CAMBIOSCOP
Carbon management towards low fossil carbon use

Role & challenges of industrial biotech in the transition towards a low fossil carbon future

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Bio & Chemical Engineering

Adebioteh
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MAKE OUR PLANET GREAT AGAIN · INVESTIR L'AVENIR · La Région Occitanie Pyrénées - Méditerranée · IAR LE PÔLE DE LA BIOÉCONOMIE

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Context: the role

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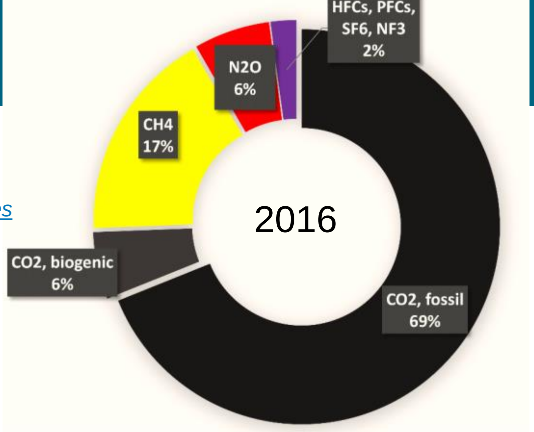
Doing all we do now … without fossil C?



Source: own compilation of data retrieved from https://www.wri.org/resources/data-visualizations/world-greenhouse-gas-emissions-2016

Routes towards low fossil C

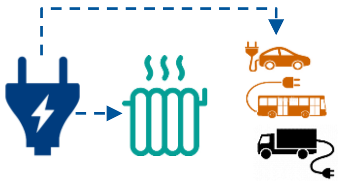
No C (decarbonize)

Biomass C

Atmospheric C

Recycle C

Essentially electricity!



Land dependant

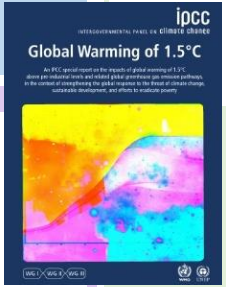
Residues

In the low fossil economy: Carbon becomes a limited resource to use as efficiently as possible!

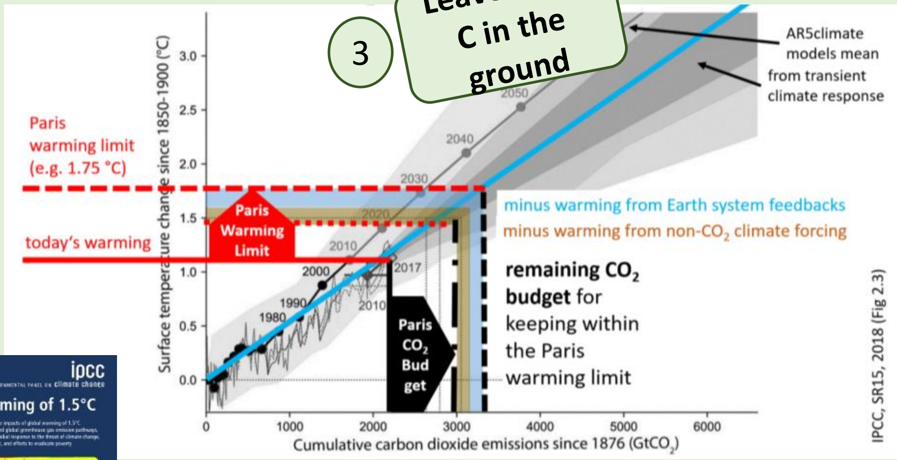
Emergency to stabilize global mean annual surface temperatures

