" Energy and Natural Resources Economics."

a.a. 2019/20

Lesson 7

Analysing a project:
(1) SWOT analysis,
(2) Life Cycle Assessment.

Tool and Methodology

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For Europe, it is vital for energy research and development to provide alternative energy options by making energy services available without excessive costs, reducing dependence on oil and gas, mitigating climate change and developing competitive sustainable energy technologies.

Strengths	Weaknesses
• Very good position in PV academic research • Excellent research and manufacturing capabilities and capacities in industry	• Fragmentation of national R&D programmes • Only $56 M (€46 M) spent in 2003 on R&D programmes, less than Japan and USA • Absence of manufacturing issues in R&D programme
• Close co-operation between industry and research laboratories • High production levels: 193 MW in 2003 (+43%) • Good public acceptance of PV technologies • Strong, world-level silicon wafer industry	• PV cells market excessively linked to national programmes for grid-connected PV systems
• Preparation of European standards and codes for PV systems	• Very limited market deployment programmes from the Member States • Too much public control of R&D policies • Lack of harmonisation of the Member States' policies and regulatory frameworks
Opportunities	**Threats**
• Take advantage of strong public support for PV to launch extensive programmes of experimentation, development and implementation of PV plants • Use the good expertise in nanotechnologies in Europe to gain a competitive advantage	• Europe does not take advantage of its current expertise (no world-class and far-reaching programmes, fragmented funding)
• Open new markets by electrifying rural dwellings in developing, Mediterranean countries eager to cooperate with Europe • Develop a specific PV-grade Silicon supply chain	• The strength of Japan's production facilities in PV industries in view of the envisaged capacity in the European countries • Stronger competition from developing Asian countries entering the market

All industrialised countries share these concerns and compete to find the new energy technologies which their market will need, ensuring them with technological advantages and economic benefits.

Climate change, the depletion of fossil fuel resources and population growth are driving the search for better, cleaner and more efficient ways to produce, distribute and use energy. That's why the EC conducted a SWOT analysis of the priority energy technologies by comparing its present situation with that of its main competitors, Japan and the USA.

Europe's competitors have industrial policies which target specific sectors and technologies. They aim to improve and strengthen domestic industries and this strategy is typified by their energy research programmes.

Whenever they use public funds to support R&D programmes precise research and performance goals are set and it is significant that their competitiveness in terms of cost are evaluated. This approach helps to keep efforts focused on technologies which are most likely to become commercially viable.

SWOT Analysis – EUROPE - Biomass

Strengths	Weaknesses
• Strong scientific and technological capabilities • Excellent basic and applied research facilities • Good technical networks	• Lack of coordination and exchange of best practices in technical networks • Development of technologies that might be too sophisticated for market needs • Lack of integrated approach for bioenergy by-product valorisation
• Market leader in electricity generation using biomass • Many industrial leaders for biomass technologies and services, with many "success stories" to promote • The world's largest biofuel CHP plant	• Cooperation between research institutes and industries • Diversity in bioelectricity pricing • High cost and relatively low availability of biomass resources
• Favourable legislation and policy with precise targets at European level • German support scheme	• Support too scattered and dispersed . Lack of integration and coordination of Member State programmes and initiatives. • Little policy coordination with agriculture • Lack of strong market deployment measures, harmonisation, and long-term commitment • Lack of standards for biofuels quality
Opportunities	**Threats**
• Research for using cheap lignocellulosic materials as feedstock for biofuels (enzymatic hydrolysis, syngas, Fischer-Tropsch synthesis, etc.) • Multi-products bio-refinery approach for cost-competitiveness	• European position on genetically engineered crops • Foreign countries gaining operational experience, thanks to a better environment for full-scale demonstration plants
• Strong market potential in Asia and non-OECD countries • Biomass resources of East European Countries	• Competition for the use of limited biomass resources
• Larger policy coordination with agriculture • Standardisation efforts for various biofuel products	

SWOT Analysis – EUROPE – Fuel Cells

Strengths	Weaknesses
• Good basic research capacity especially in the fields of chemistry, material sciences and energy systems • Recent focus on the most promising technologies (PEMFC and SOFC) • Strong support for stationary demonstration programmes in Germany for niche markets • Several programmes of FCV demonstration and the world's largest bus demonstration programme CUTE • New instruments within FP6 (and future FP7) to improve the coherence of RTD efforts	• Lack of knowledge transfer between industries and universities • Lack of coordination between European and national or regional programmes
• European utilities (EDF, RWE, etc.) are active in the development of systems • Leading MCFC-type fuel cell companies and good involvement in the SOFC area • Commitment of Mercedes-Benz • Strong know-how in electric drive systems	• Only European companies specialised in MCFC and SOFC have reached a high industrial level compared with the USA • The very few leading industries developing PEMFC stacks or membranes are in competition with the USA and Japan • Since the end of the FEVER programme, the European fuel cell manufacturers have not seemed well-positioned to get into the automotive market
• Strong support of the German government • FCV tax exemption legislation in Norway • The German "CHP law" will support the FC/CHP market for decentralised power generation	
Opportunities	**Threats**
• Develop new membranes or electrodes for PEMFC • Make a breakthrough in SOFC (thermal cycling resistance) • Make a breakthrough in MCFC (taking advantage of Europe's good position in biomass use and strong industrial players) • Optimise the balance of plant or systems	• The USA attracts innovative European ideas • The European FP structure is not adapted to respond to changing R&D needs
• Strategic technical alliance with North America or Japan, especially for PEMFC • Entering the niche markets • Develop know-how of the BOS for energy and vehicle markets • Develop cooperation for the very large Chinese market	• Difficulties in introducing fuel cell cars on the market • Fuel cell cost and reliability • Aggressive patenting of Japanese and American companies • North American/Japanese Joint-Venture • USA and Japan developing knowledge of operating large stationary systems • Large North American companies buy Europe's small innovative companies
• Take advantage of national commitments on fuel cells such as in Germany, UK, France, Norway, Italy, Finland	• USA could be more attractive than Europe for getting innovative ideas into products

Solar Plant: S.W.O.T. Analysis

Forza	Debolezza
- Zero emissioni di CO_2 nel processo di trasformazione dell'energia da radiante solare ad elettrica; - Costi di manutenzione ordinaria bassi; - Occupazione di superfici già cementificate (tetti degli edifici); - Produzione e consumo in loco (impianti stand alone) evita dispersione di energia causata dal trasporto; - Tecnologia adattabile a molteplici circostanze e necessità di potenza diversa.	- Inquinamento relativo alla produzione dell'impianto; - Elevati costi sunk di investimento iniziale; - Sfruttamento di aree verdi per l'installazione di grandi centrali fotovoltaiche; - Basso rendimento energetico; - Perdita di rendimento nel tempo; - Elevato costo dell'energia elettrica prodotta; - Produzione di energia elettrica imprevedibile.
Opportunità	**Minacce**
- Incentivi statali; - Ricerca e sviluppo stanno dando importanti risultati in termini di miglioramento del rendimento energetico.	- Riuscire a produrre energia elettrica tramite fusione nucleare renderebbe inutili gli impianti fotovoltaici; - Smantellamento degli impianti obsoleti e riciclaggio; -Scarsità delle materie prime con cui è composta una cella fotovoltaica.

Energia impiegata per le tecnologie dei moduli al Silicio ed emissioni associate in Europa e in Cina

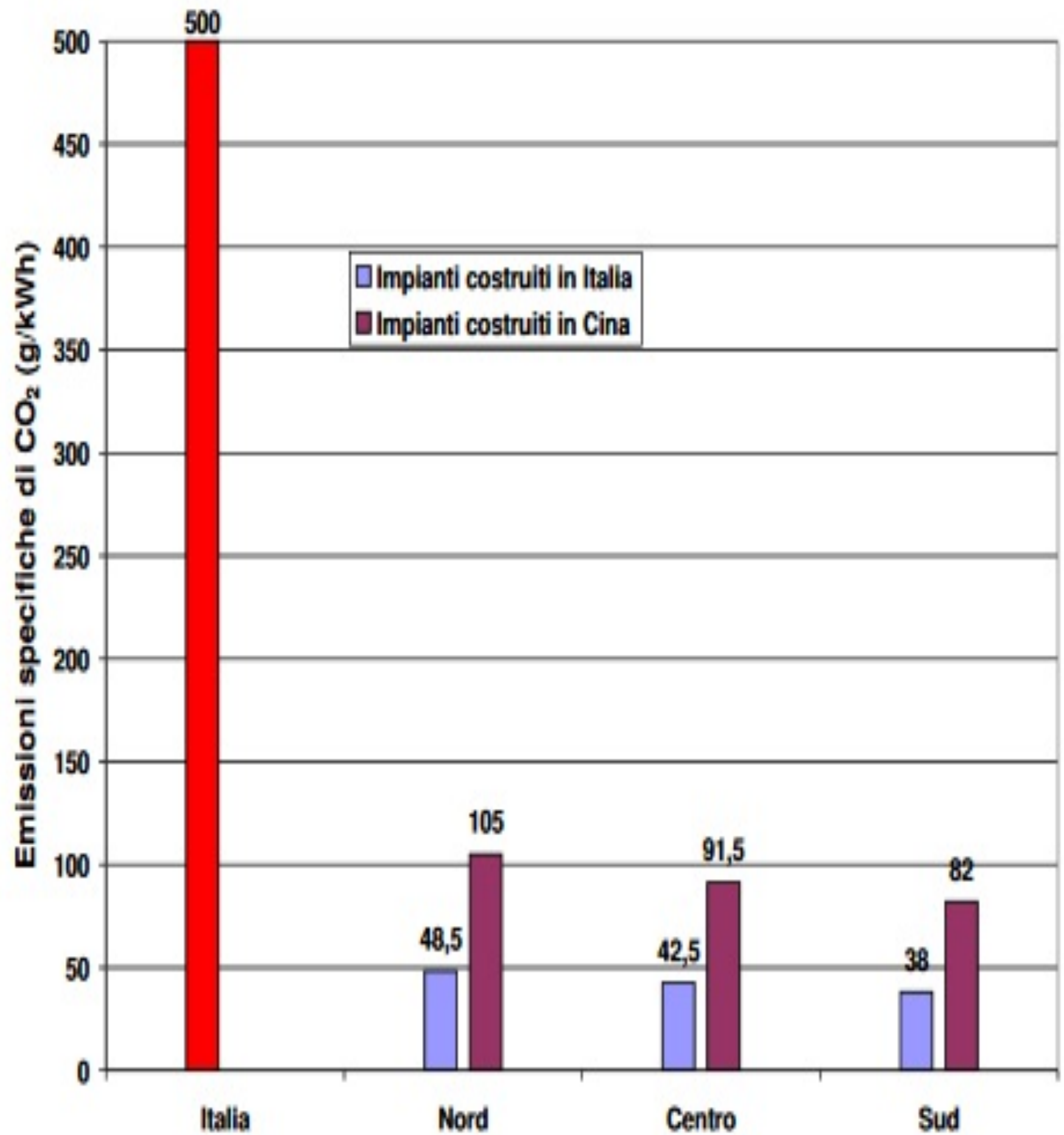
Tecnologia moduli PV	Efficienza moduli (%)	Energia impiegata[1] (kWh/kWp)	Emissioni CO_2 Europa[2] (Kg/kWp)	Emissioni CO_2 Cina[3] (Kg/kWp)
Monocristallino	13,7	3301	1584	3433
Policristallino	13,2	2531	1215	2632
Amorfo	11,5	1981	951	2060

[1] Comprende il contributo di 74,96 kWh delle strutture di sostegno e dei cavi e 166,38 kWh dovuti all'inverter
[2] Valore ottenuto assumendo per il sistema di generazione elettrica europeo il valore medio delle emissioni specifiche di CO2 equivalente pari a 0,48 kg/kWh
[3] Valore ottenuto assumendo per il sistema di generazione elettrica cinese il valore medio delle emissioni specifiche di CO 2 equivalente pari a 1,04 kg/kWh, dati forniti per il 2007 dall'International Energy Agency (IEA, 2009)

Emissioni di CO2 associate ai kWh fotovoltaici in Italia

Zona	Produttività annuale (kWh/kWp)	Emissioni in fase di costruzione (Kg/kWp)	Quota di emissioni di CO_2 impianto italiano (grammi/kWh)	Quota di emissioni di CO_2 impianto cinese (grammi/kWh)
Nord	1000-1200	1584	53-44	115-95
Centro	1200-1300	1584	44-41	95-88
Sud e isole	1300-1500	1584	41-35	88-76

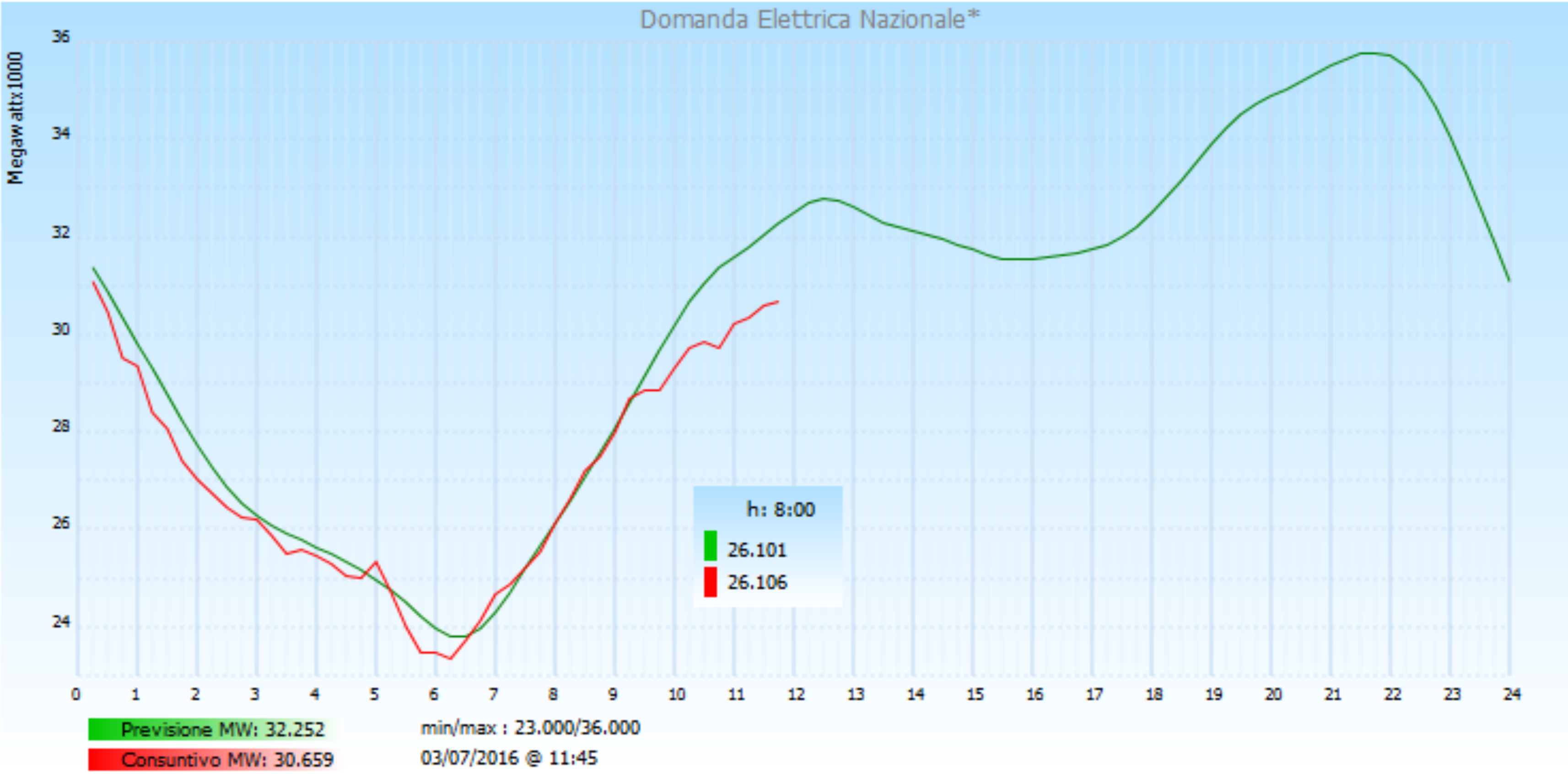
Fig.3 – Emissioni specifiche di CO_2 equivalente per impianti fotovoltaici a silicio monocristallino istallati in Italia, rispettivamente di costruzione nazionale e cinese.



