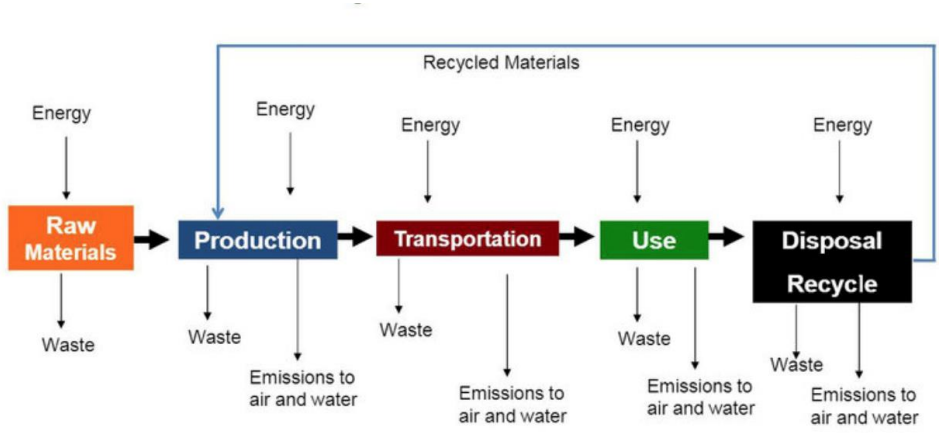
LCA BOBCAT model

environmental analysis of the production model of cardoon cells

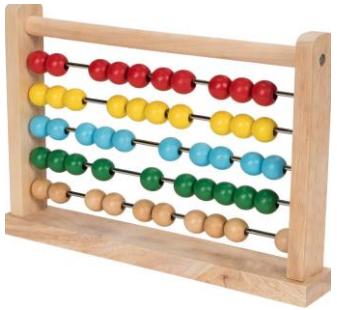
What is LCA

Life cycle assessment (**LCA) is a multi-step procedure for calculating the environmental impact of a product (or service).**

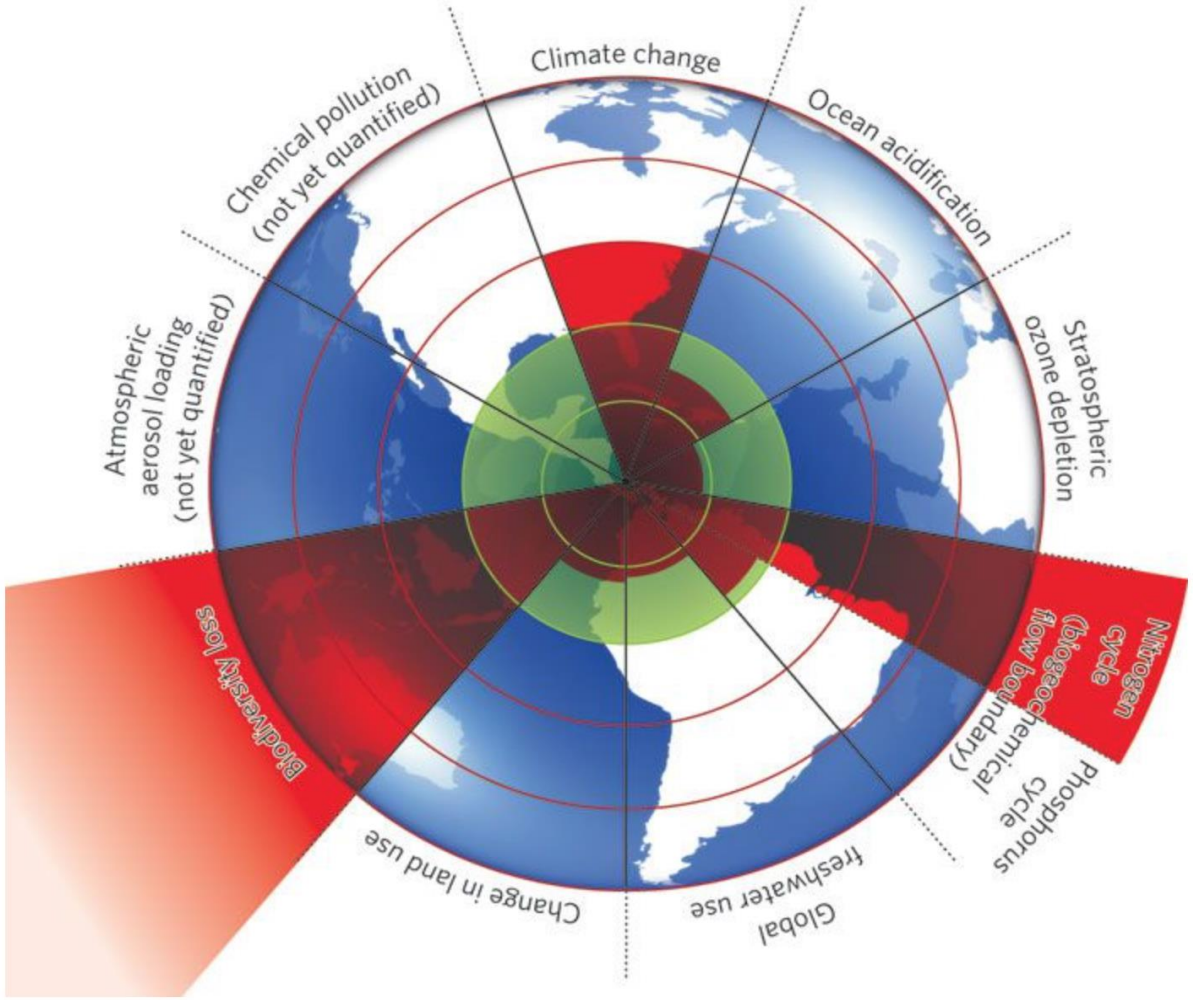
It consists of tracking of all the flows in and out (inputs and outputs) of the system, including raw resources materials, energy, water, and emissions to air, water and soil by specific substance.