1 GHG reductions now!

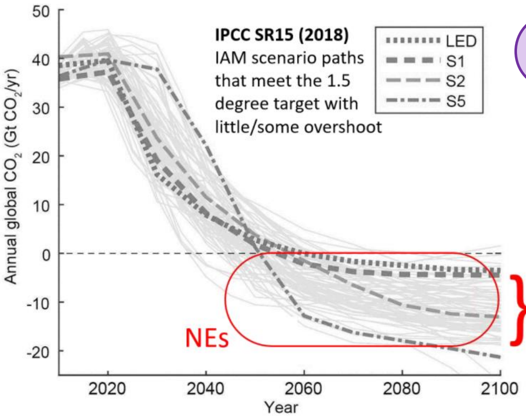
- Limiting warming to 1.5°C requires:
  - Reducing GHGs by 45% (40-60%) by ~2030 (vs 2010 levels) … and to ZERO by ~2050 (2045-2055)
- Limiting warming to below 2°C requires:
  - Reducing GHGs 20% (10-30%) by ~2030 (vs. 2010 level) … and to ZERO by ~2075 (2065-2080)



3 Leave fossil C in the ground



2 We need CDR



… pathway (SSP2)
S5 = high energy demand pathway (SSP5)

In comparison:
Current Global Land Sink
9.2 sink – 5.5 LUC loss $GtCO_2$/yr
= 3.7 $GtCO_2$/yr

In comparison:
Current Global Ocean Sink
= 11.5 $GtCO_2$/yr

Required CO2 extraction (CDR):
5 to 15 $GtCO_2$/yr

Table 2.2 | The assessed remaining carbon budget and its uncertainties.

for a 2/3 likelihood of meeting the target

Additional Warming since 2006–2015 [°C]*(1)	Approximate Warming since 1850–1900 [°C]*(1)	Remaining Carbon Budget (Excluding Additional Earth System Feedbacks*(5)) [$GtCO_2$ from 1.1.2018]*(2)		
		Percentiles of TCRE		
		33rd	50th	67th
0.3		290	160	80
0.4		530	350	230
0.5		770	530	380
0.53	~1.5°C	**840**	**580**	**420**
0.6		1010	710	530
0.63		1080	770	570
0.7		1240	900	680
0.78	~1.75 °C	1440	1040	800
0.8		1480	1080	830
0.9		1720	1260	980
1		1960	1450	1130
1.03	~2°C	2030	1500	1170

Source: All elements of this slide are retrieved and/or adapted from IPCC SR1.5 report. https://www.ipcc.ch/sr15/

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Paris agreement: a delicate balance

Recognizing that "climate change represents an urgent and potentially irreversible threat" to humanity, the Paris Agreement calls for limiting global average temperature to well below 2°C above pre-industrial levels. It also calls for a "balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century".

GHG mitigation

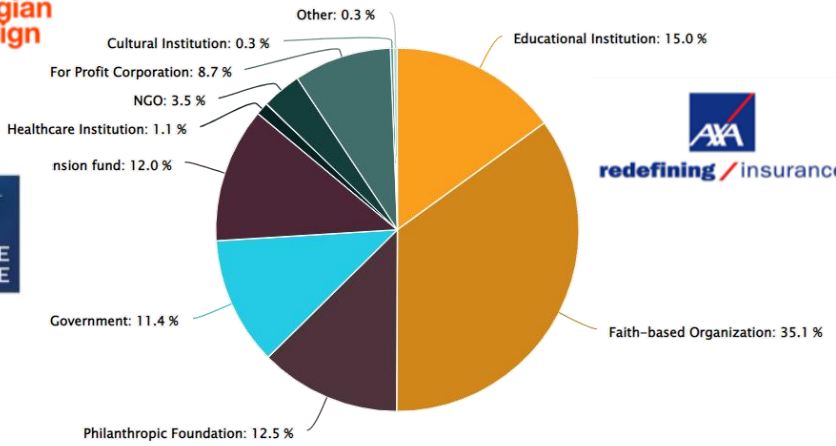
(biophysical) CO_2 removals

Keep fossil C in the ground

Seems we are really going there…

Global divestment database

What kinds of institutions are divesting?