Il parametro LCOE, Levelized Cost Of Energy, fornisce un'indicazione approssimata circa il costo totale unitario di energia elettrica prodotta da un certo generatore. Questo parametro si ottiene dalla somma delle voci di costo del generatore in esame.

Riepilogo dei costi complessivi per fonte energetica

Fonte energetica	LCOE(€/MWh)	Costo esterno (€/MWh)	Costo totale (€/MWh)
Carbone	53-65	50-70	103-135
Gas (CCGT)	70-86	20	90-106
Idroelettrica	60-380	Trascurabile	60-380
Eolica	102-152	Trascurabile	102-152
Biomasse	129-276	30-65	159-341
Termovalorizzatori	47-118	n.d.	-
Fotovoltaica	150-329	2	152-331
Geotermica	51-144	n.d.	-



* fabbisogno nazionale composto per l'89% da rilevazioni in tempo reale e per il restante 11% da stime fuori linea.

Andamento del fabbisogno di energia elettrica in tempo reale

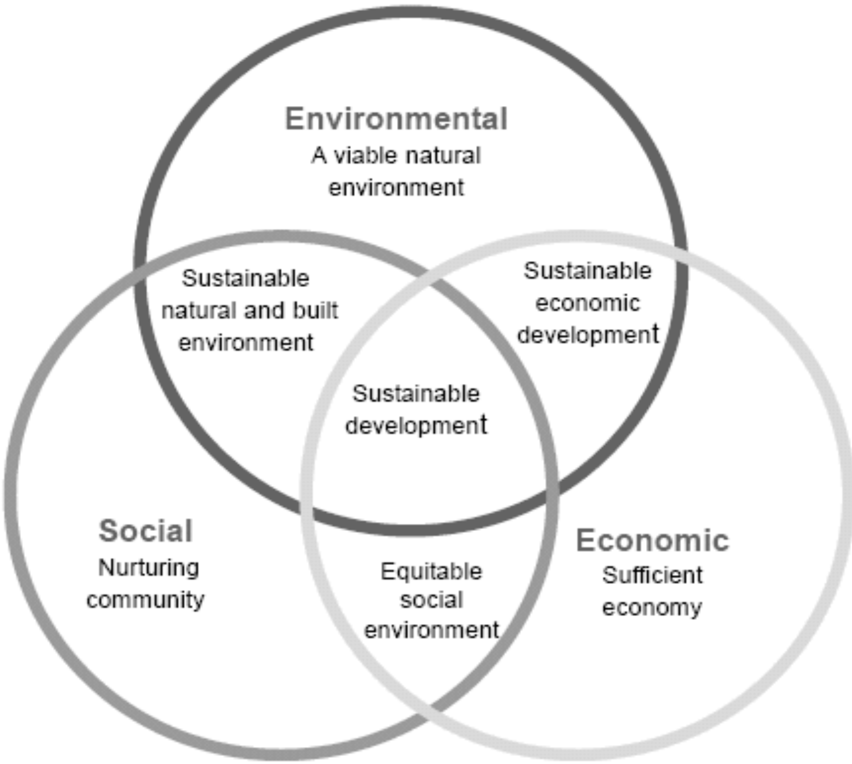
Terna, nello svolgere le attività di trasmissione e dispacciamento dell'energia elettrica, acquisisce tramite un sistema ad avanzata tecnologia tutte le informazioni necessarie al controllo in sicurezza del sistema elettrico a **380-220-150-132 kV.**
Tali informazioni (telemisure e telesegnalazioni) rendono possibile la gestione in tempo reale del sistema elettrico, finalizzata a garantire, in ogni istante e con prefissati livelli di sicurezza, l'equilibrio tra produzione e fabbisogno di energia elettrica.
Il grafico riportato sul sito presenta le due seguenti curve:

previsione del fabbisogno nazionale (curva verde) elaborata il giorno prima sulla base dei valori di consumo relativi a giorni analoghi di periodi precedenti, tenendo conto delle variabili che influenzano la richiesta di energia elettrica quali i fattori meteorologici e climatici e le componenti socioeconomiche;

consuntivo provvisorio del fabbisogno nazionale (curva rossa) elaborata in base alle informazioni acquisite dal sistema di controllo, per una quota corrispondente approssimativamente all'89% in base a stime fuori linea, per la parte rimanente.

I dati numerici e il grafico del fabbisogno si aggiornano automaticamente ogni 15 minuti

Sustainable Development requires balancing environmental, economic and social factors



Worldwide growing interest in the life cycle concept is being ignited by

- *Concerns about Global Climate Change ("An Inconvenient Truth")*
- *Walmart Scorecard development*
- *Green/Sustainable buildings*
- *General interest by companies to be 'green'*

LCA provides analysts with a quantitative data to determine and analyses the environment impact of such product / system and enable changes to be made to justify in respect to the cost and environmental impacts of the product/process.

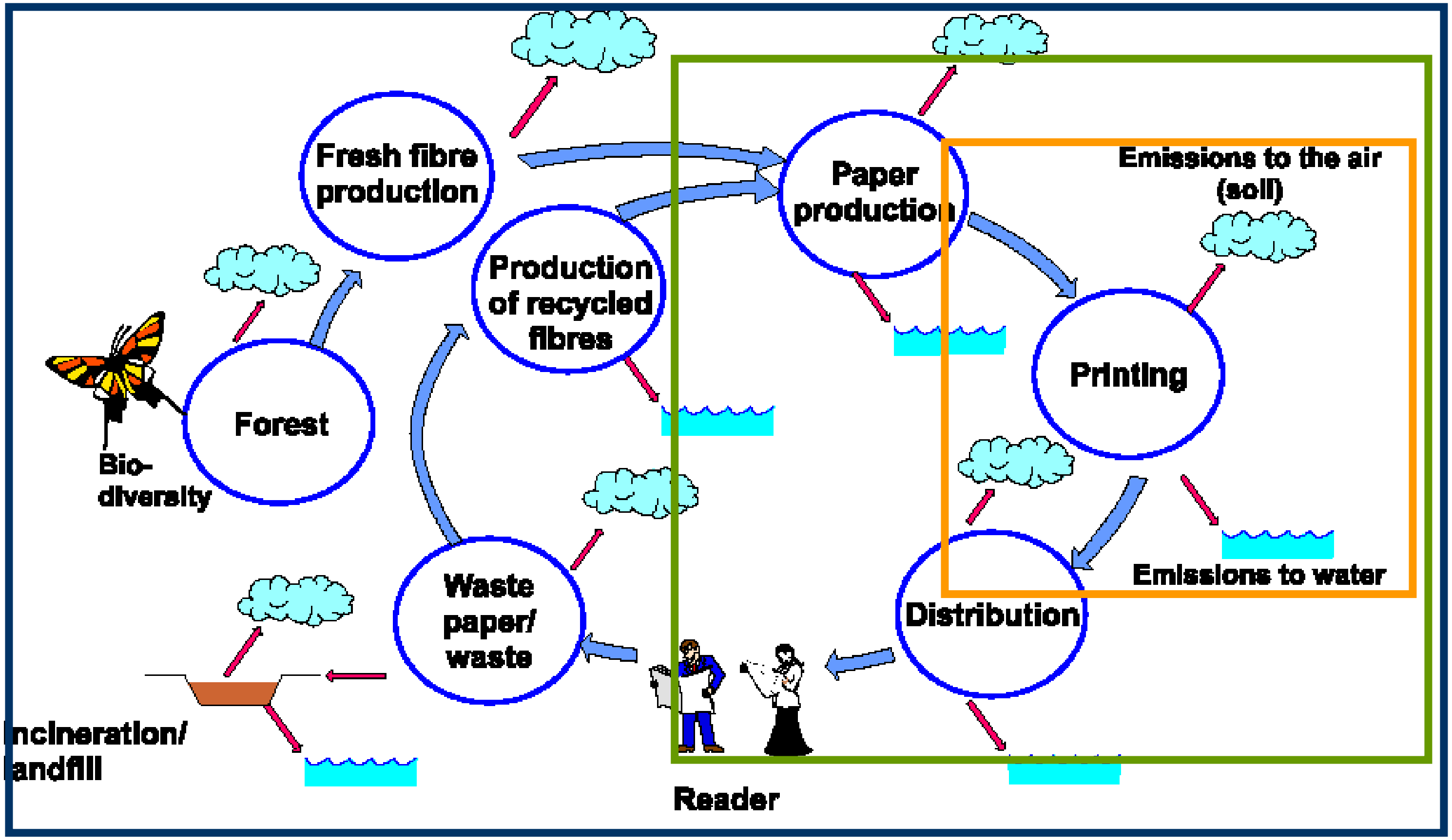
What is Life Cycle Analysis (LCA)

- United Nations Environment Programme - tool for the **systematic evaluation** of the **environmental aspects** of a product or service system through **all stages** of its life cycle
- often termed as "cradle to grave"- starts from raw material to final disposal of the product
- Looks into all the processes/stages & considering environmental aspects and potential impacts of the process/stages, considering all the **inputs** and **outputs**

LCA provides analysts with a quantitative data to determine and analyses the environment impact of such product / system and enable changes to be made to justify in respect to the cost and environmental impacts of the product/process.

Fig. 1: Product life cycle
References: Ecoassessment Center of Excellence, General Electric - Niskayuna/US

Life-cycle –
Identify the boundaries



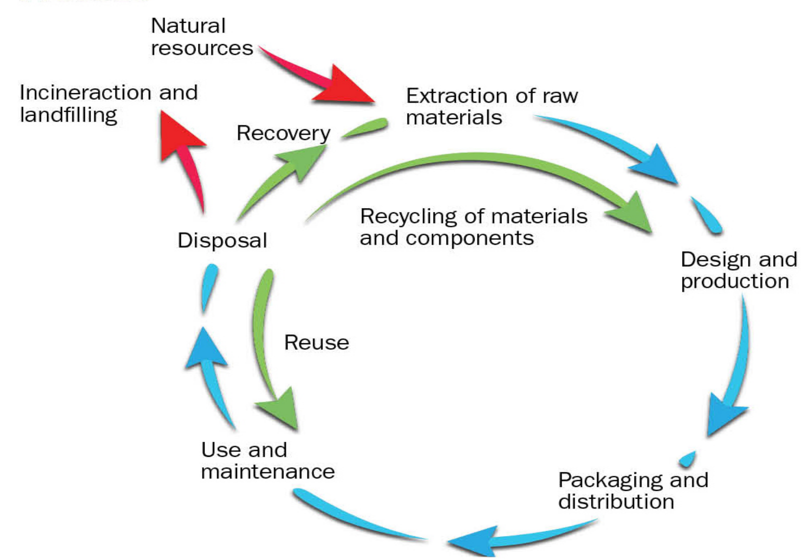
Life Cycle Assessment

Life Cycle Thinking = Taking account of the environmental, social, economic impacts of a product over its entire life cycle

History of LCA

Life cycle thinking is being applied but often not called LCA.
For example: "Report Biofuels: Is the Cure Worse than the Disease?", OECD, Sept 2007
These studies reveal bigger picture issues of making (more) bioethanol, such as land availability, water use, soil and water quality, and food-for-fuel issues.

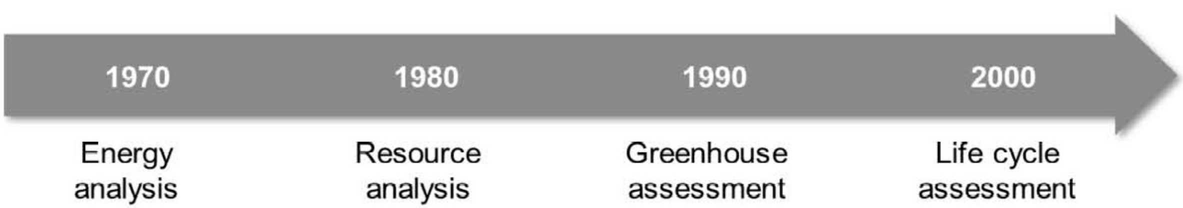
Life Cycle Assessment Iterative Process



Developed in the late 1960s/early 1970s.

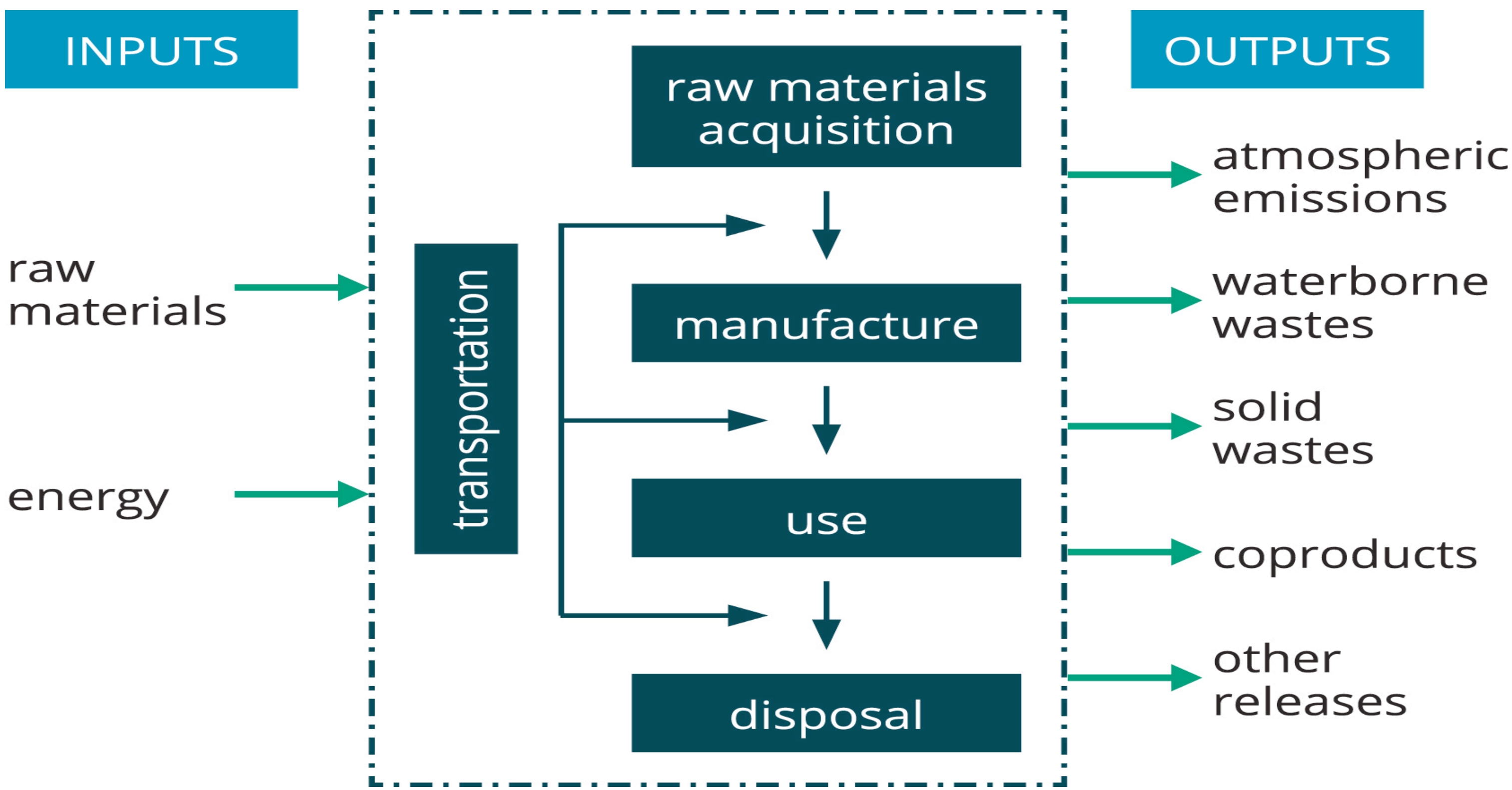
Evolved from "eco-profiles" to current 4 basic, interdependent stages of an LCA:

- Goal and Scope
- Inventory Analysis
- Impact Assessment



LCA is a decision-making tool used to identify environmental burdens and evaluate the potential environmental impacts of goods or services over their life cycle from cradle-to-grave.