In brief, an LCA practitioner is the accountant of environmental resources!!!



Impacts indicators
A measure of the pressure on environment



To avoid catastrophic environmental change humanity must stay within defined 'planetary boundaries' for a range of essential processes (Rockström et al 2009).

These boundaries define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical sub-systems.

Humanity has just passed the boundaries of climate change, and eutrophication, i.e. imbalance in the nitrogen cycle, and biodiversity.

boundaries for global freshwater use, change in land use, ocean acidification and the global phosphorous cycle are at risks.

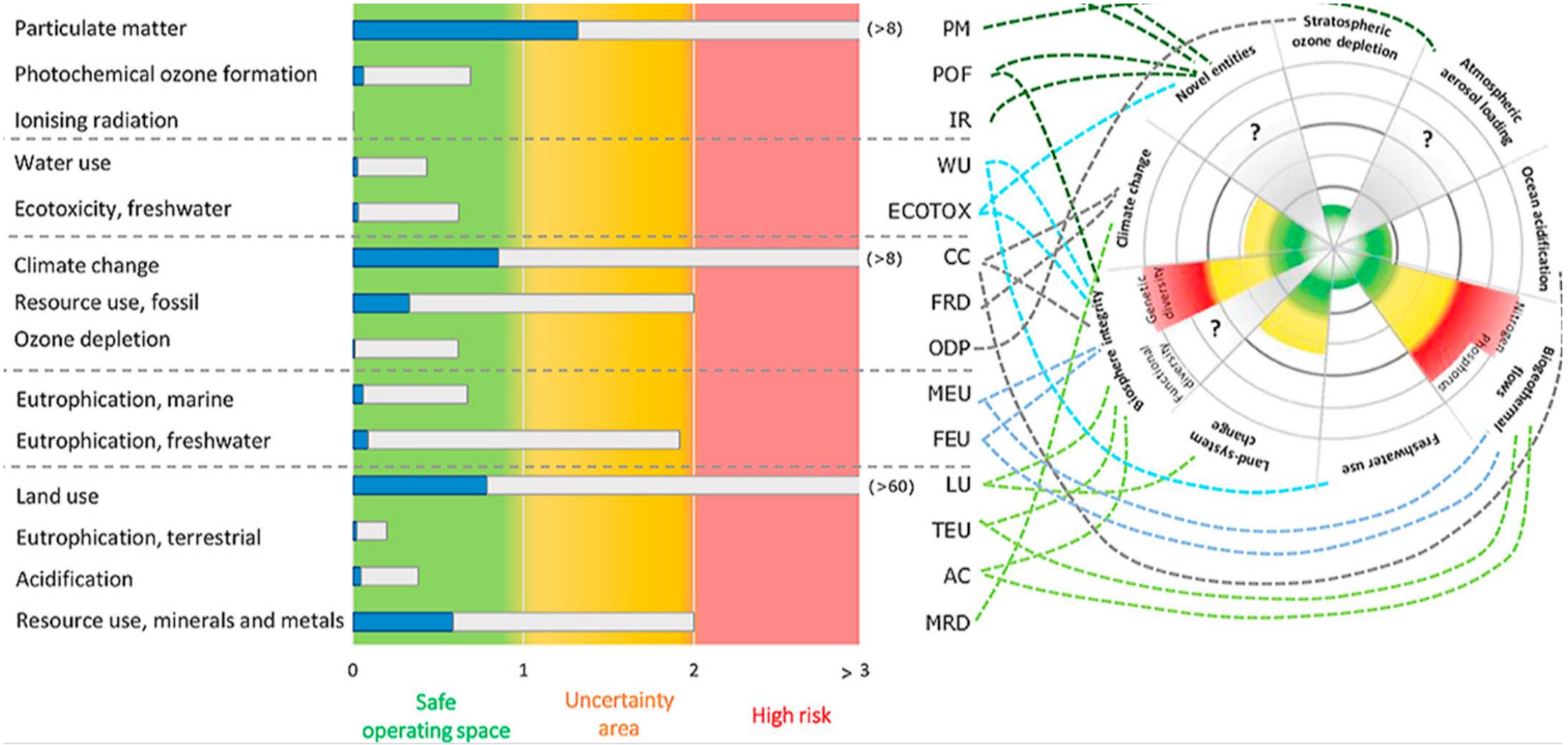
Some impacts indicators

Climate change	GHG production expressed as CO2 equivalent
Ozone depletion	Depletion of ozone . Expressed as kg CFC-11 eq
Terrestrial acidification	Describe changes in soil chemical properties following the deposition of nutrients (nitrogen and sulfur) in acidifying forms. It assess the environmental impact of nitrogen oxides (NOx), ammonia (NH3), and sulfur dioxide (SO2) Generally due to the agronomical input (fertilizers and manure spreading)