Source: https://divestmentdatabase.org/

Norwegian Sovereign Wealth Fund

LA BANQUE POSTALE

redefining / insurance

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

ONE PLANET SUMMIT

United Nations Global Compact

2

Context: the challenges

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The challenges of biotech – seen from an environmental scientist

Land

Energy

Water

Nutrients

Innovation (more efficient processes)

3

The land challenge

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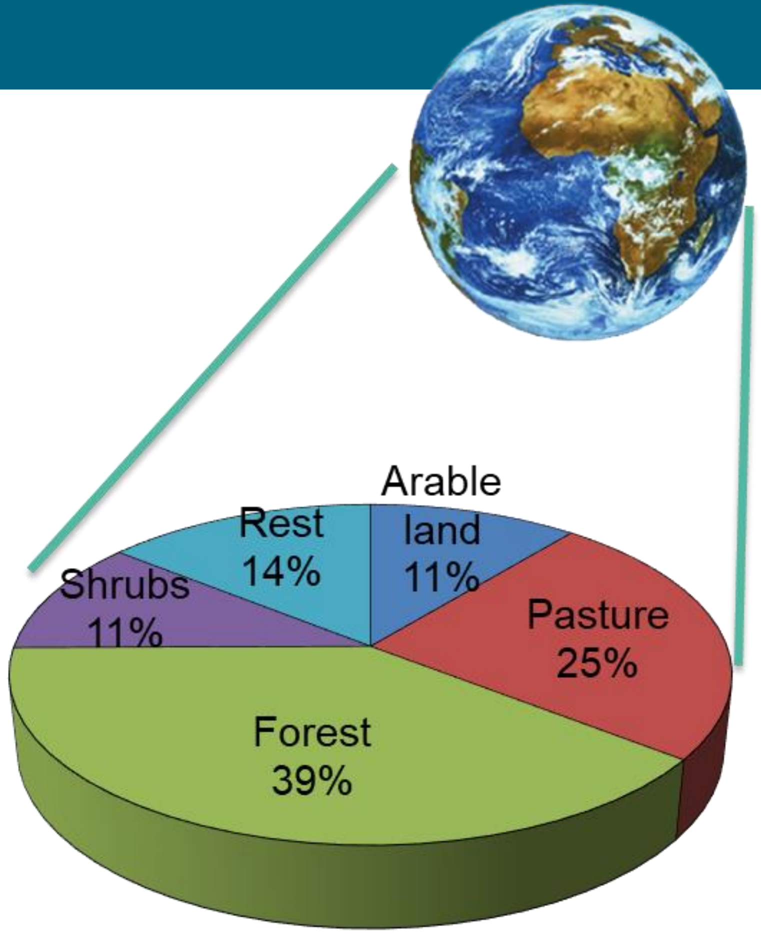
Global outlook on land use

