Life Cycle Thinking" AND "policies". No time span or territorial boundaries are introduced. Screening and data cleaning are conducted firstly by title, secondly by abstracts and thirdly by text by verifying the coherence and usefulness with the purpose of the research. In this poster only creative, unusual, and key papers are reported.

Graphical abstract



Example of integration and combination between Green Chemistry, LCA and policies

Principle of Green Chemistry		Ref.	LCA methodology[1]	International Policies	Ref.	Local policies
GC1	It is better to prevent waste than to clean up waste after it is formed	2	LCA for preventive studies	Policy of Prevention of waste	15	Slow the growing trend of waste production from cities to regions
GC2	Synthetic methods should be designed to maximise the incorporation of all materials used in the process into the final product (atom economy)	3 4	LCA used at micro-level and possibility of implementation of micro-LCA	Circular Economy	16 17	Promotion of districts and industrial clusters
GC3	Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment	5	Accounting of Human Health impact using different Impact assessment models and characterisation factors	REACH framework and policies on chemicals	18	Cooperation with regional Universities for new design of chemicals and products
GC4	Chemical products should be designed to preserve efficacy of function while reducing toxicity	6	Accounting of toxicity to water, air, and soil by using different Impact assessment models and characterisation factors	REACH framework and policies on chemicals	19	Cooperation with near factories to implement processes
GC5	The use of auxiliary substances (e.g. solvents, separating agents) should be made unnecessary wherever possible and innocuous when used	7	Calculation of impacts of auxiliary substances in a life cycle perspective	REACH framework and policies on chemicals	20	Monitoring of material flows. Incentives for innovation at regional-national level
GC6	Energy requirements should be recognized for their environmental and economic impacts and should be minimized	8	Material and energy flow accounting. Global warming potential accounting. Energy use. CO_2 emisisions.	Policies on Climate change	21	Energy managers involvement, at local scale, in private and public sector
GC7	A raw material or feedstock should be renewable rather than depleting, wherever technically and economically practicable	9	Use of renewable and no-renewable sources	Renewable resources promotion	22 23	Local circular flows for biomaterials and bio-waste
GC8	Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible	10	Life cycle perspective in processes application	Optimisation, technology, information technology	24	Cooperation with Universities for design and with industries for implementation
GC9	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents	11	LCA for analysis of syntheses and reactions	Industrial policies and incentives	25 - 27	Cooperation with Universities for new synthesis
GC10	Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products	12	Impact category of waste. LCA of overall waste management	Plastic reduction policies	28	End of waste framework
GC11	Analytical methodologies need to be further developed to allow for real-time, in-process monitoring, and control prior to the formation of hazardous substances	13	These methodologies allow the collection of inventory data	International monitoring of air pollutants	29	Monitoring of substances by local agencies and by enterprises
GC12	Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, fires	14	Integration with health and safety concerns – need of integrating environmental aspects with safety ones	Policies for high-risk factories	30	Local plans for emergency in high-risk factories

LCA and Green Chemistry: innovative research areas

Goal and Scope Definition
- Preventive studies (GC1)
- Micro LCA for atom economy (GC2) and catalysis (G9)
- Process LCA (G8)
- Waste management LCA (G10)

Inventory
- Accounting of auxiliary substances (G5)
- List of materials (renewable and no-renewable) (G7)
- Monitoring of data for inventory (GC11)

Impact Assessment
- Health Impacts in environmental category (G3)
- Toxicity impacts calculated in characterization factors (G4)

Interpretation of results
- Attention to energy impacts and GHG emissions (G6)
- Integration with health and safety concerns (GC12)

Policies and Green Chemistry relations in a LCT perspective

Slowing consumption, ban of plastics, prevention of waste and promotion of End-of-waste	GC1, GC10
Circular economy, renewable resources, districts and industrial clusters	GC2, GC7
REACH Regulation and cooperation with universities, companies, public sector	GC3, GC4 GC5, G8
Climate change actions and energy policies	GC6
New product and processes, innovation technology, industrial policies and incentives	GC8, GC9
Monitoring of pollutants and health and safety policies	GC11, GC 12

Discussion and conclusions

This research highlights that Life Cycle Thinking and Green Chemistry might be integrated in theoretical and practical case studies, since many interconnections exist. These interconnections permit to use the best characteristics of each method to improve the reliability of the other method and finally, to afford environmental, industrial, and engineering problems with a more comprehensive approach. Moreover, Green Chemistry principles can be easily associated to main environmental policies at international, national, regional, and local level. This allows to use results, knowledge, and expertise of the Green Chemistry and Life Cycle Assessment framework and to apply them to industries, territories, and communities. The similarities highlighted among policies, Life Cycle Assessment and Green Chemistry need further investigation since they might help decision making process based on environmental issues, technical data, engineering advance, interdisciplinary consensus, making benefits in overall sustainability improvements and conducting to a better Life Cycle Management implementation for industrial strategies and public policies.

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