LCA has been standardized under the International Organization for Standardization (ISO) and forms the conceptual basis for a number of management approaches and standards that consider the life cycle impacts of product systems.
System Boundaries



LCA metrics commonly used also as ***environmental management tool ….*** *to:*

1. Apply a system-wide examination
2. Use a multi-media approach (air, water, solid waste)
3. Identify trade-offs among alternatives
4. Identify opportunities to improve systems
5. Support environmental decision making
6. Achieve sustainable development

LCA is the Right Tool to examine:

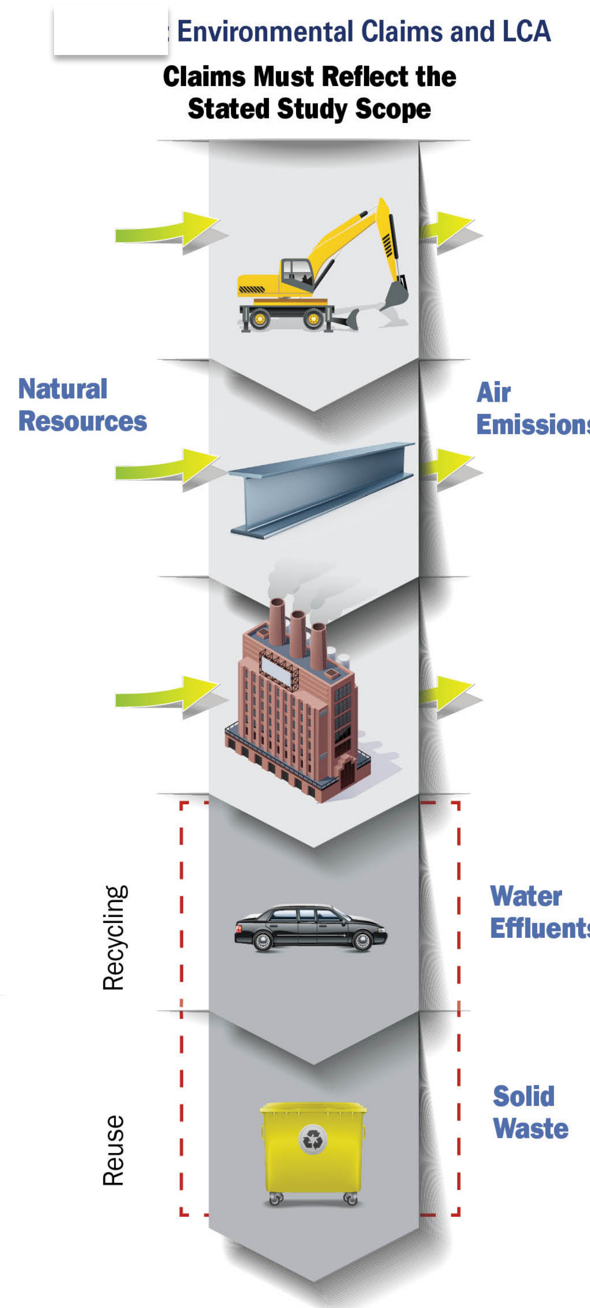
- ✓ Product environmental/energy attributes
- ✓ Trade-offs
- ✓ Consideration of life cycle stages, unit processes and flows

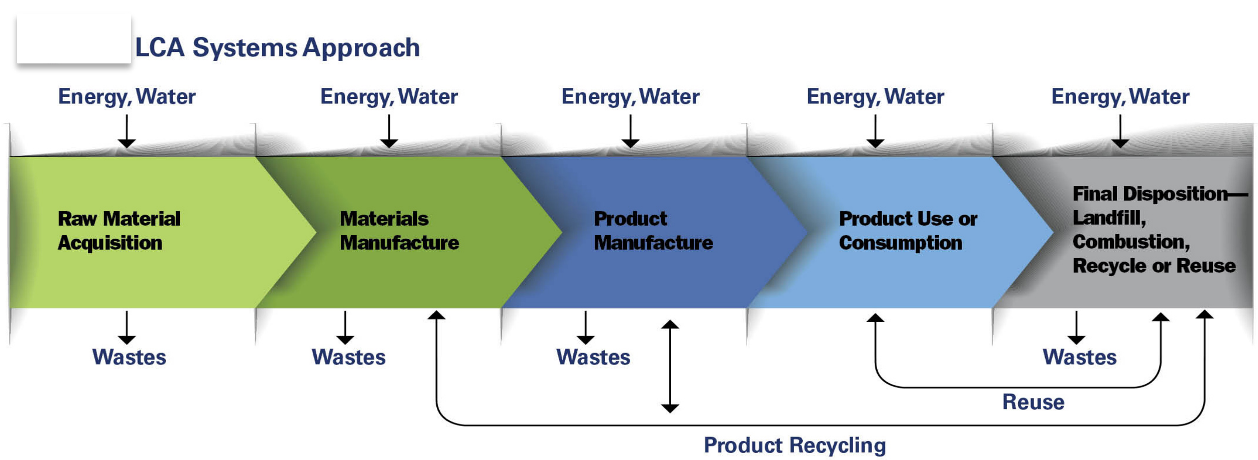
International/U.S. sources identified and defined key metrics, **addressing**:

- Energy Demand
- Global Warming
- Ozone Depletion
- Water Footprint
- Eco and Human Toxicity Assessment
- Land Use

What Can LCA Do?

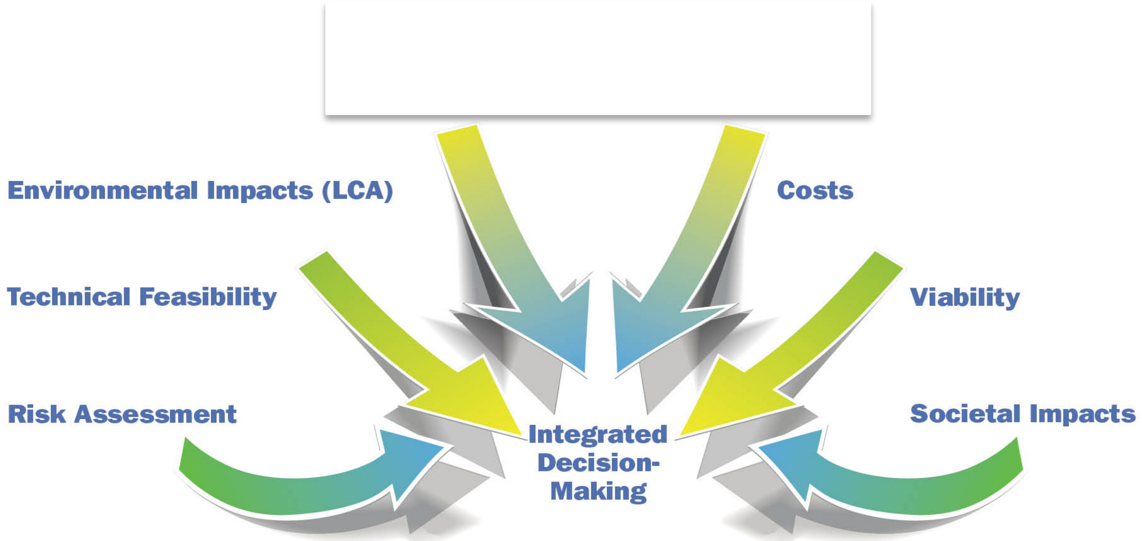
- *Highlight value chain efficiency opportunities*
- *Promote understanding of product manufacture and delivery systems*
- *Identify areas in value chain that need improvement*
- *Ensure that changes do not “shift the burden”*
- *Highlights trade offs*
- *Compare two systems that deliver same service*
- *Benchmark progress*
- *Provide footprinting data*
- *Support environmental claims*





A tool for …
Integrated Decision Making

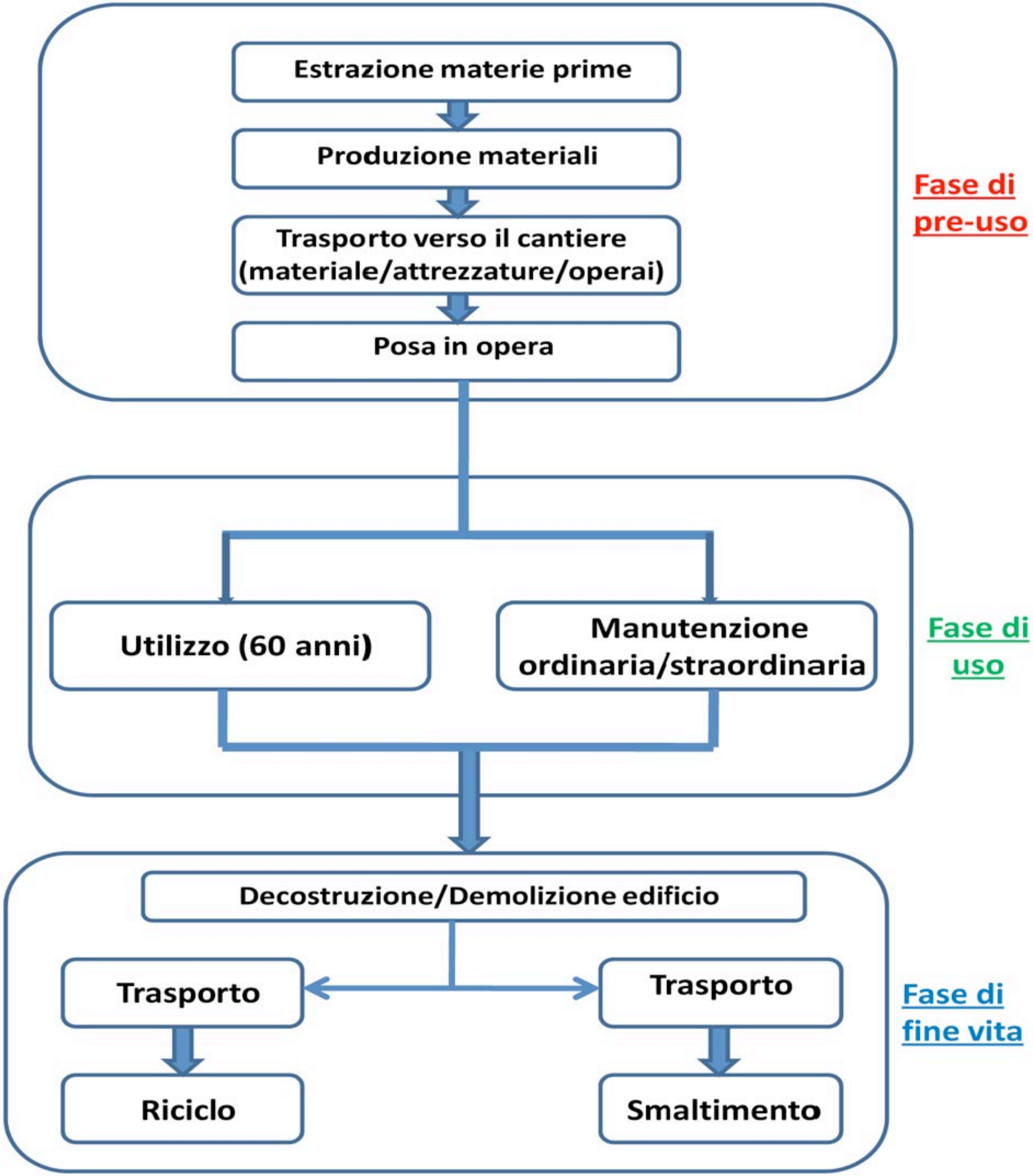
- Review of decision making process and tools – including and separate from an LCA
- Summary of the strengths and limitations of an LCA

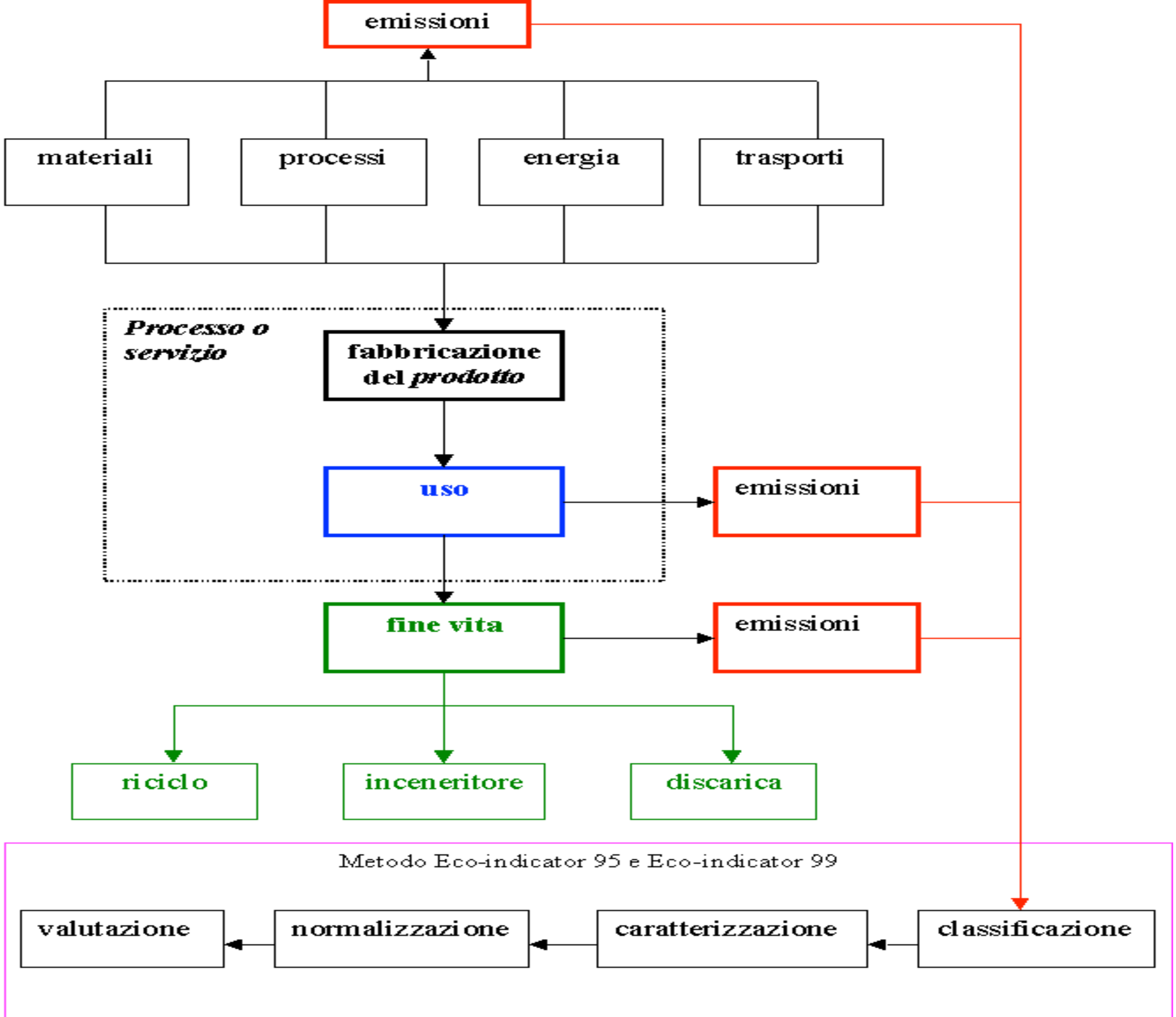


Factors important for decision-making	Combustion based				Nuclear	Hydro	Wind	Solar
	Coal	Oil	Gas	Biomass				
Energy accessibility (related to the direct costs of energy)	F	M	M	M	F	F	D	D
Energy availability (related to the security/reliability dimension)	F	M	M	M	F	F	D	D
Energy acceptability (environmental externalities)	D	D	M	F	F	F	F	F

Relative rankings in the perspective of factors important for decision-making:

F = energy source in **favourable** position
M = energy source in **medium/neutral** position
D = energy source in **disfavoured** position


Estrazione materie prime
Produzione materiali
Trasporto verso il cantiere (materiale/attrezzature/operai)
Posa in opera
Fase di pre-uso
Utilizzo (60 anni)
Manutenzione ordinaria/straordinaria
Fase di uso
Decostruzione/Demolizione edificio
Trasporto
Trasporto
Riciclo
Smaltimento
Fase di fine vita


emissioni
materiali
processi
energia
trasporti
Processo o servizio
fabbricazione del prodotto
uso
emissioni
fine vita
emissioni
riciclo
inceneritore
discarica
Metodo Eco-indicator 95 e Eco-indicator 99
valutazione
normalizzazione
caratterizzazione
classificazione

This study indicates that polymer bottles have considerably lower environmental impacts than glass across all categories. Weight comparison of common bottle sizes indicated an average 78,7% reduction. The specific medical waste disposal scenario for a typical US site shows that approximately 406 EUR can be saved annually assuming 11 700 units of contrast media consumed.