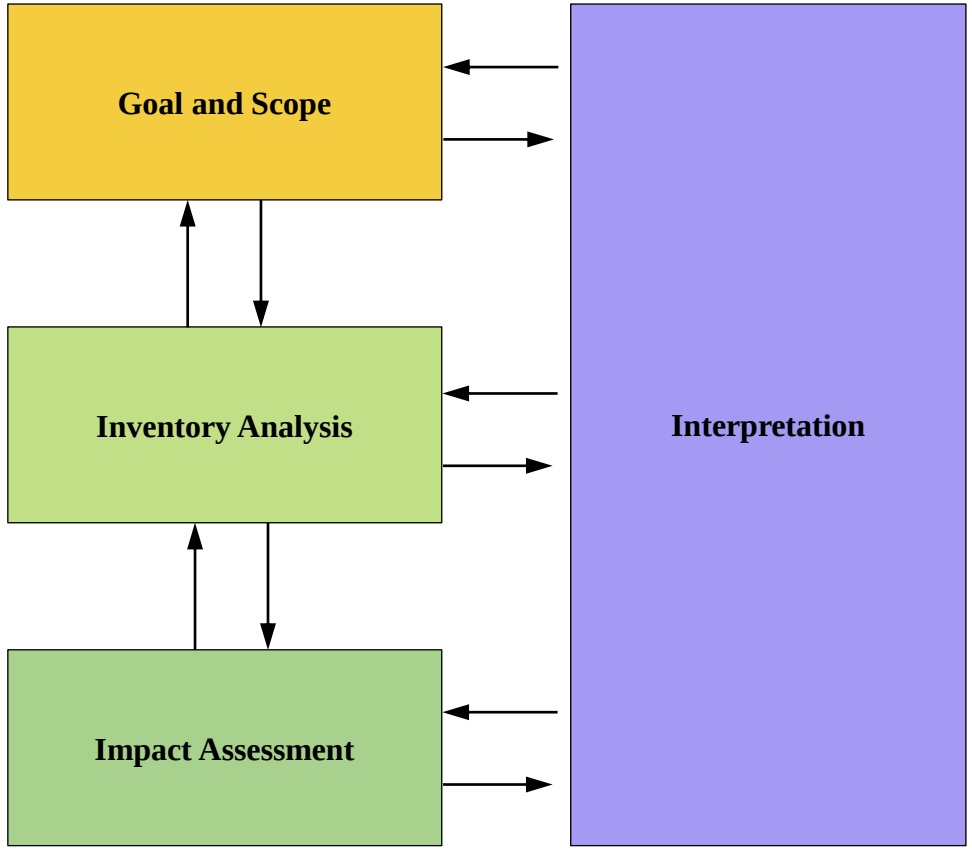
Some impacts indicators

Freshwater eutrophication	Refers to the increase of nutrients leading to excessive primary productivity and biodiversity losses. The two most common nutrients driving aquatic eutrophication are nitrogen (N) and phosphorus (P), particularly in LCIA, is assumed that freshwater eutrophication is caused by P.
Marine eutrophication	Refers to the amount of N that will end up in coastal water, causing an increase in primary productivity.
Particulate matter formation	Refers to the emission of NOx, NH3, SO2, or primary PM2.5 to the atmosphere, followed by atmospheric transformation in the air. Is expressed as PM10 equivalent. In scenario 1 and 2 the main items contributing to this category are: electricity, nitrogen fertilizer and in scenario 2 traction for the production of feed. The mixotrophic scenario results in a 16% decrease.

Step forward:link with planetary boundaries



LCA steps



The need for LCA in BOBCAT project

Comparisons with state of the art technologies to get the same products, highlighting pros and cons

Ecodesign: identify and improve the hotspot (more hidden if they are emissions vs inputs)

From lab to full scale

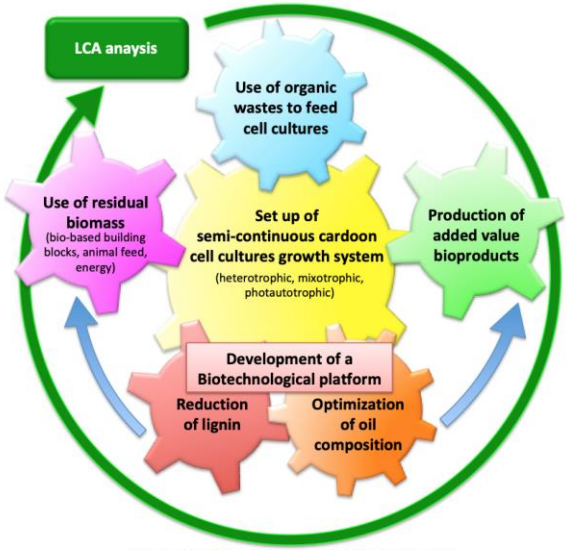
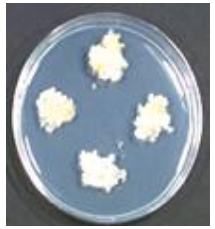
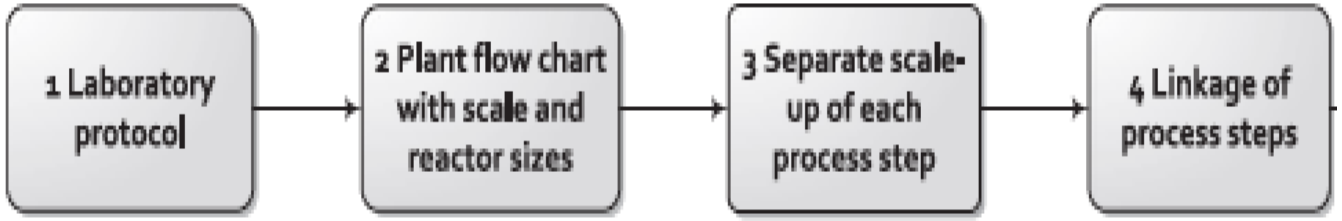