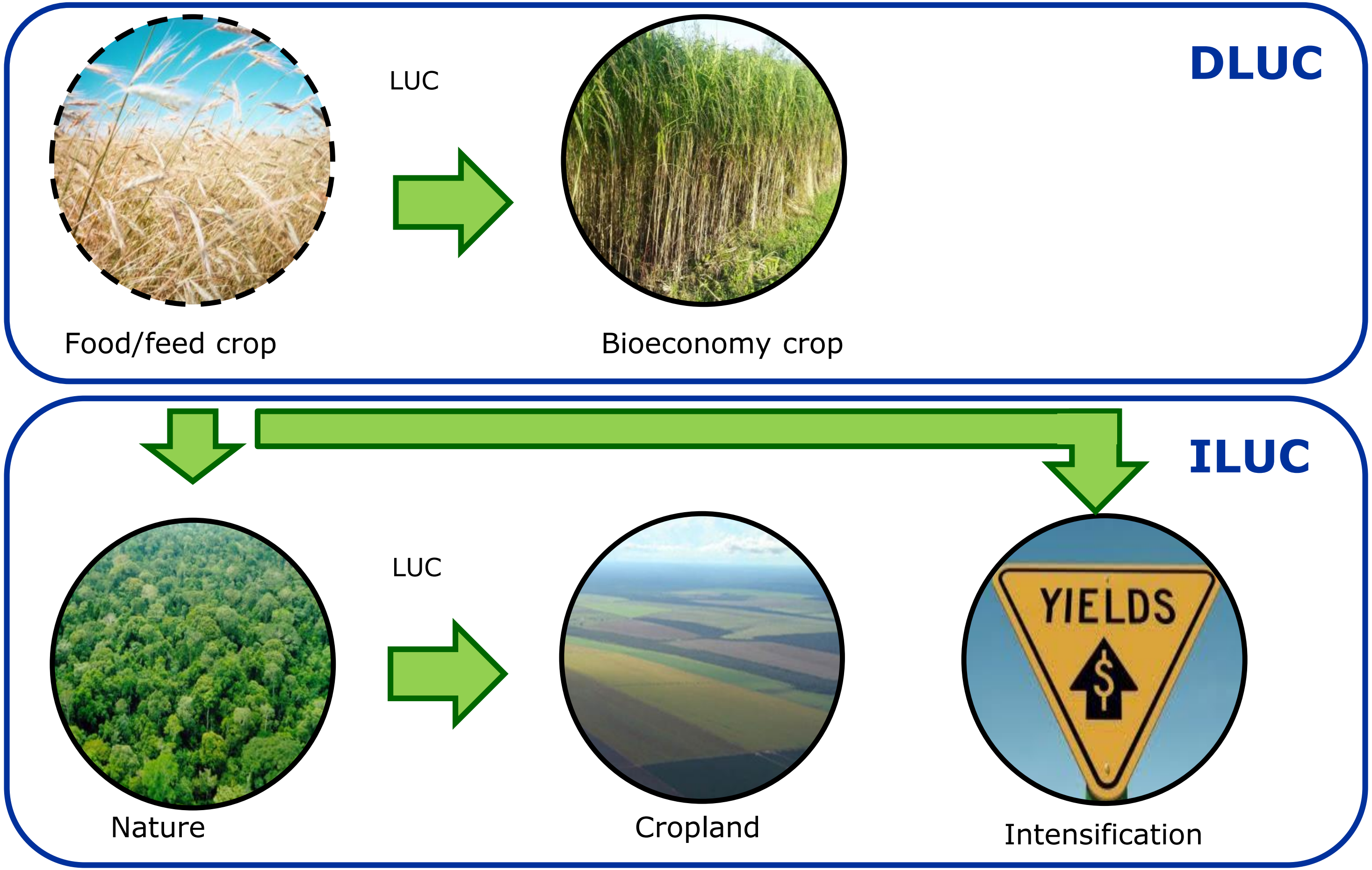
12.5 Gha of land area on Earth*:

- **4.5 Gha agricultural land**
  - 1.4 Gha arable land;
  - 3.1 Gha pastures
- **4.9 Gha forest**
  - ~1.6 Gha primary forest;
  - ~ 0.3 Gha plantations;
  - ~ 2.9 Gha naturally regenerated;
- **3.1 Gha other land**
  - 1.7 Gha uncultivable (permanent snow, water);
  - 0.08 Gha rest (urban)
  - 1.4 Gha shrub



*(*Excludes Antarctica; FAOSTAT, retrieved in 2020 (data for 2017; MODIS data); FAO 2010; Kampman et al. 2008; Kok et al. 2008); Inconsistencies due to rounding*

Land Use Changes: case of crops




COMMENT · 27 MARCH 2019

Why the US–China trade war spells disaster for the Amazon

An analysis of global soya-bean production forecasts massive deforestation in Brazil – stakeholders must act fast to prevent it, warn Richard Fuchs and colleagues.