Environmental Life Cycle Assessment

The polymer bottle significantly outperforms the glass bottle for all environmental impact categories considered (Fig. 3).

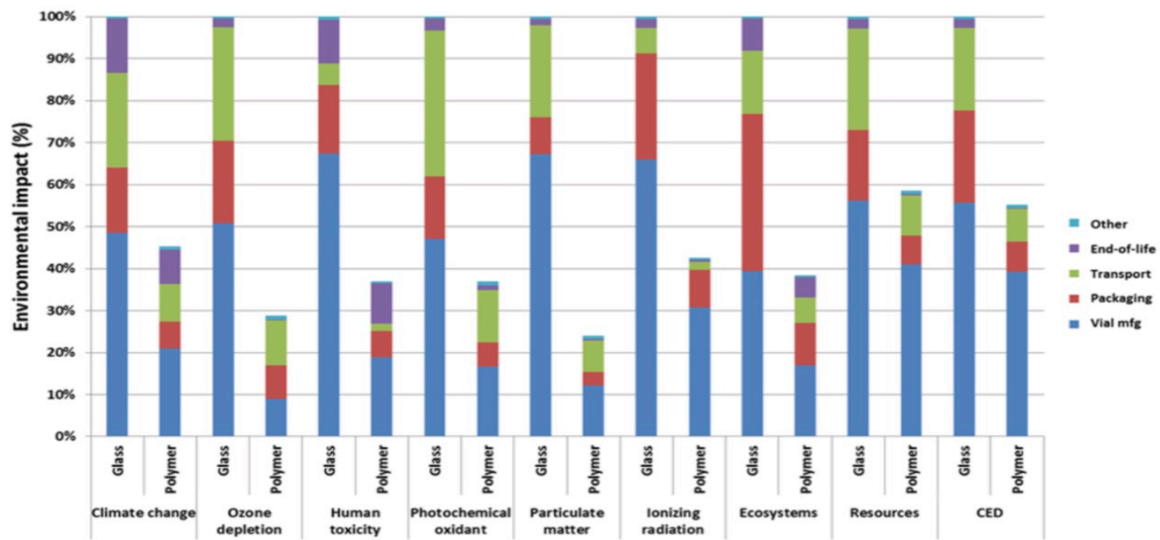


Fig. 3: Life cycle comparison of 100-mL polymer and glass bottles for contrast media. Vial manufacturing includes vial body, cap, stopper, crimp, depyrogenation, and autoclaving. Packaging includes secondary packaging and shipping container. Transport includes raw material transport and distribution transport. 'Other' includes QC reject, broken and frozen bottles, lost contrast media, and incubation.
References: Ecoassessment Center of Excellence, General Electric - Niskayuna/US

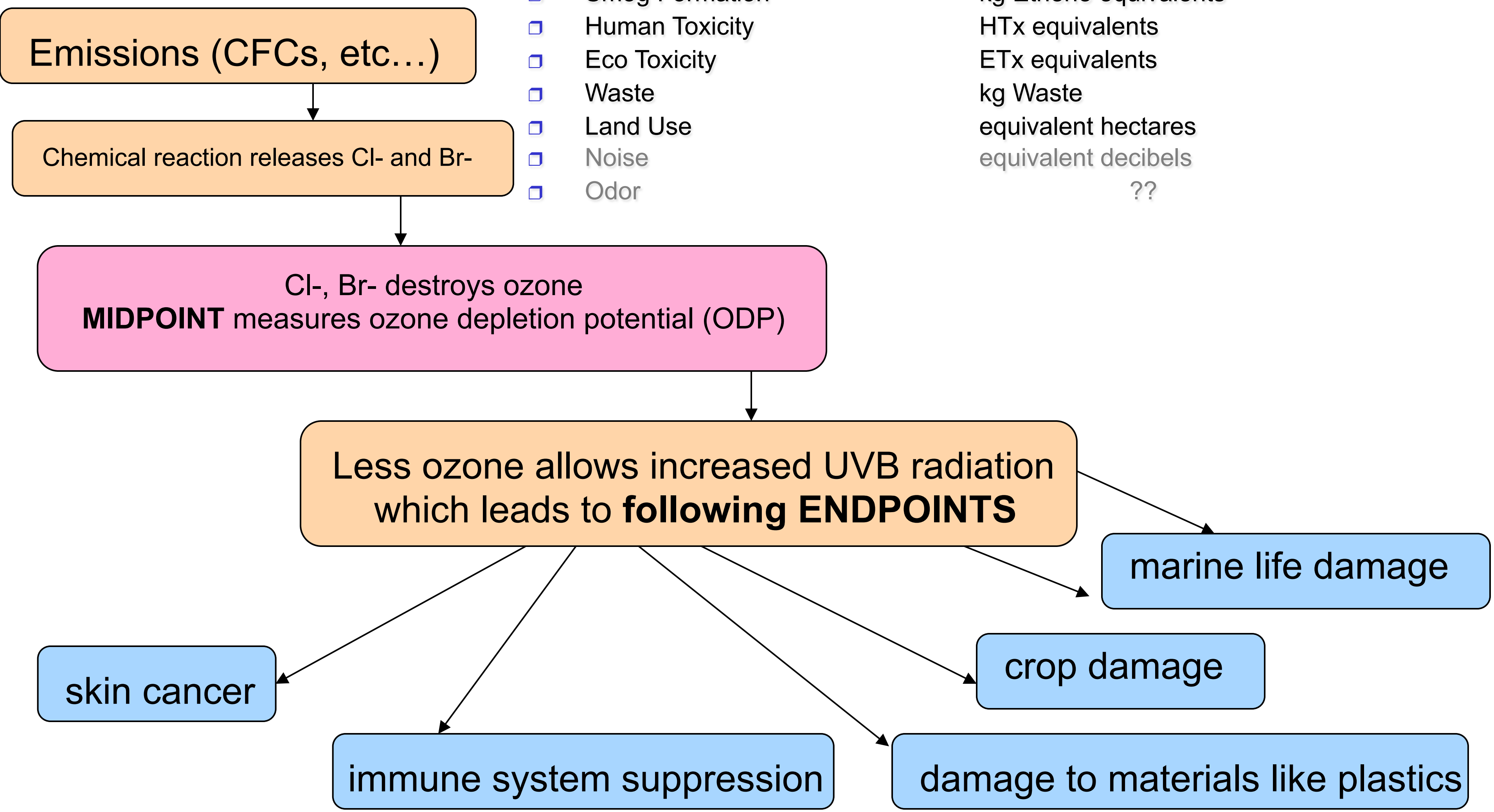
Compared to glass, the polymer bottle offers the following life cycle environmental benefits:

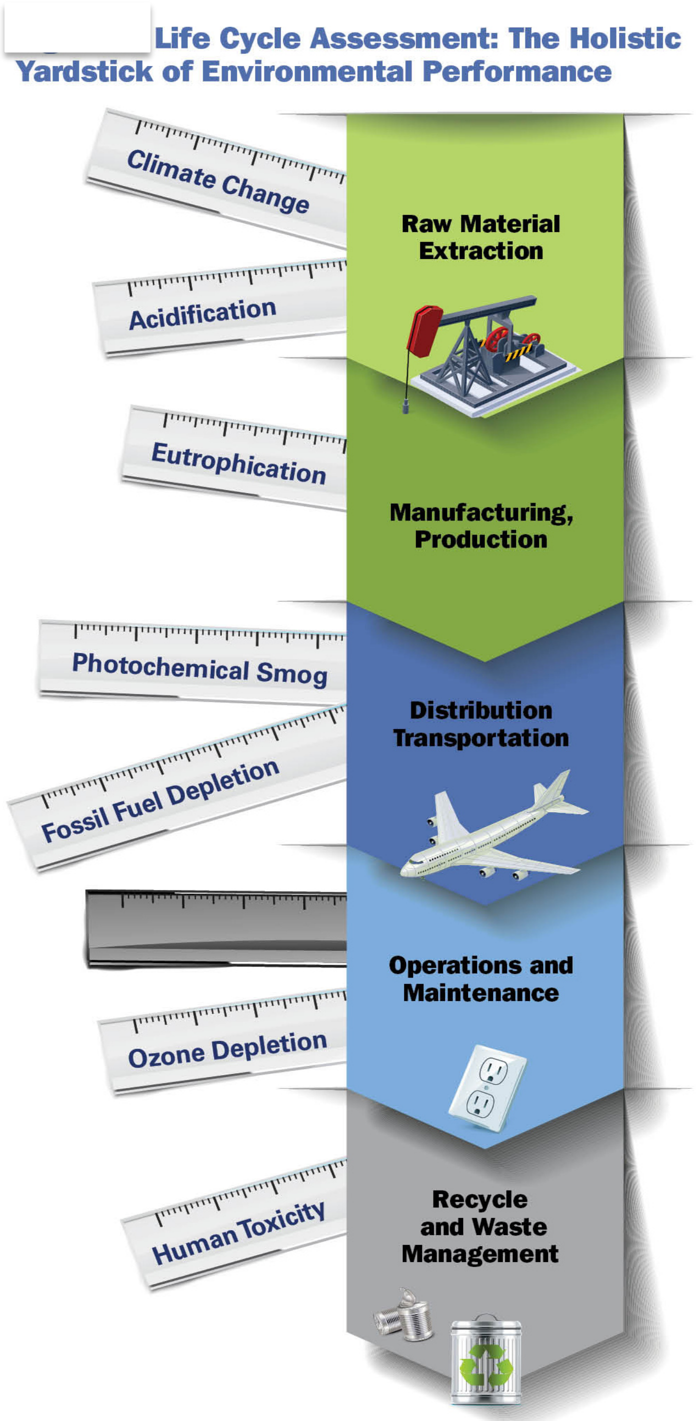
- significantly lower greenhouse gas emissions (46%)
- significantly less cumulative energy (55%)

Fig. 1: Product life cycle
References: Ecoassessment Center of Excellence, General Electric - Niskayuna/US

Impact Assessment
Common Impact Categories

Impact Category	Indicator Measurement
Resources	kg Scarce Resources
Water	m^3 Water
Global Warming	kg $CO_{2\,e}$quivalents
Ozone Depletion	CFC-11 equivalents
Acidification	kg SO_2 equivalents
Eutrophication	kg PO_4^{3-} equivalents
Smog Formation	kg Ethene equivalents
Human Toxicity	HTx equivalents
Eco Toxicity	ETx equivalents
Waste	kg Waste
Land Use	equivalent hectares
Noise	equivalent decibels
Odor	??





Methological preconditions

Data Availability, Quality and Sources

1. Basic data quality requirements to consider before conducting an LCA
2. Different types of data:
   - Primary company data
   - Public or purchased data

Data availability is a barrier to conducting LCAs

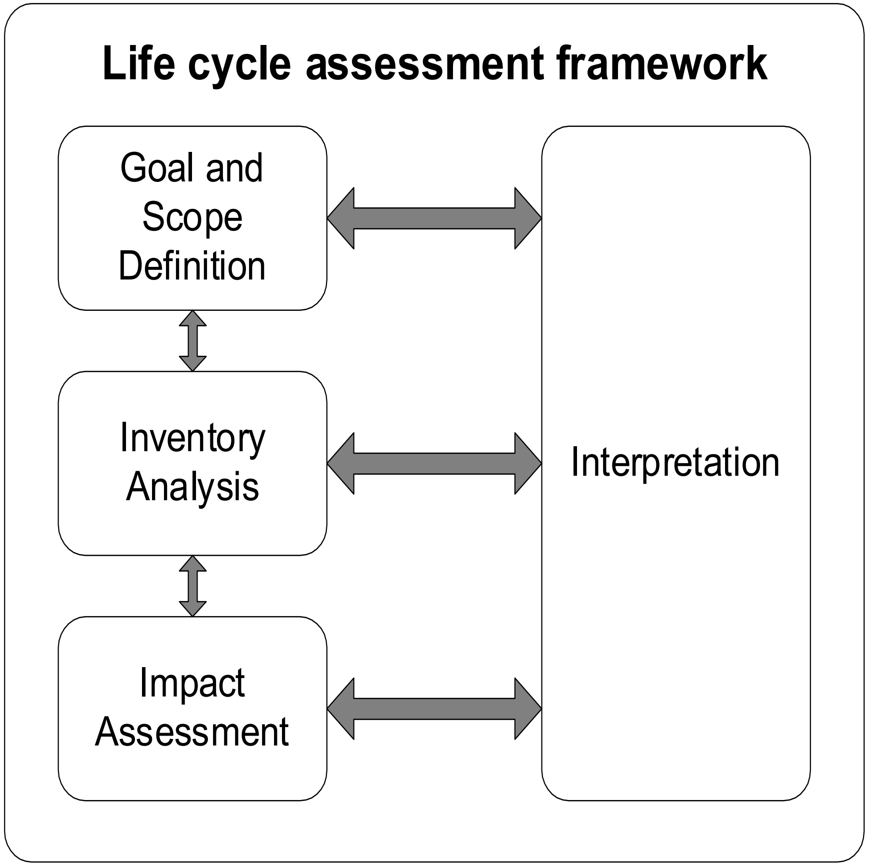
- National LCI database still being developed (www.nrel.gov/lci)
- Data come from many different sources, such as:
  - Proprietary company data
  - Consultants, labs, universities
  - Public, e.g., Toxics Release Inventory (EPA)
- Databases use different units or different reference flows; report on different time periods
- Often more than one source is needed to calculate the necessary inventory data
- Data for new products must be estimated

Standardized tool&process for conducting LCAssessment

- ISO 14040 “Life Cycle Assessment – Principles and Framework” 1997
- ISO 14044 “Life Cycle Assessment – Requirements and Guidelines” 2006

* *ISO – International Standards Organisation*

ISO 14040 Standards



Life cycle perspective - what ISO14001 includes

Why include life cycle perspective?
According to ISO 14001 - *A systematic approach to environmental management can provide top management with information to build success over the long term and create options for contributing to sustainable development by controlling or influencing the way the organization's products and services are designed, manufactured, distributed, consumed and disposed by using a life cycle perspective that can prevent environmental impacts from being unintentionally shifted elsewhere within the life cycle.*

What is a life cycle?
The definition of life cycle is '*Consecutive and interlinked stages of a product (or service) system, from raw material acquisition or generation from natural resources to final disposal. Life cycle stages include acquisition of raw materials, design, production, transportation/delivery, use, end-of- life treatment and final disposal.'*

Is a life cycle assessment a requirement in ISO 14001?
No, it is not a requirement as clearly stated in Annex to ISO 14001 A6.1.2: '*When determining environmental aspects, the organization considers a life cycle perspective. **This does not require a detailed life cycle assessment;** thinking carefully about the life cycle stages that can be controlled or influenced by the organization is sufficient. Typical stages of a product life cycle include raw material acquisition, design, production, transportation/ delivery, use, end-of-life treatment and final disposal. The life cycle stages that are applicable will vary depending on the activity, product or service.'*

Why consider life cycle perspective?
The reason according to ISO 14001 is that *'Some of the organization's significant environmental impacts can occur during the transport, delivery, use, end-of-life treatment or final disposal of its product or service. By providing information, an organization can potentially prevent or mitigate adverse environmental impacts during these life cycle stages. The organization considers the extent of control or influence that it can exert over activities, products and services considering a life cycle perspective.*

Guidance from ISO 14004 - Practical help – Life cycle perspective
A life cycle perspective includes consideration of the environmental aspects of an organization's activities, products, and services that it can control or influence. Stages in a life cycle include acquisition of raw materials, design, production, transportation/delivery, use, end of life treatment, and final disposal.

When applying a life cycle perspective to its products and services, the organization should consider the following:

- the stage in the life cycle of the product or service,
- the degree of control it has over the life cycle stages, e.g. a product designer may be responsible for raw material selection, whereas a manufacturer may only be responsible for reducing raw material use and minimizing process waste and the user may only be responsible for use and disposal of the product,
- the degree of influence it has over the life cycle, e.g. the designer may only influence the manufacturers production methods, whereas the manufacturer my also influence the design and the way the product is used or its method of disposal,
- the life of the product,
- the organization's influence on the supply chain,
- the length of the supply chain, and
- the technological complexity of the product.