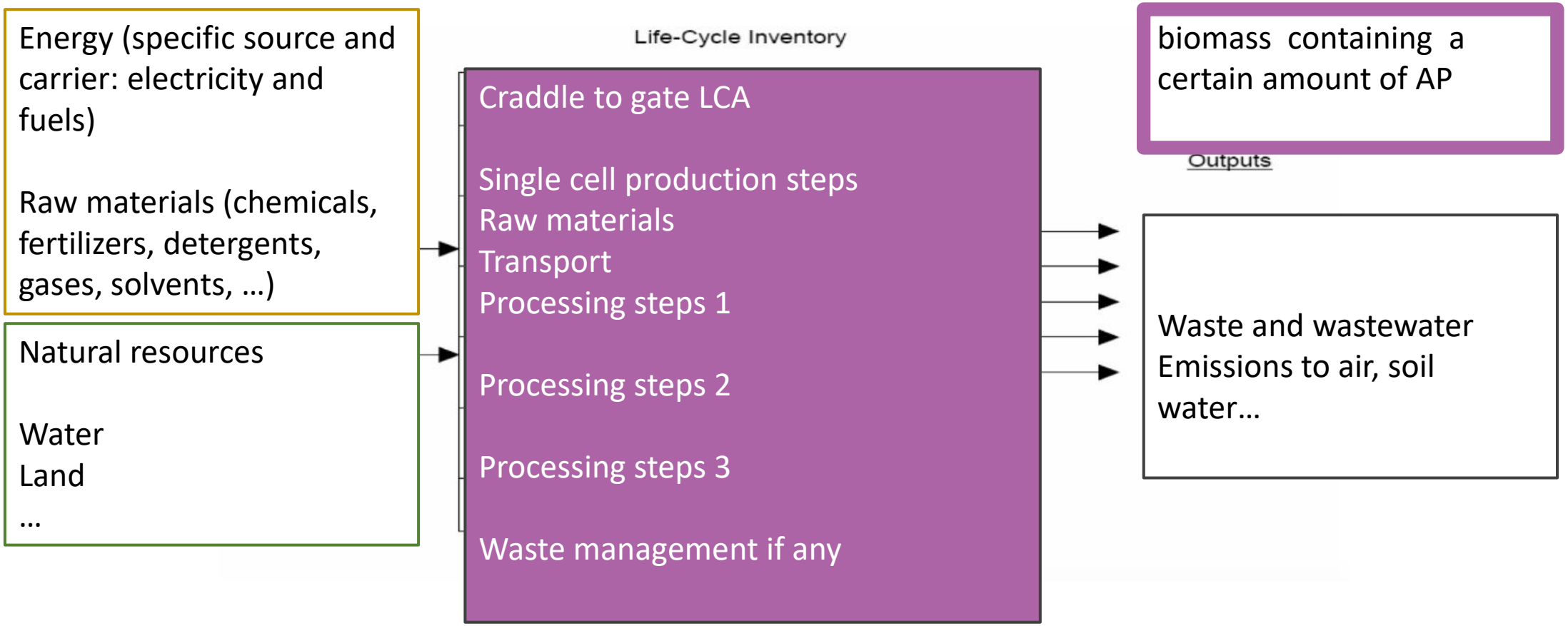
Figure 1. Objectives and strategy of BOBCAT project