Peter Alexander, Calum Brown, Frances Cossar, Roslyn C. Henry & Mark Rounsevell
Richard Fuchs

Fields of soya beans (left) sit alongside untouched natural forest in the Cerrado ecoregion of Brazil. Credit: Marizilda Cruppe/Greenpeace

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doi: 10.1038/d41586-019-00896-2

Source: Hamelin (2013). https://www.ceesa.plan.aau.dk/publications/phd-dissertations/

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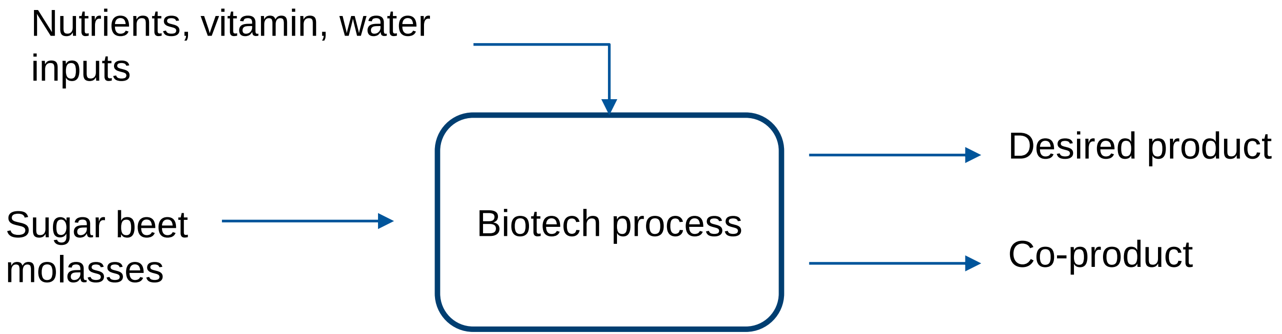
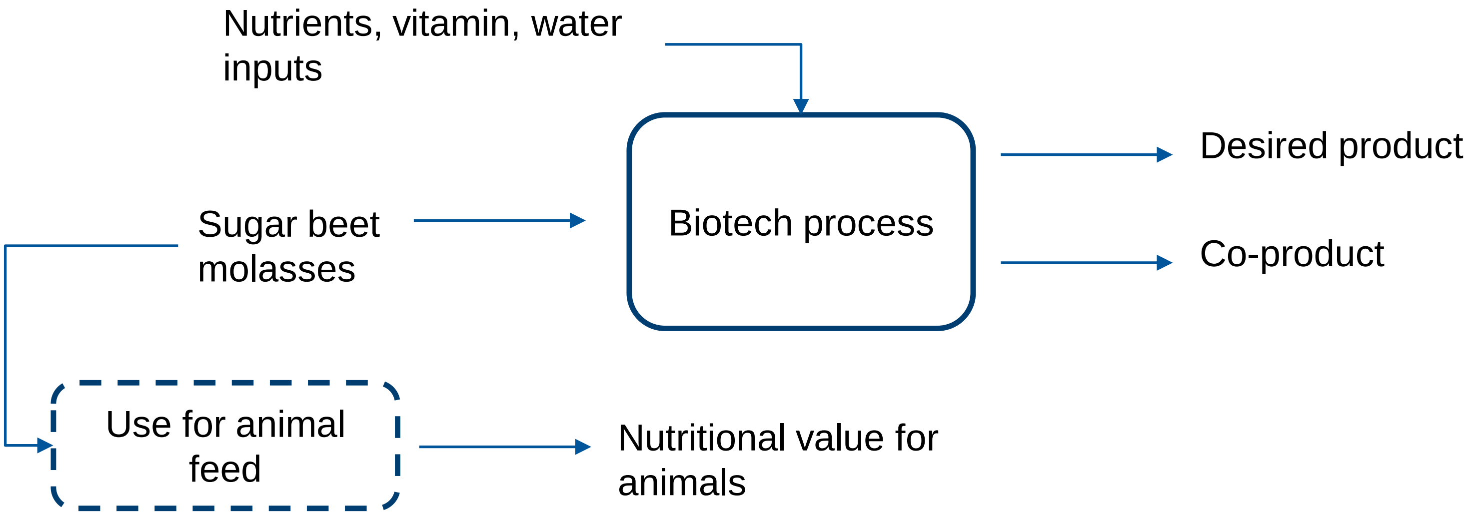
The case of coproducts as input feedstock