The organization can consider those stages in the life cycle over which it has the greatest control or influence as these may offer the greatest opportunity to reduce resource use and minimize pollution or waste.

LCA. Application to differents types of Bags

Table 1.1 Carrier bag types used in UK supermarkets included in this study.

Bag type	Picture example	Weight* [g]	Volume capacity* [litres]
Conventional HDPE bag		7.5 – 12.6	17.9 – 21.8
HDPE with prodegradant additive		5.9 – 8.2	16 – 19.6
Heavy duty LDPE bag ('bag for life')		27.5 – 42.5	19.1 – 23.9
Non-woven PP bag		107.6 - 124.1	17.7 – 21.8
Paper bag		55.2	20.1
Biopolymer bag		15.8	18.3
Cotton bag		78.7 – 229.1	17 – 33.4

* Some supermarkets have supplied data, others are based on measurements by the authors (see annex B).

Many artificial materials are found on the Earth nowadays. The influence of many of them on environmental and humans health is still unknown. As was already mentioned, plastics belong to this category. People mostly focus on the good characteristics, such as low cost, large capacity and variety, high strength, ease of use, etc., and forget about long-term harmful consequences and impacts. Lightweight plastic bags are used by almost by everyone all around the world. When we throw them away, we forget about their existence. Unfortunately, degradation of plastic is a long period process, much longer than the life of many living beings.
To deal with plastic, different countries have done research and implemented different strategies and instruments, such as bans, plasttax, voluntary campaigns and many others. Scientists have widely used life cycle assessment as a tool for choosing the best alternative for carry bags and have achieved quite good results.

1.conventional high-density polyethylene (HDPE);
2.high-density polyethylene (HDPE) with a prodegradant additive; starch-polyester (biopolymer) blend;
3.paper;
4.low-density polyethylene (LDPE);
5.non woven polypropylene (PP); and
6.cotton.

Table 3.1 The assumed volume, weight, items per bag and required reference flow for each carrier bag (excluding primary reuse).

Bag type	Volume per bag (litres)	Weight per bag (g)	Items per bag	Refflow – No. bags
Conventional high-density polyethylene (HDPE) bag	19.1	8.12	5.88	82.14
High-density polyethylene (HDPE) bag with a prodegradant additive	19.1	8.27	5.88	82.14
Starch-polyester blend bag	19.1	16.49	5.88	82.14
Paper bag	20.1	55.20	7.43	64.98
Low-density polyethylene (LDPE) bag	21.52	34.94	7.96	60.68
Non-woven polypropylene (PP) bag	19.75	115.83	7.30	66.13
Cotton bag	28.65	183.11	10.59	45.59

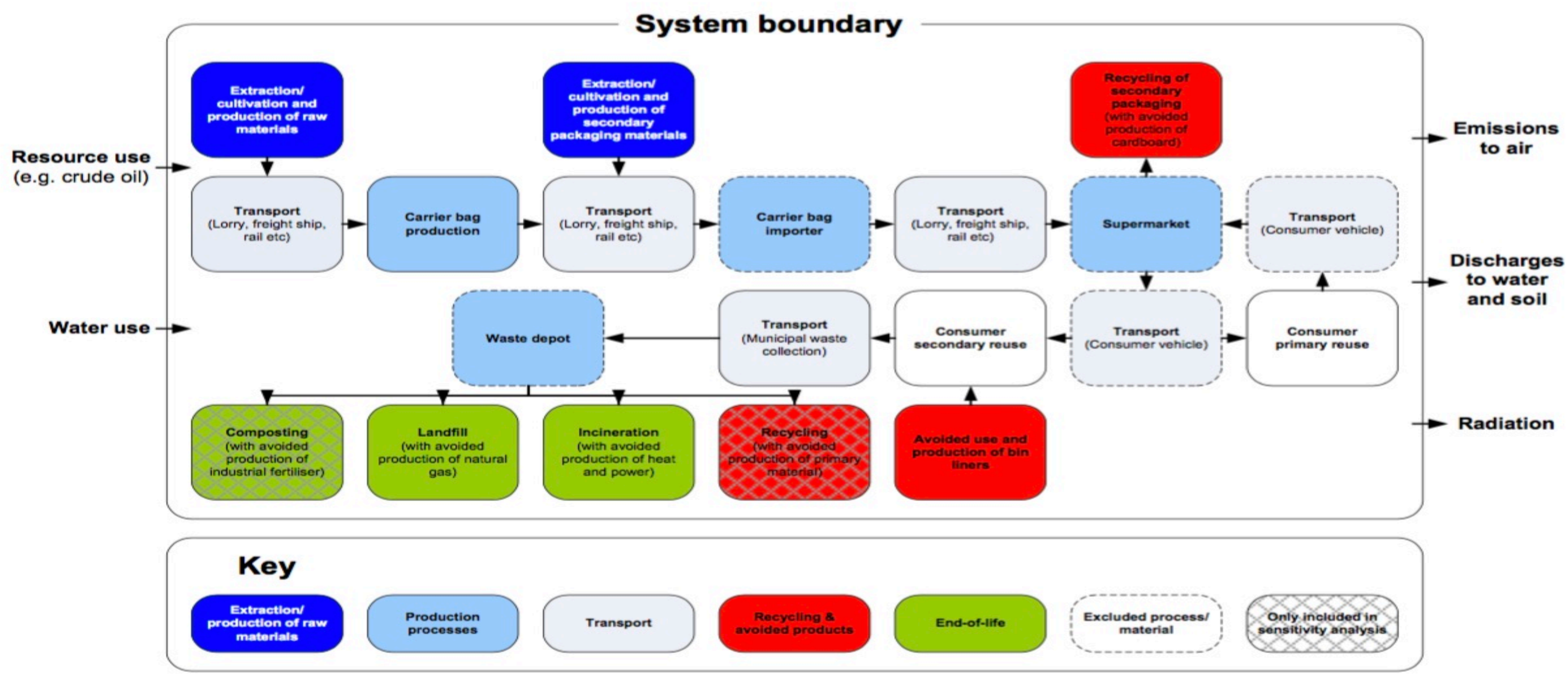


Table 1. Inventory data of traditional and biodegradable plastic bags production.

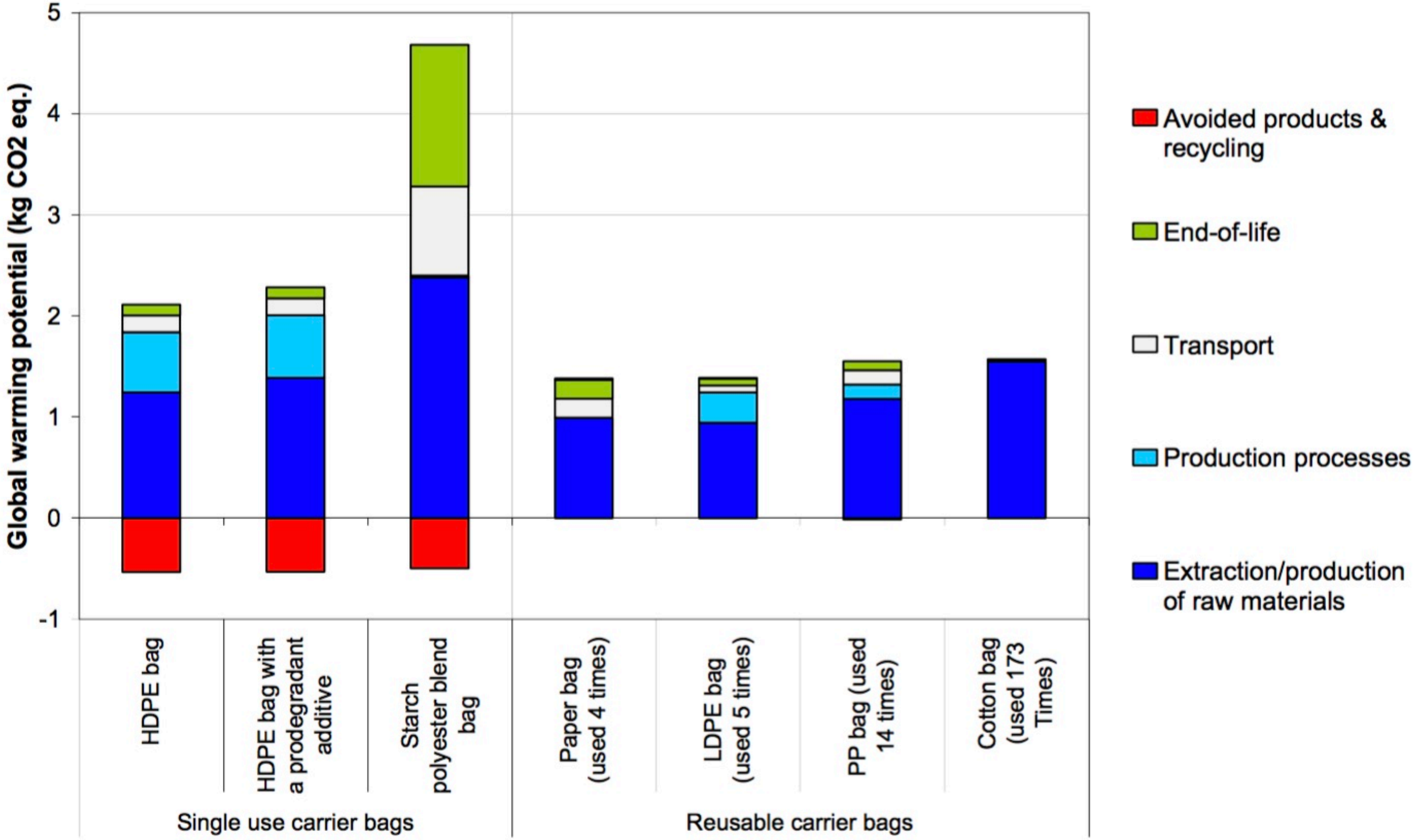
Resources / Emissions	Units	Traditional Bags	Biodegradable Bags
Resources			
Polyethylene, LDPE, granulate	kg	12.6	4.6
Polyethylene, HDPE, granulate	kg	10.7	6.3
Polylactide, granulate	kg	0	11.7
Diesel	kg	0.0681	0.076
Dyes:			
Ethanol from ethylene	kg	2.1432	2.2816
Ethyl acetate	kg	0.453	0.485
1-propanol	kg	1.8753	1.996
Toluene E		0.643	0.643
Air Emissions			
Abietic acid	kg	0.00812	0.00791
Butyl acetate	kg	9.7005	9.7855
Toluene	kg	3.9917	4.1275
Ethanol	kg	1.9401	1.9575
Butanol, 2-methyl-1-	kg	3.9917	4.0275
Carbon monoxide	kg	0.0080683	0.000849
NMVOC (non-methane volatile organic compounds)	kg	0.0011	0.0011
Methane	kg	3.26197E-5	3.53243E-5
Nitrogen dioxide	kg	0.0041	0.0044
Soot	kg	0.0005	0.0006
Nitrogen monoxide	kg	1.56574E-5	1.69557E-5
Carbon dioxide	kg	0.409441992	0.4434
Benz(o)pyrene	kg	3.91436E-6	4.23891E-6
Sulfur dioxide	kg	0.0005	0.0006

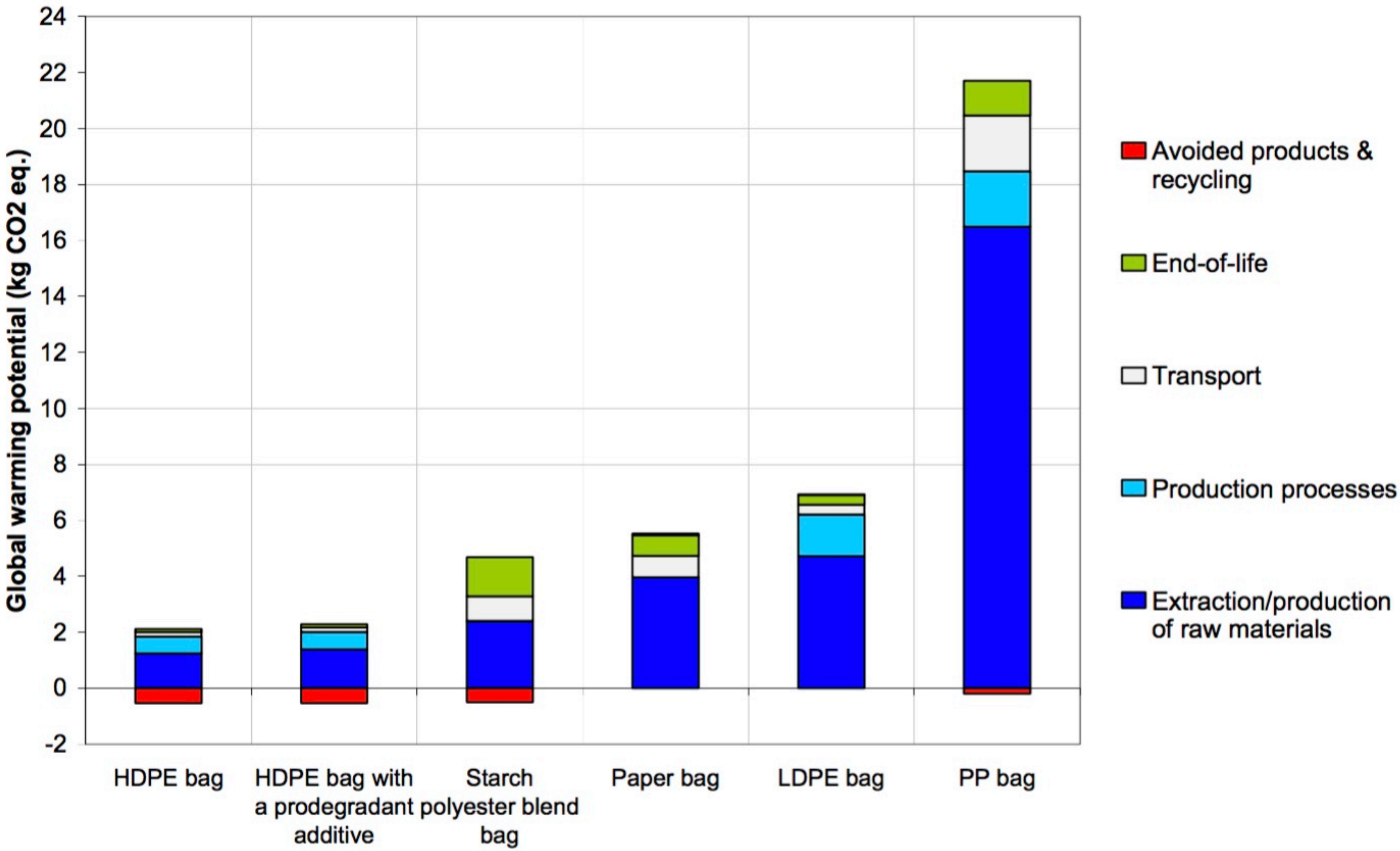
Sel	Impact category	Unit	biovest-bags	traditional vest-bag
☑	Carcinogens	kg C2H3Cl eq	3,14	5,29
☑	Non-carcinogens	kg C2H3Cl eq	0,121	0,247
☑	Respiratory inorganics	kg PM2.5 eq	0,0365	0,0295
☑	Ionizing radiation	Bq C-14 eq	1,44E3	246
☑	Ozone layer depletion	kg CFC-11 eq	4,95E-6	1,33E-6
☑	Respiratory organics	kg C2H4 eq	7,46	7,38
☑	Aquatic ecotoxicity	kg TEG water	4,66E3	1,18E3
☑	Terrestrial ecotoxicity	kg TEG soil	219	153
☑	Terrestrial acid/nutri	kg SO2 eq	1,06	0,714
☑	Land occupation	m2org.arable	13,7	0,0342
☑	Aquatic acidification	kg SO2 eq	0,252	0,21
☑	Aquatic eutrophication	kg PO4 P-lim	0,029	0,00527
☑	Global warming	kg CO2 eq	64,5	53,8
☑	Non-renewable energy	MJ primary	1,86E3	2,22E3
☑	Mineral extraction	MJ surplus	0,514	0,146