The lab data are used to simulate a scale-up scenario

Data collection for the inventory

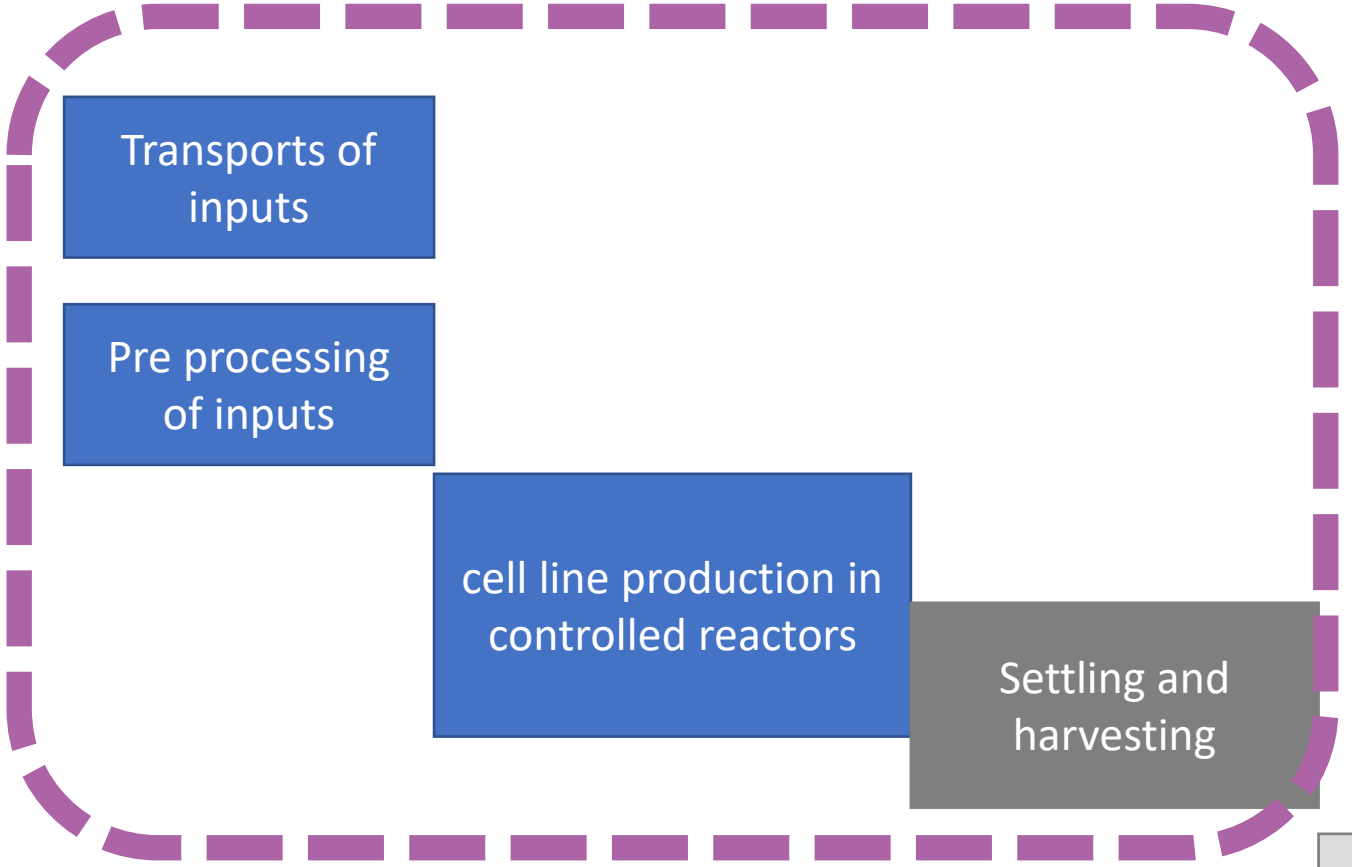


Modelling the “full scale biorefinery”

Consorzio Italbiotec

Single cell line R&D

Inputs:
Water,
light
Energy-fuel
Chemicals, nutrients,



Biomass rich in Active Principles (AP)

Emissions
wastewater
solid wastes
Air-soil emissions

Extraction

Modelling the “full scale biorefinery”

Consorzio Italbiotec

Lab phase R&D

Pre processing of inputs

Inputs:
Water,
recovered
wastes
energy

Cardoon cell line production in controlled reactors

Inputs:
Water, light
Energy (e.g
stirring,areation
lighting ..)
Chemicals, nutrients,
gases recovered waste

Emission to air,
wastewater or solid
wastes

Settling and harvesting
*S(L separation…*etc..

Inputs:
Energy, chemicals

Extraction

Inputs:
Energy,
Chemicals

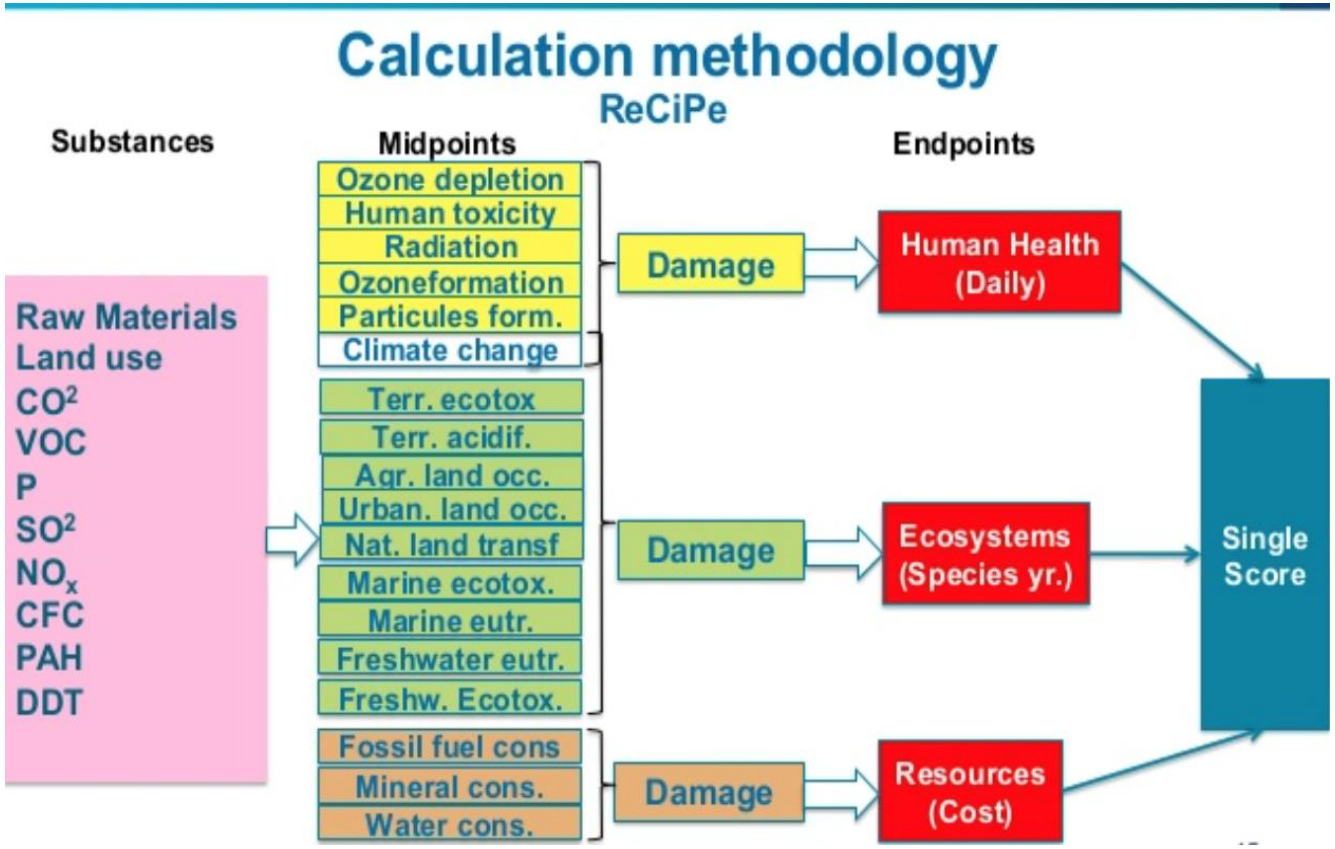
Emission to air,
wastes

Biomass rich in AP
Flavonoids
cynarin, silymarin,luteolin
Apigenin
Fenolic compound
caffeoylquinic acids….

building blocks (cellulose, lignin and oil)

Animal feed

From inventory to impacts category



What affect the final results

The concentration in active principles : purer and higher level of AP make the production more sustainable

Some recent researchs report increase of AP in calli cells than in field cultivated leaves (Menin et al 2020)

Productivity:

The concentration of cell in the growth culture at the maximum of growth: (1-10-20g/l....)