The case of coproducts as input feedstock



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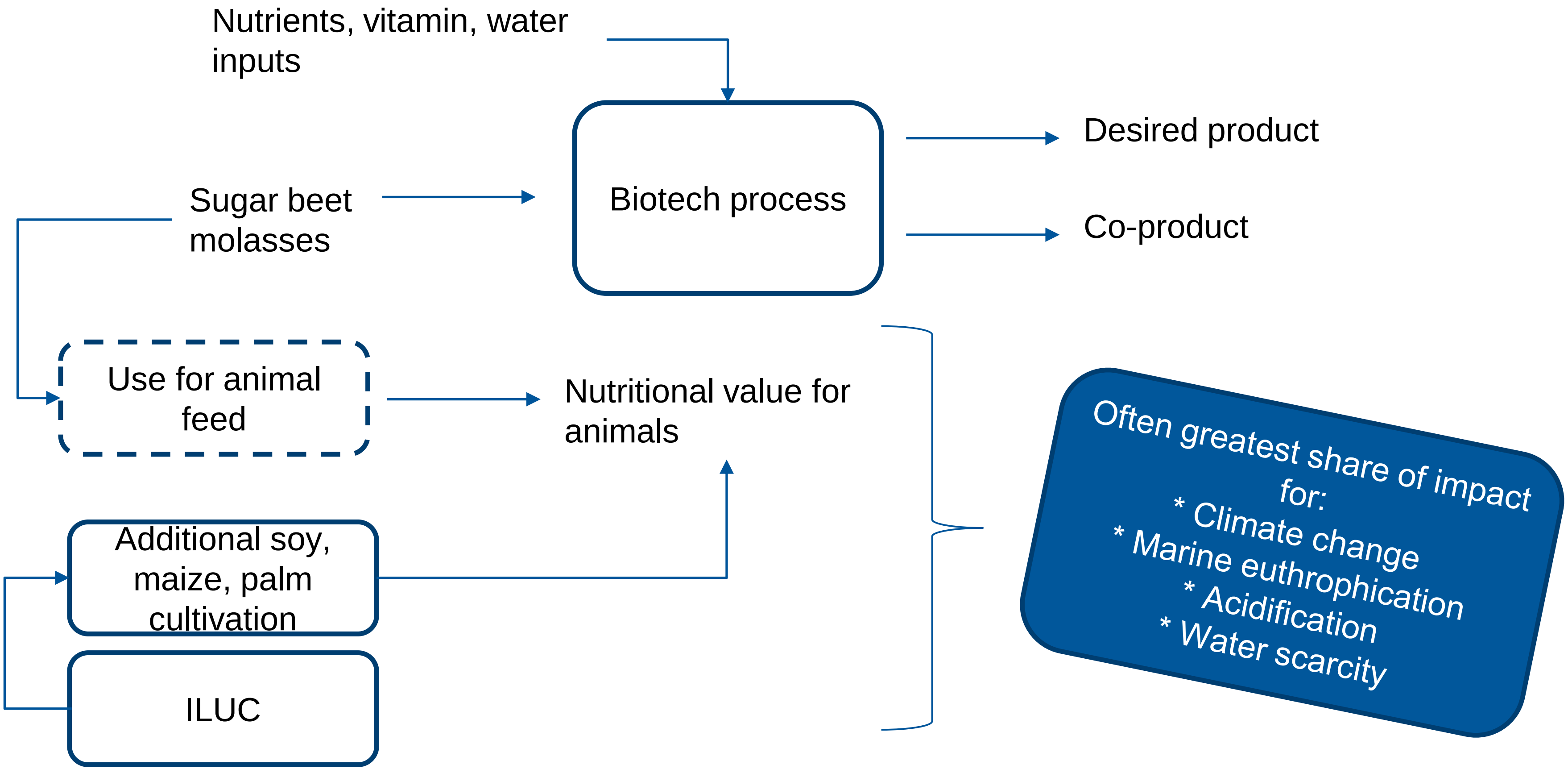
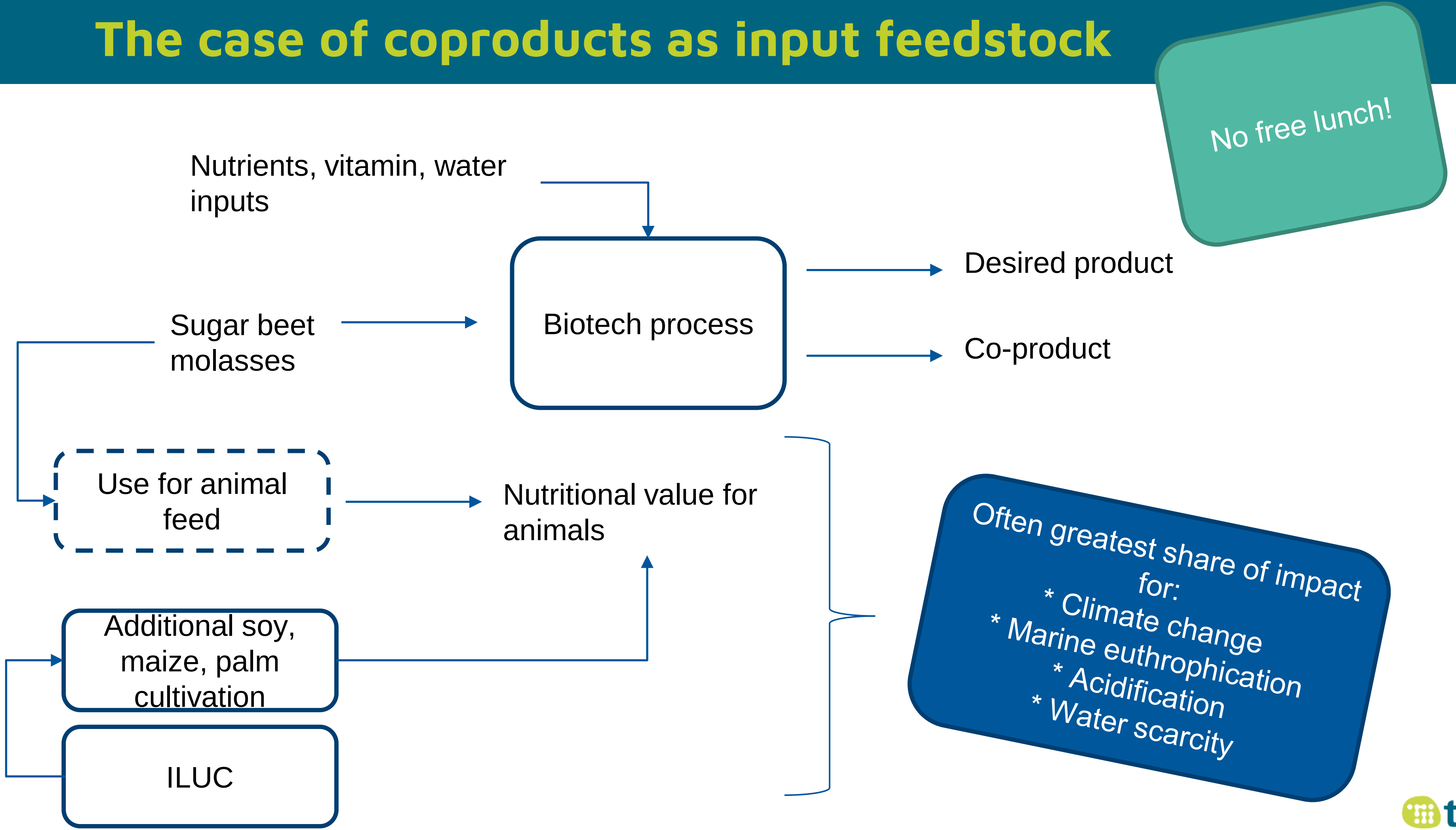