Bag type	Electricity	Heat (from natural gas)	Heat (from heavy fuel oil)	Waste
Conventional high-density polyethylene (HDPE) bag	6.151 kWh (22.144 MJ) (0.758 kWh/kg)			418.4 g
High-density polyethylene (HDPE) bag with a prodegradant additive	6.392 kWh (23.011 MJ) (0.773 kWh/kg)			426.1 g
Starch-polyester blend bag	17.24 kWh (62.064 MJ) (1.045 kWh/kg)			94.8 g
Low-density polyethylene (LDPE) bag	32.58 kWh (117.288 MJ) (0.932 kWh/kg)	13.953 kWh (50.23 MJ) (0.399 kWh/kg)		171.2 g*
Non-woven polypropylene (PP) bag			87.75 kWh (315.9 MJ) (0.758 kWh/kg)	5,850 g
Cotton bag	11 kWh (39.6 MJ) (0.06 kWh/kg) *			1,800 g*

	HDPE bag (No secondary reuse)	HDPE bag (40.3% reused as bin liners)	HDPE bag (100% reused as bin liners)	HDPE bag (Used 3 times)
Paper bag	3	4	7	9
LDPE bag	4	5	9	12
Non-woven PP bag	11	14	26	33
Cotton bag	131	173	327	393

Bag type	Sensitivity changes	IPCC 2007 Global warming potential (kg CO2 eq)
HDPE bag	No secondary use	2.082
	40.28% secondary use	1.578
	100% secondary use	0.830
HDPE prodegradant bag	No secondary use	2.254
	40.28% secondary use	1.750
	100% secondary use	1.003
Starch-polyester bag	No secondary use	4.691
	40.28% secondary use	4.184
	100% secondary use	3.433

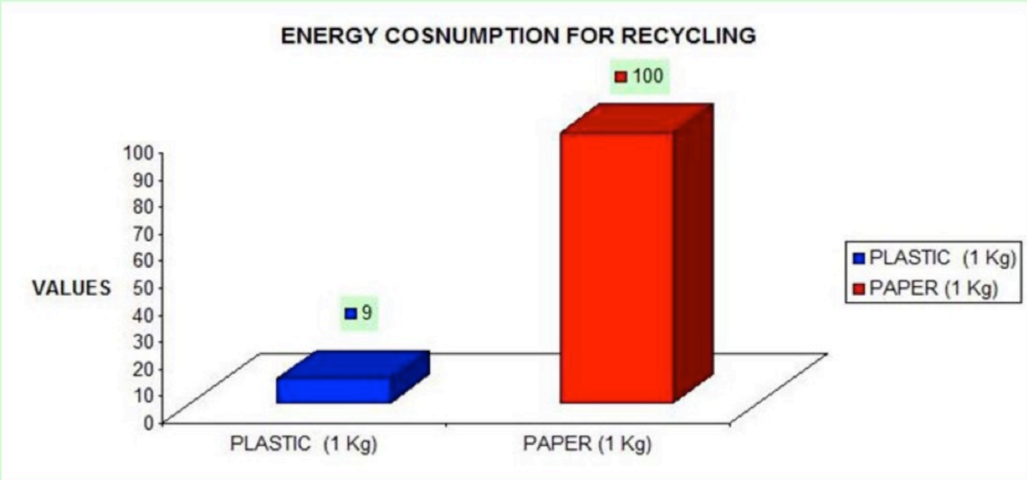

Global warming potential (kg CO2 eq.)
5
4
3
2
1
0
-1
HDPE bag
HDPE bag with a prodegradant additive
Starch polyester blend bag
Paper bag (used 4 times)
LDPE bag (used 5 times)
PP bag (used 14 times)
Cotton bag (used 173 Times)
Single use carrier bags
Reusable carrier bags
Avoided products & recycling
End-of-life
Transport
Production processes
Extraction/production of raw materials



Global warming potential (kg CO2 eq.)
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
HDPE bag
HDPE bag with a prodegradant additive
Starch polyester blend bag
Paper bag
LDPE bag
PP bag
Avoided products & recycling
End-of-life
Transport
Production processes
Extraction/production of raw materials

Bag type	Sensitivity changes	IPCC 2007 Global warming potential (kg CO2 eq)
HDPE bag	Baseline	1.578
	Recycling	1.400
	Recycling (no reuse)	1.785
HDPE prodegradant bag	Baseline	1.750
Starch-polyester bag	Baseline	4.184
	Composting	2.895
	Composting (no reuse)	3.329
Paper bag (4 uses)	Baseline	1.381
	Recycling	1.090
	Composting	1.256
LDPE bag (5 uses)	Baseline	1.385
	100% Recycling	1.196
PP bag (14 uses)	Baseline	1.536
	100% Recycling	1.292
Cotton bag (172 uses)	Baseline	1.579

PLASTIC & PAPER CARRY BAGS



Plastics and Paper both can be recycled. However it takes 91% less energy to recycle a kg of plastic than a kg of paper.

Source: ULS LCA Report, USA and other reports

Example of LCA 1: Paper vs. Plastic Bag

Category	Paper Bag	Plastic Bag
Raw materials	Wood (renewable)	Oil / gas (non-renewable)
Energy to make	1.7 mJ	1.5 mJ
Solid waste	50 g	14 g
Total emissions to air	2.6 kg	1.1 kg
Global warming equivalents (CO2 equivalents)	0.23 kg	0.53 kg

It depends!

This study indicates that polymer bottles have considerably lower environmental impacts than glass across all categories. Weight comparison of common bottle sizes indicated an average 78,7% reduction. The specific medical waste disposal scenario for a typical US site shows that approximately 406 EUR can be saved annually assuming 11 700 units of contrast media consumed.

Environmental Life Cycle Assessment

The polymer bottle significantly outperforms the glass bottle for all environmental impact categories considered (Fig. 3).

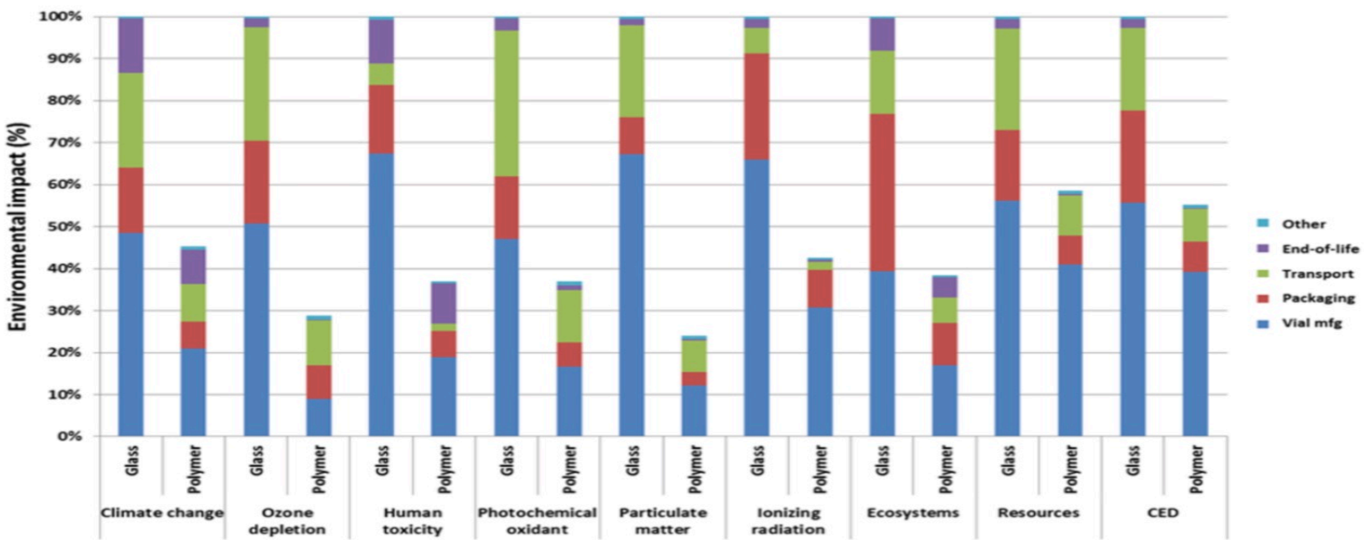


Fig. 3: Life cycle comparison of 100-mL polymer and glass bottles for contrast media. Vial manufacturing includes vial body, cap, stopper, crimp, depyrogenation, and autoclaving. Packaging includes secondary packaging and shipping container. Transport includes raw material transport and distribution transport. 'Other' includes QC reject, broken and frozen bottles, lost contrast media, and incubation.

References: Ecoassessment Center of Excellence, General Electric - Niskayuna/US

Compared to glass, the polymer bottle offers the following life cycle environmental benefits:

- significantly lower greenhouse gas emissions (46%)
- significantly less cumulative energy (55%)

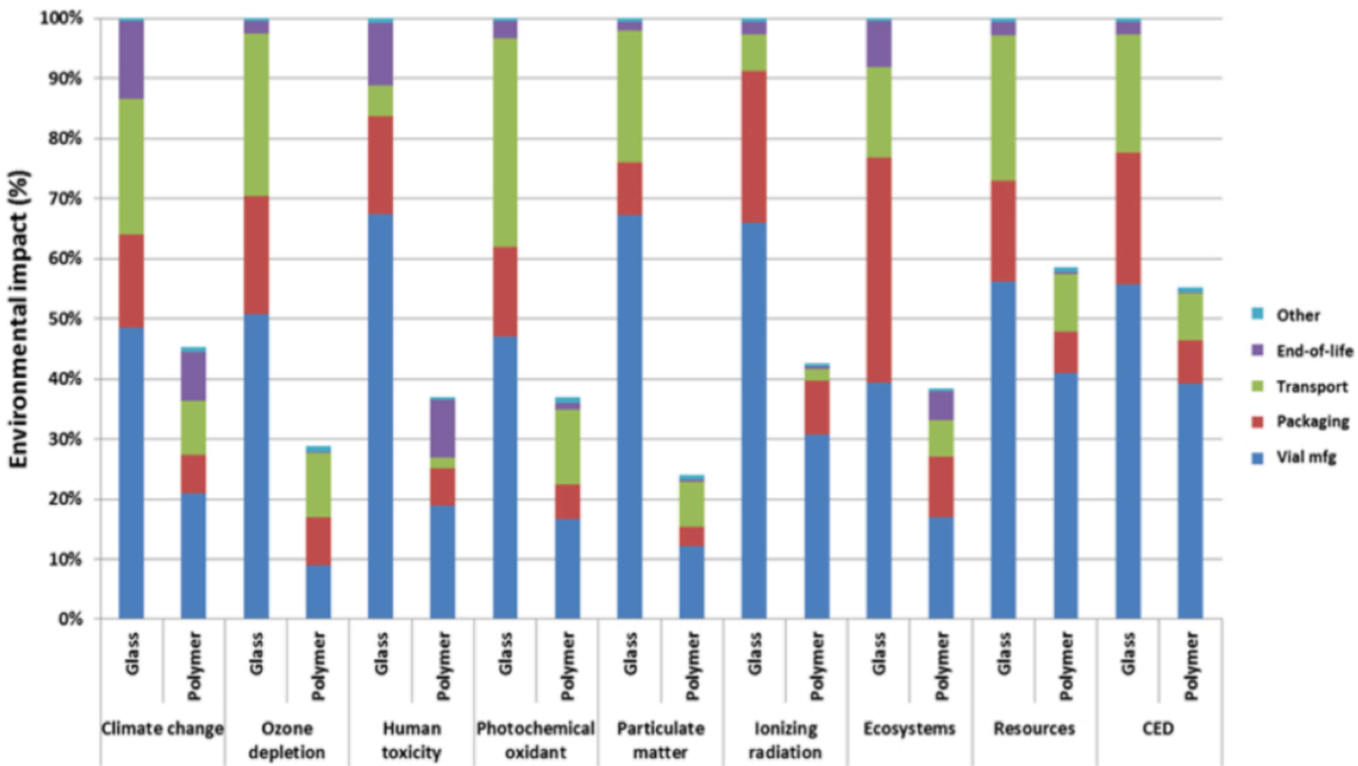


Fig. 3: Life cycle comparison of 100-mL polymer and glass bottles for contrast media. Vial manufacturing includes vial body, cap, stopper, crimp, depyrogenation, and autoclaving. Packaging includes secondary packaging and shipping container. Transport includes raw material transport and distribution transport. 'Other' includes QC reject, broken and frozen bottles, lost contrast media, and incubation.

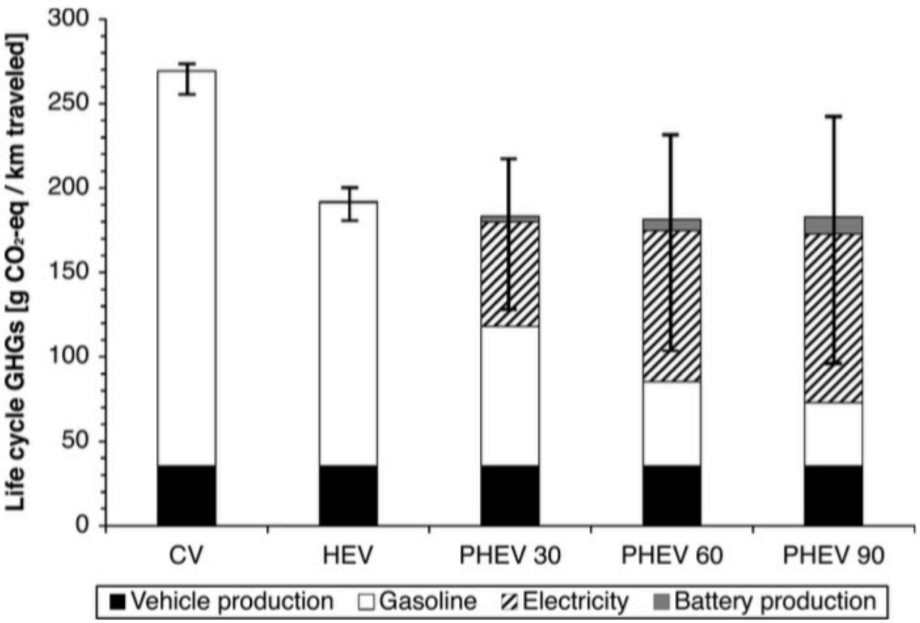


FIGURE 1. Life cycle GHG emissions (g CO_2-eq/km) of conventional vehicles (CVs), hybrid electric vehicles (HEVs), and plug-in hybrids (PHEVs) with all-electric ranges of 30, 60, or 90 km. Life cycle GHG intensity of electricity is 670 g CO_2-eq/kWh (186 g/MJ; U.S. average scenario). Uncertainty bars represent changes in total emissions under the carbon-intensive (950 g CO_2-eq/kWh) or low-carbon (200 g CO_2e/kWh) electricity scenarios.

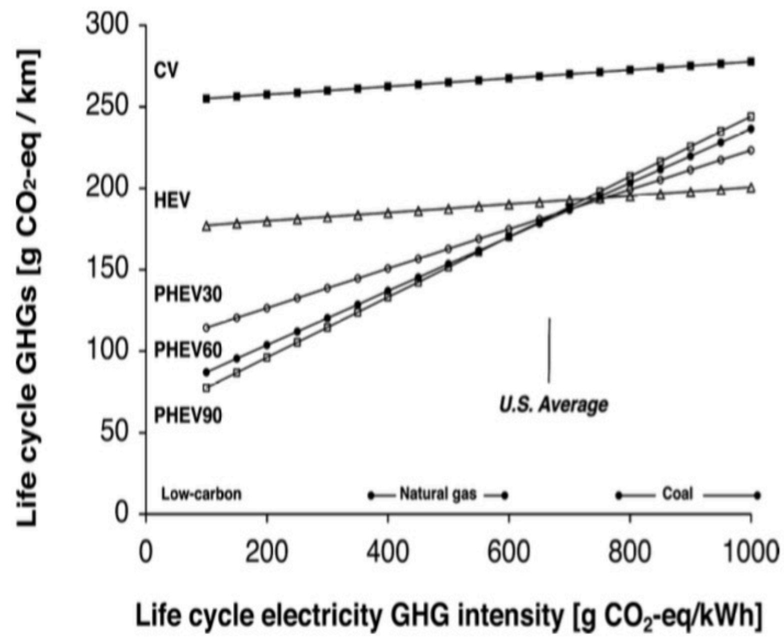


FIGURE 2. Life cycle GHG emissions from vehicles shown as a function of the life cycle GHG intensity of electricity generation. Electricity is used during production of the vehicles, and the slight slope of the CV and HEV lines reflect GHG intensity of electricity used during production. The chart indicates which generation options correspond to various GHG intensities to provide some insight into generation mixes. The low-carbon portfolio could comprise nuclear, wind, coal with carbon capture and sequestration, and other low-carbon electricity generation technologies (see Table S6). The vertical line at 670 g CO2-eq/kWh indicates the U.S. average life cycle GHG intensity.