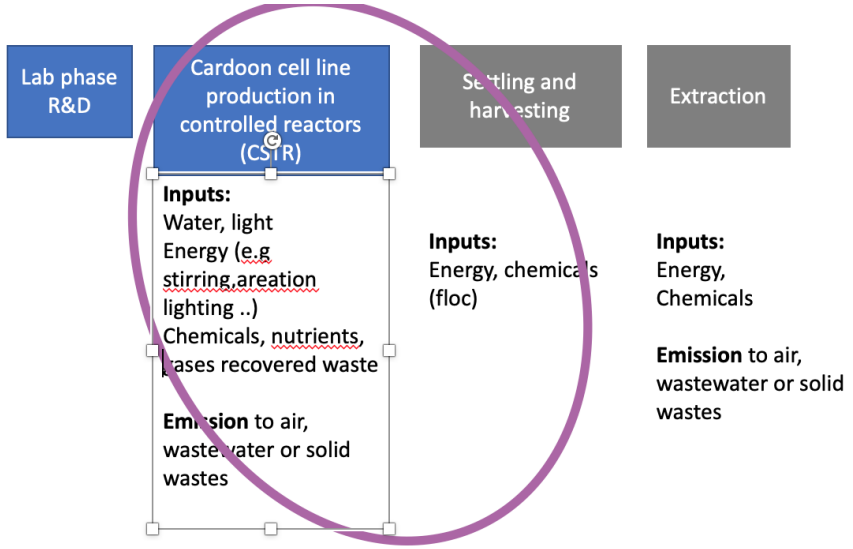
(global yield and harvesting effort)

The time to achieve maximum growth: HRT o batch time (5 -15-20 days).

(This affect the energy demand of the process and the dimensioning of equipment's)

Efficiency of use of byproducts: recovery of carbon in the waste stream vs carbon rich growth media discharged

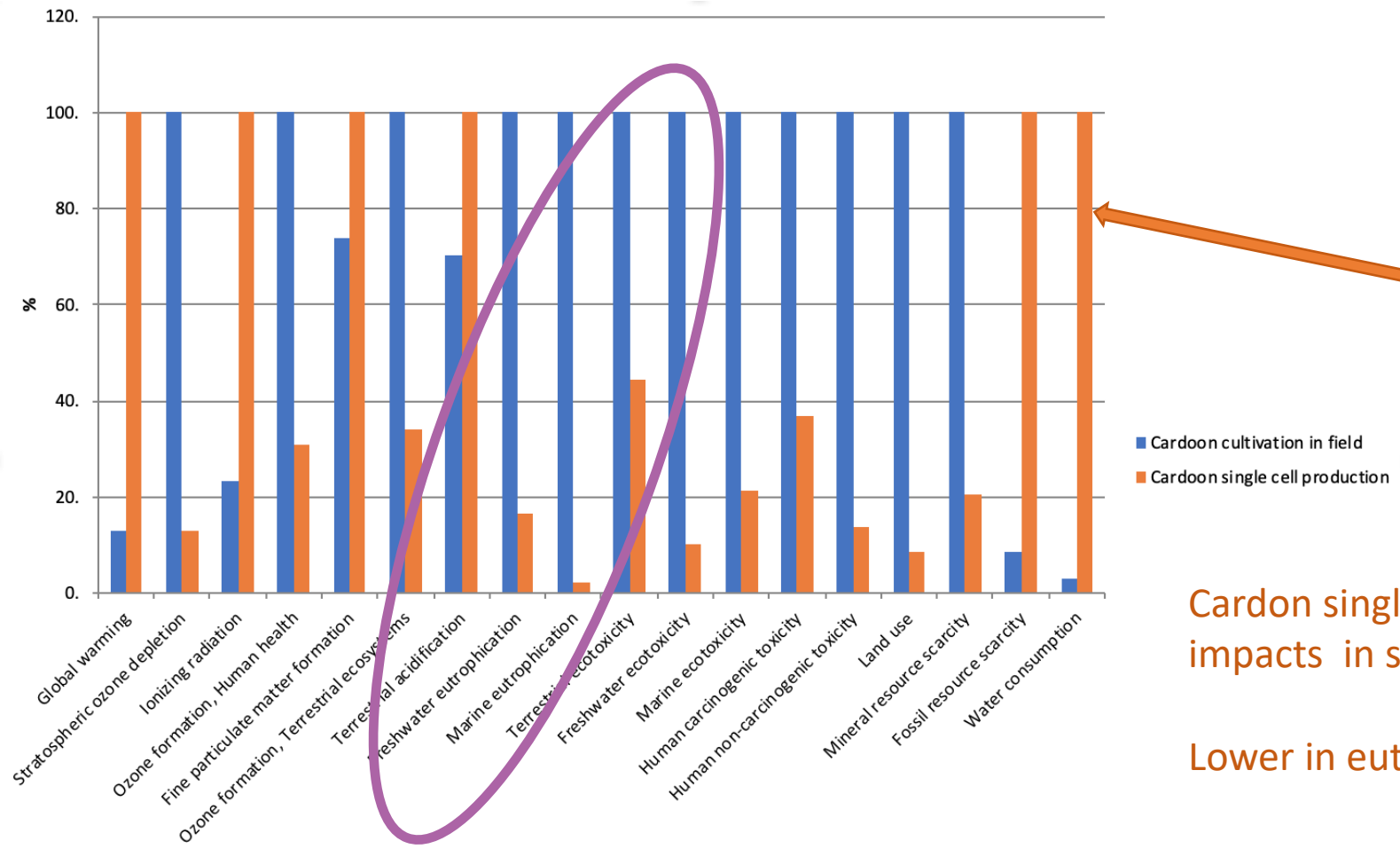
Extraction optimization due to low lignin content vs field cultivation