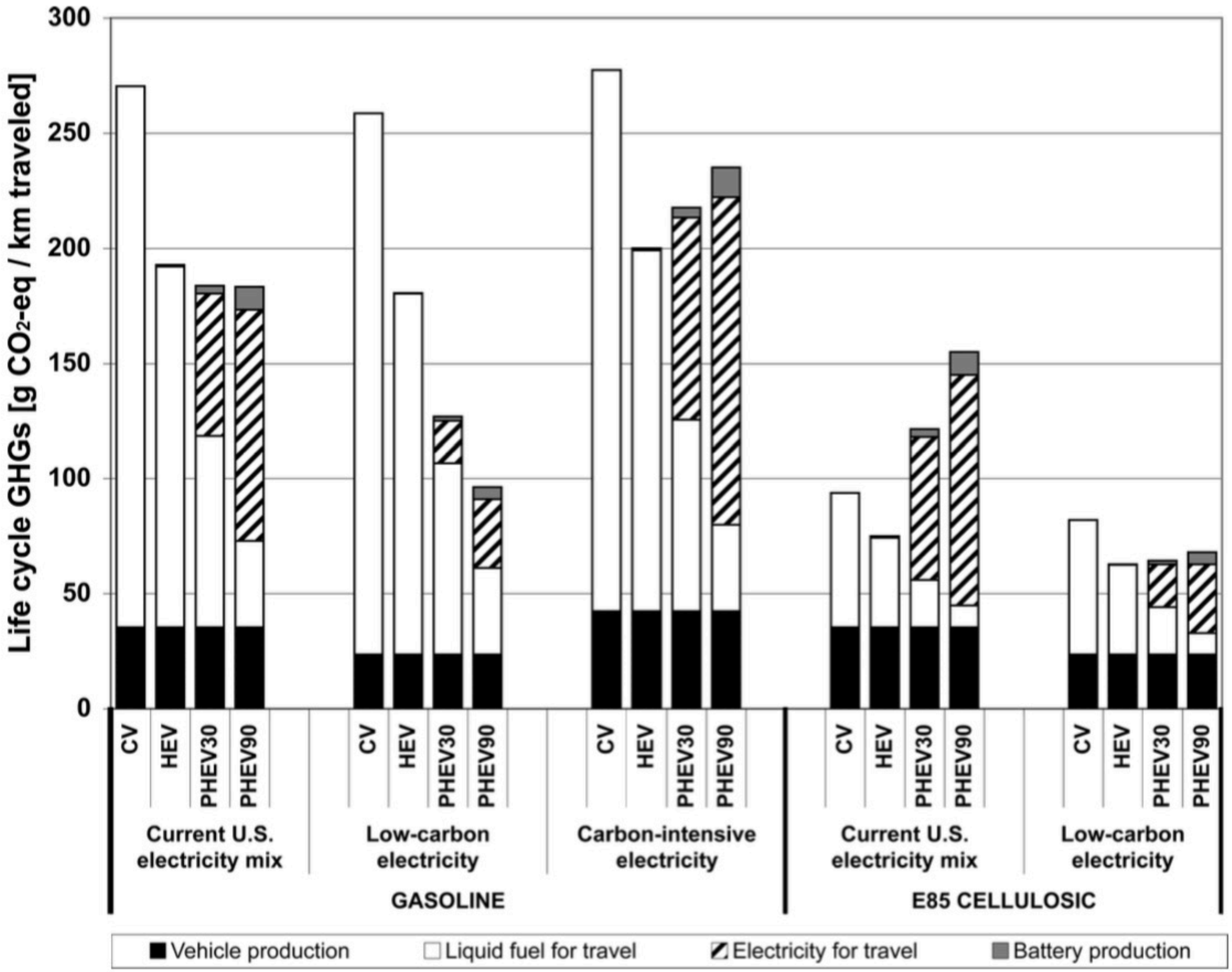


FIGURE 3. Life cycle GHG emissions sensitivity of CVs, HEVs, and PHEVs with 30 and 90 all-electric km ranges under different fuel and electricity carbon intensities. Life cycle carbon intensity of electricity assumed to be 670, 200, and 950 g CO_2-eq/kWh for U.S. average, low-carbon, and carbon-intensive scenarios, respectively. "E85" is a liquid fuel with 85% cellulosic ethanol (volume basis), and the remainder gasoline. Life cycle carbon intensity of gasoline and E85 are 86 and 21 g CO_2-eq/MJ, respectively.

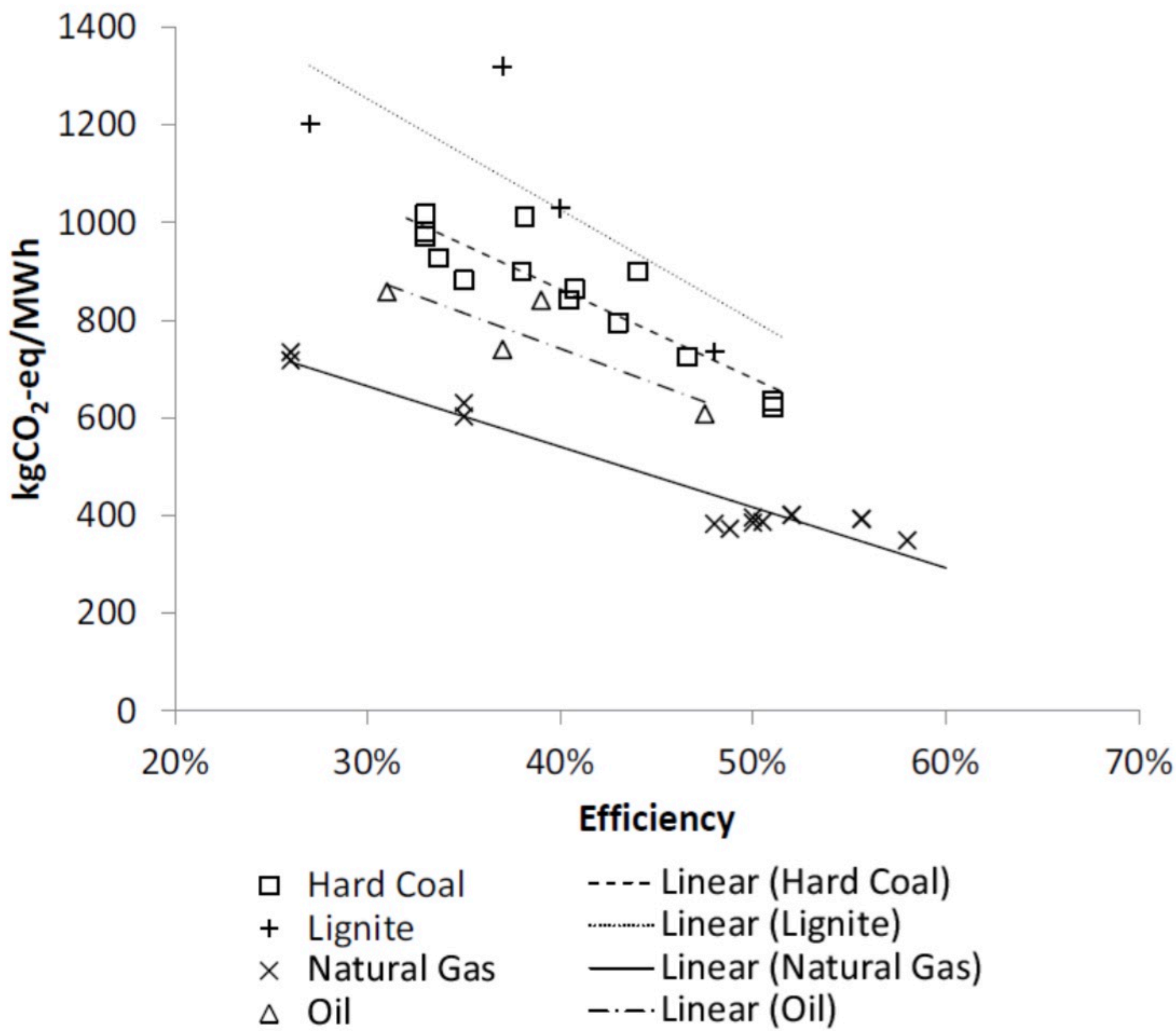
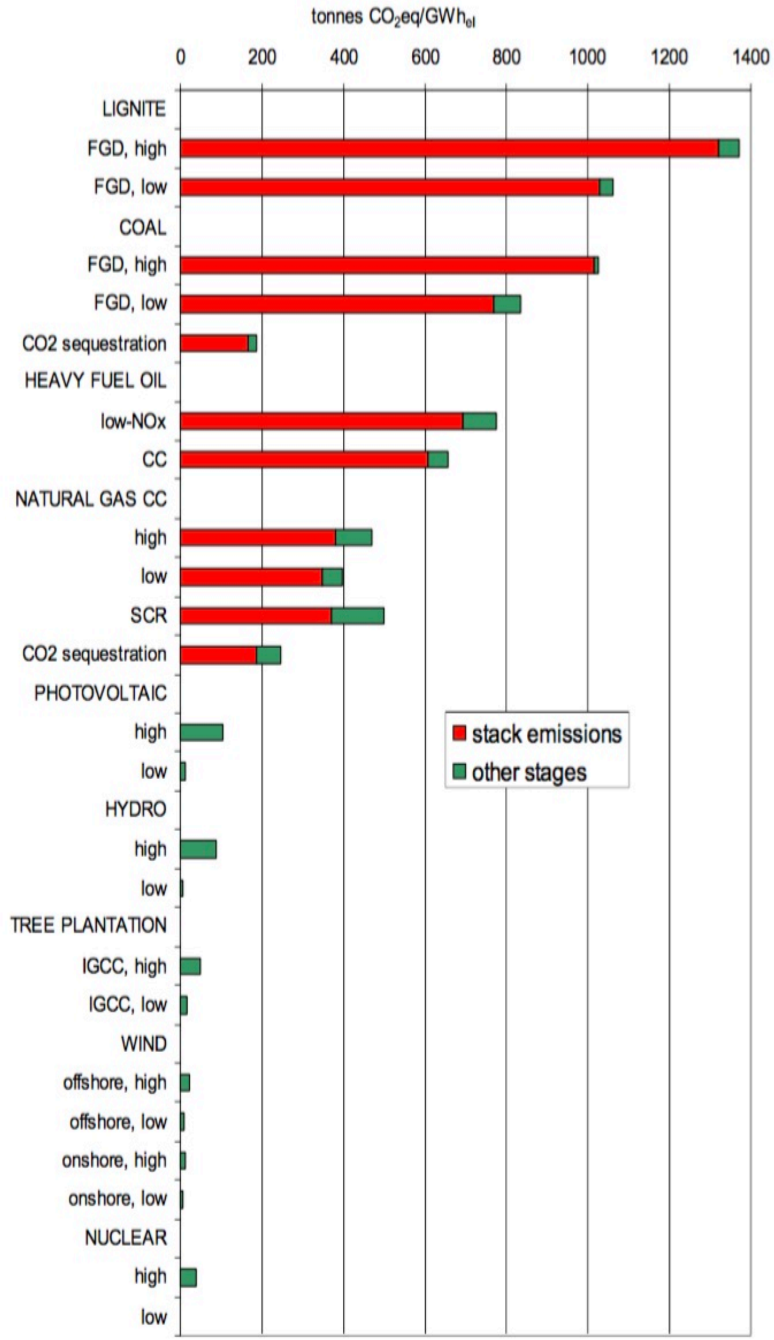
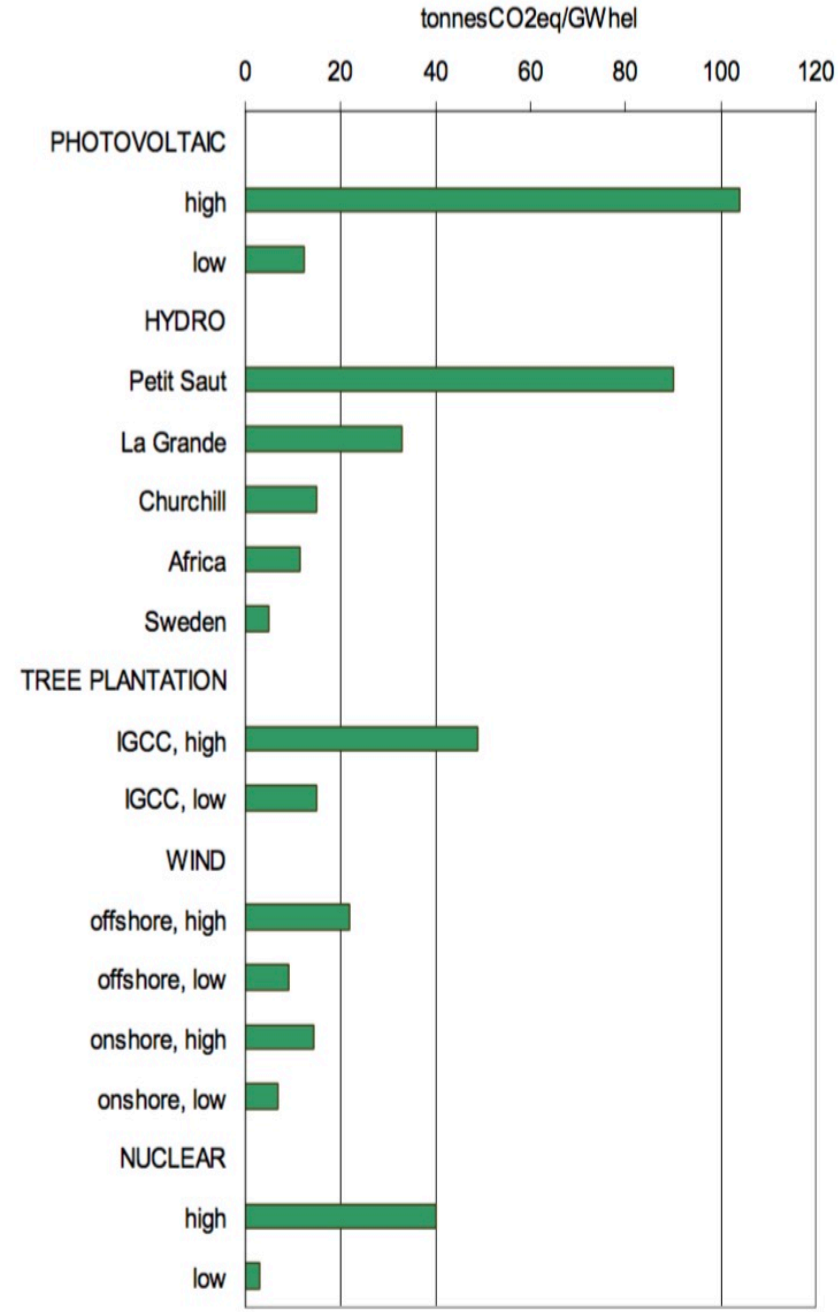


Figure 2. Relationship between plant efficiency and GHG direct emissions for hard coal, lignite, natural gas and oil



tonnes CO_2eq/GWh$_{el}$
0
200
400
600
800
1000
1200
1400
LIGNITE
FGD, high
FGD, low
COAL
FGD, high
FGD, low
CO2 sequestration
HEAVY FUEL OIL
low-NOx
CC
NATURAL GAS CC
high
low
SCR
CO2 sequestration
PHOTOVOLTAIC
high
low
HYDRO
high
low
TREE PLANTATION
IGCC, high
IGCC, low
WIND
offshore, high
offshore, low
onshore, high
onshore, low
NUCLEAR
high
low
stack emissions
other stages



tonnesCO2eq/GWhel
0
20
40
60
80
100
120
PHOTOVOLTAIC
high
low
HYDRO
Petit Saut
La Grande
Churchill
Africa
Sweden
TREE PLANTATION
IGCC, high
IGCC, low
WIND
offshore, high
offshore, low
onshore, high
onshore, low
NUCLEAR
high
low