Simulation of tentative scenarios (best –worst case)

Consorzio Italbiotec

Worst scenario: AP same and long growth time



These a preliminary simulation !!!!!!

All is to be confirmed by on going research work and data

High water consumption is related to the energy inputs more than direct use of water

Cardon single cell culture displays higher impacts in some categories (CC)

Lower in eutrophication (nutrient cycle)

Simulation of tentative scenarios (best –worst case)

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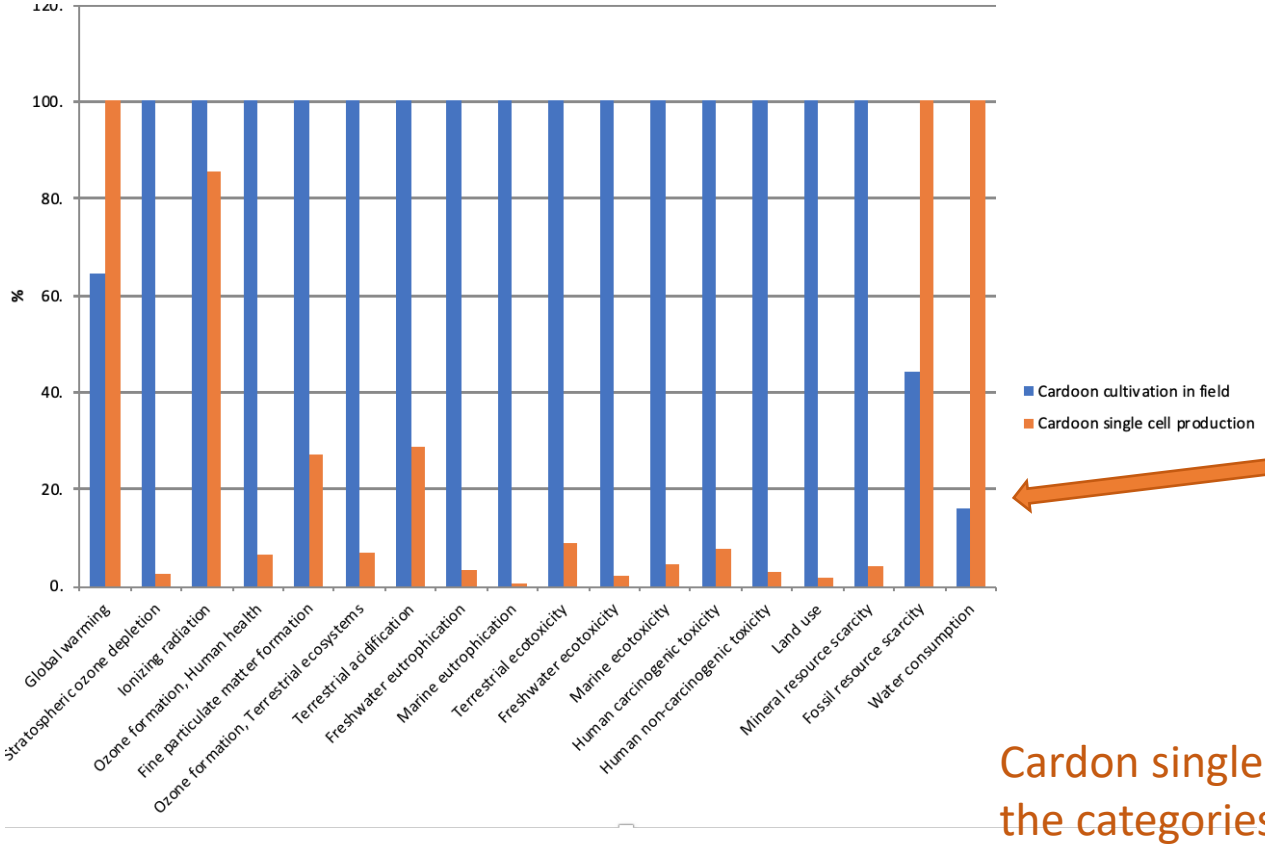
Best scenario: AP increased (conservative estimation)



These a preliminary simulation !!!!!!