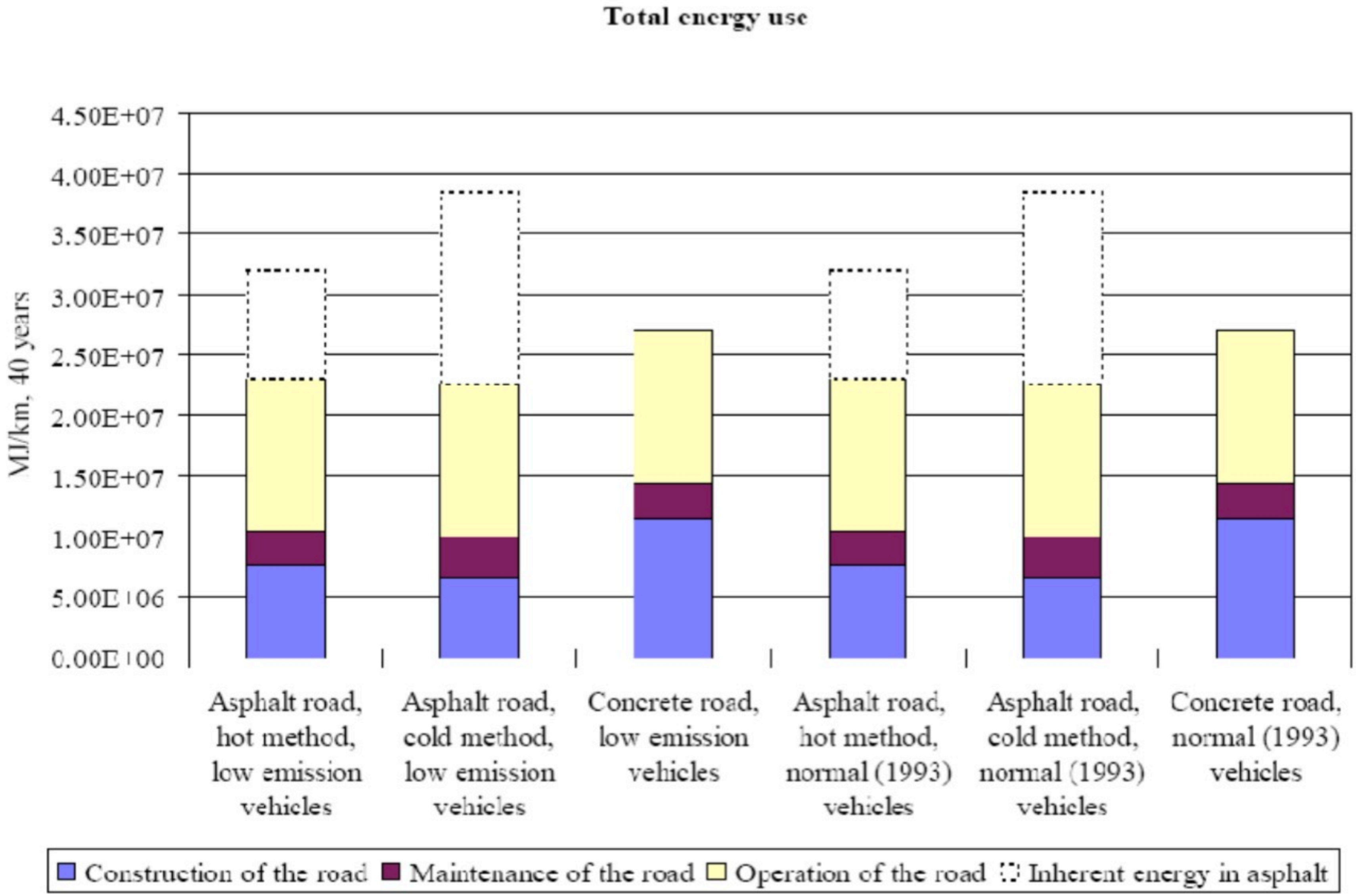


Figure MR-1.1: Results of life cycle inventory analysis for energy of three types of roadways. Dotted lines represent stored energy in asphalt. (Stripple, 2001)

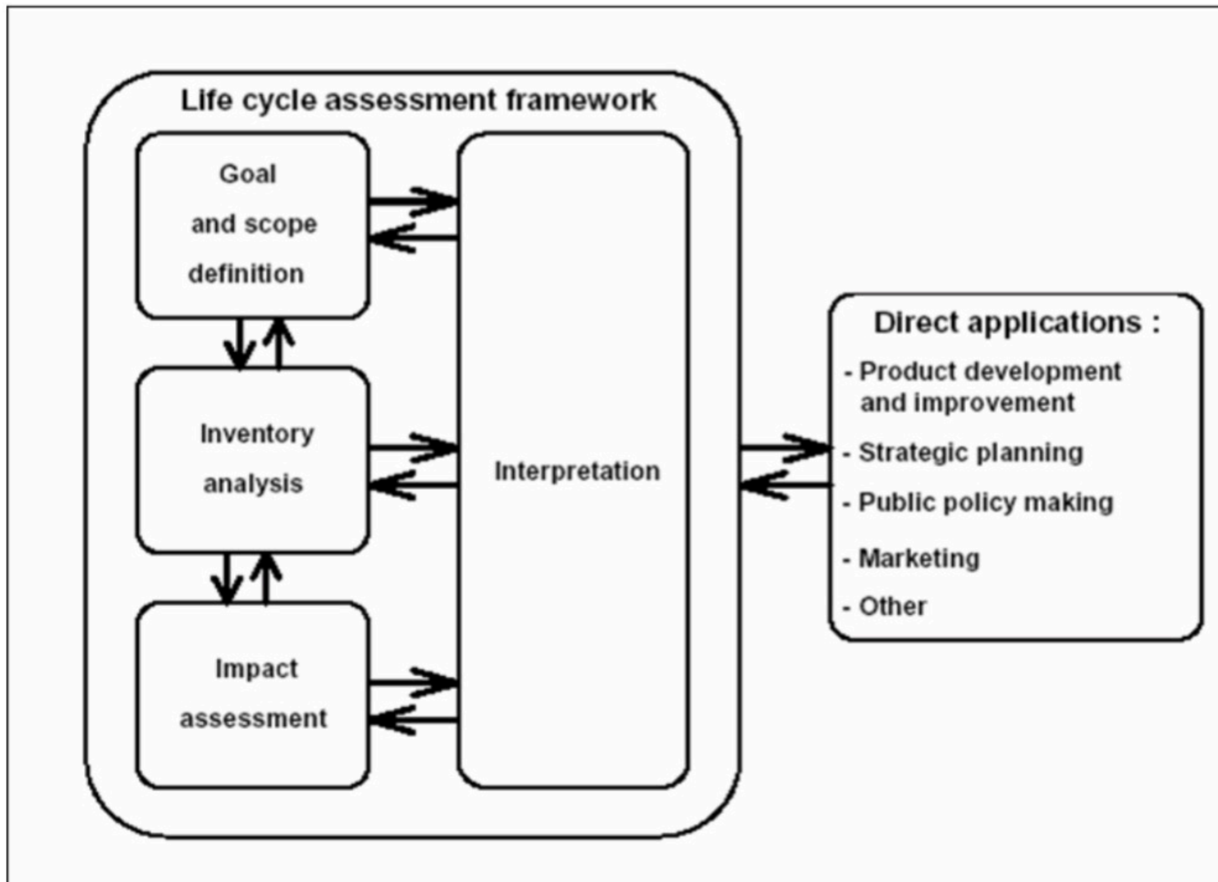
The full report (2nd edition) is available from the IVL Swedish Environmental Research Institute, Ltd. here: http://www3.ivl.se/rapporter/pdf/B1210E.pdf

LCA is a method used to evaluate the environmental burdens associated with a product, process, or activity which includes the identification of energy, materials and substances used and emissions and wastes released to the environment, over the whole life cycle of the prod- uct, process or activity. The life cycle represents all relevant interventions and measures of

- resources extraction,
- transports,
- energy supply,
- production,
- use and
- end-of-life

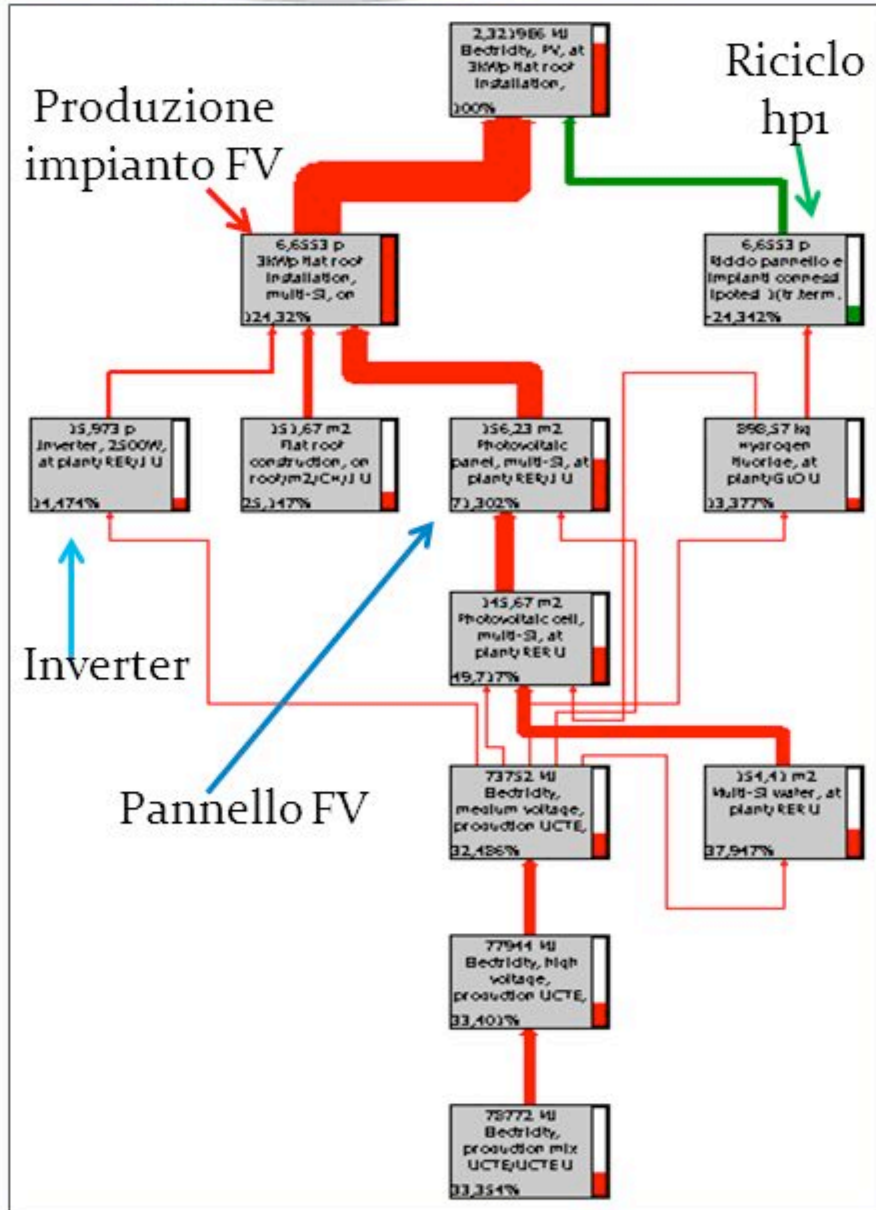
of the product, process or activity under study. All relevant interventions and measures must be within the system boundaries2. The boundary conditions3 determine the circumstances related to geographical, temporal and technical representativeness of the system. With this method, a variety of environmental effects, such as

- resource and energy consumption,
- global warming,
- acidification,
- stratospheric ozone depletion,



LCA *"cradle to cradle"*

- Confini del sistema: dall'estrazione delle materie prime alla produzione di semilavorati dall'impianto FV (ipotesi 1 di riciclo).
- Unità funzionale: energia prodotta durante la vita dell'impianto pari a 644'971 kWh.
- Danno, valutato con IMPACT, è pari a 10,8 Pt (circa 3 Pt in meno del caso *"cradle to gate"*).



Building a Life Cycle Inventory Database for REEs Concept

Why? To create a benchmark for the industry and to measure and communicate the environmental impact of rare earth oxide-containing (REO) products … As the world places more and more emphasis on the “green technologies” to address climate change issues and UN sustainable development goals, it is increasingly important to understand the life cycles of the underlying raw materials. Several Life Results? Cycle Assessments (LCAs) studies pointed out that the production impacts of REOs are high in the case of several REO containing products.

What’s about REEs? Rare earth elements (REEs) are essential for the transition toward sustainability. However, rare earths are critical metals with one of the highest supply risks and environmental impacts

LCA is a decision-making tool used to identify environmental burdens and evaluate the potential environmental impacts of goods or services over their life cycle from cradle-to-grave. LCA has been standardized under the International Organization for Standardization (ISO) and forms the conceptual basis for a number of management approaches and standards that consider the life cycle impacts of product systems.

System Boundaries

The system boundary of the study included a cradle-to-gate life cycle inventory from the extraction of the rare earth ore at the mine to the production of rare earth oxide.

Rare Earth Elements (REEs) are a collection of 17 chemical elements that are critical to the functionality of a host of modern commercial industries including emerging clean energy technologies, electronics, medical devices, and national defense applications. Despite their key importance in multiple industries, to-date there has been little emphasis on environmental systems analysis of REE production. Rapid growth in these industrial sectors could result in heightened global demand for REE. As such, assessing the broader ramifications of REE production on human health and the environment is crucial for guiding the sustainable development of these industries. In this study, life cycle assessment (LCA) is performed to evaluate the environmental impacts and resource intensity of producing rare earth oxides (REO) from the Bayan Obo mine located in Inner Mongolia, China. Analysis indicates that the mining, as well as extraction and roasting phase(s), had the greatest contribution to overall life cycle environmental impacts. Additionally, the results reveal that the production of heavy REO consumes over 20 times more primary energy as compared to steel (per unit mass). The high primary energy consumption and life cycle environmental impacts of REO production highlight the critical need for development of REE recycling operations and infrastructure.

From: "Supporting Information for: Environmental Life Cycle Perspective on Rare Earth Oxide Production", by *George G. Zaimes1, § , Berlyn J. Hubler2,§ , Shuo Wang1, & Vikas Khanna1,**

Rare Earth Elements (REEs) have been widely applied in hybrid vehicles, energy-efficient lighting, aerospace and metallurgy. With the global clean technology market grows, the REEs demand is likely to grow in the next years. Currently, global production of REEs is mainly concentrated in China, and Bayan Obo mine situated in Inner Mongolia supply about half of China's total production, the environment issues associated with its rare earth oxides production has also receive close attention from the society. This paper analyzes the process flow and energy consumption in the production of REO in Bayan Obo mine, uses life cycle assessment methodology widely used in the international market for evaluation of environmental impacts overall evaluates the environmental impacts of the REO production in Bayan Obo mine, the results indicated that the environmental impacts from smelting are higher than that in mining and dressing, and the main environmental impacts are concentrated in global warming, acidification, human toxicity and resource depletion, the results provide a valuable data for assessing environmental impacts in rare earth industry and downstream industry based on REEs.

From: The Life Cycle Assessment of Rare Earth Oxides Production In Bayan Obo, by B. L. Zhou*, Z. X. Li, Y. Q. Zhao, & S. Q. Wang

Recently, several ***energetic ionic salts and liquids*** have been proposed as novel high-energy materials, propellants, and explosives. The life cycle environmental impacts of these new energetic salts have not been previously studied. Environmental impacts arise both from release of these energetic materials themselves as well as from their synthesis. In "*Energetic Ionic Materials: How Green Are They? A Comparative Life Cycle Assessment Study, by Amirhossein Mehrkesh and Arunprakash T. Karunanithi*,* for the first time, we report the results of cradle-to-gate life cycle environmental impacts of production of energetic ionic salt 1,2,3-triazolium nitrate and compare it with traditional energetic material 2,4,6-trinitrotoluene (TNT). The results indicate that the production processes of ionic salt have a significantly higher environmental footprint than conventional energetic materials. The above result was consistent across all nine impact categories analyzed and can be directly attributed to energy intensive steps needed to prepare the ionic salt and its precursors. The findings suggest that ionic energetic materials have higher environmental impact than TNT from a life cycle perspective.