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High water consumption is related to the energy inputs more than direct use of water

Cardon single cell culture displays lower impacts in most of the categories (still not in CC)

Single cell process vs field production

respect to environmental impacts

Possibly less direct emissions

Less use of natural resources (water and land)

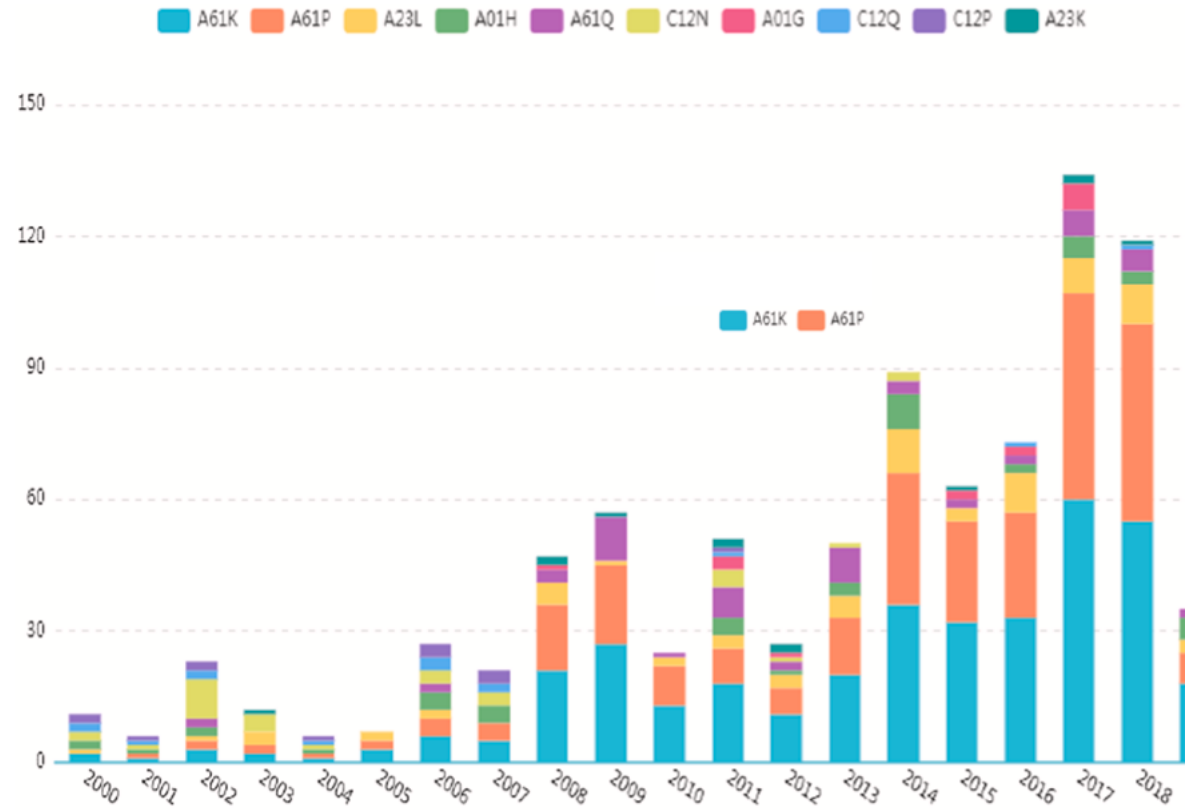
Use of electricity in a future scenario with higher share of renewable electricity

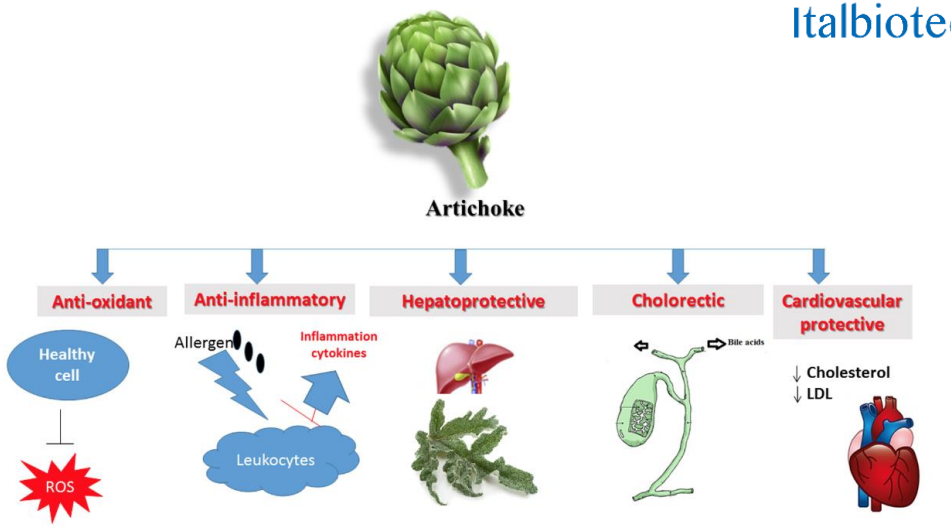
Higher energy demand (electricity inputs)

A larger outlook to set the goal and scope of LCA

New patents worldwide for cardoon use :
Preparations for medical purposes
Specific therapeutic activity

The main topic of patents is « farma and nutraceutics»





Zayed et al 2020

A61K = Preparations for medical purposes;
A61P = Specific therapeutic activity
A23L = Foods, foodstuffs, or non-alcoholic beverages;
A01H = New plants or processes
A61Q = cosmetics or similar;
…….

The LCA analysis should frame this added value products production-

Conclusions

Data form lab work will feed the results to describe the real process inputs (according to productivity, time and AP concentration)

Improvement in scale up performances requires time. Productivity and specific energy demand are the target of the efforts!

LCA can address the critical points to improve

Future scenarios, such as different energy source, can change the burdens we face now in sustainability

Direct emissions such as the ones occurring in open field agriculture should be greatly diminished in reactor culturing (such as the use of natural resources as land), opposite in controlled reactors energy input are higher

Some aspects such as the quality of AP and purity cannot be fully captured by LCA analysis (i.e. pesticides or other contaminants from open field production…)

For Added value molecules field culture is not the correct comparison

The research paves the way to the biotech use of single cell as platform for AP production. This is the start.

Thank you for your attention