The case of coproducts as input feedstock



Co-products : acknowledged prioritization in circular economy

D.A. Teigiserova et al. / Science of the Total Environment 706 (2020) 136033

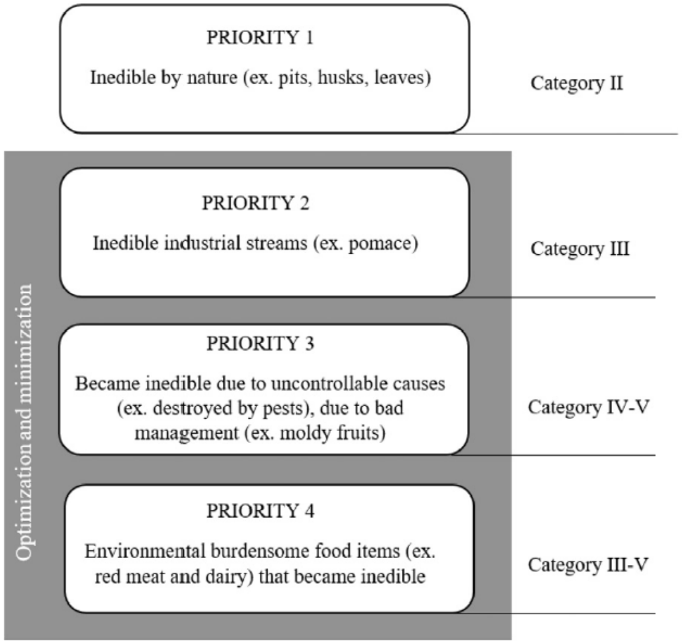


Fig. 3. Ranking proposed to prioritize which inedible food waste stream to use in future food waste biorefineries. Linked to categor

Table 3
Categorization of FSWL in connection with edibility and possibility of avoidance.

Edible	Inedible		Other
Avoidable	Unavoidable	Partly avoidable	
I. All edible food	II. Naturally inedible (ex. bones, pits, leaves) III. Processing waste residues (ex. apple pomace, tea leaves)	IV. Became inedible due to natural causes (crops damaged due weather) V. Became inedible due to inefficient management a. poor functioning of the FSC (lack of proper refrigeration, inadequate infrastructure, etc.) b. avoidable negligence	VI. Not accounted for
Surplus food	Food waste		Food loss

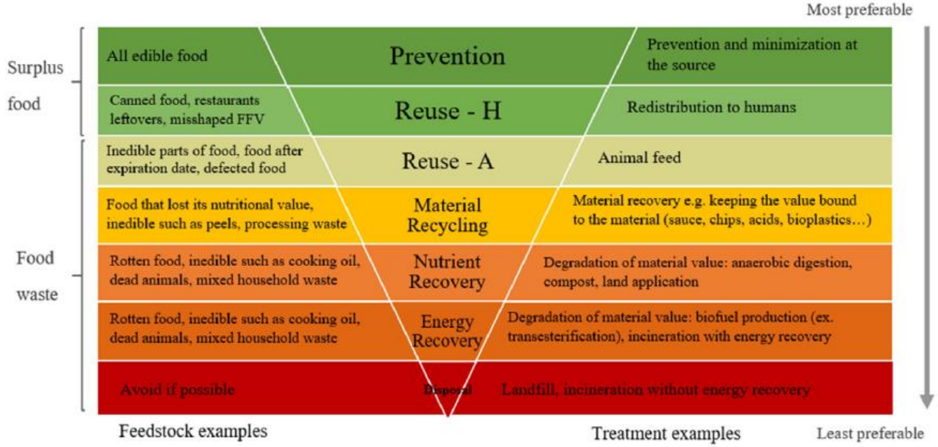


Fig. 1. Updated hierarchy for food surplus and waste proposed herein building on terminology from major European and national projects (UNEP, 2014; WRAP, 2013; FUSIONS: Östergren et al., 2014). *FFV fresh fruits and vegetables.

Source: Teigiserova et al. (2020); doi.org/10.1016/j.scitotenv.2019.136033

4

Fluctuating power challenge

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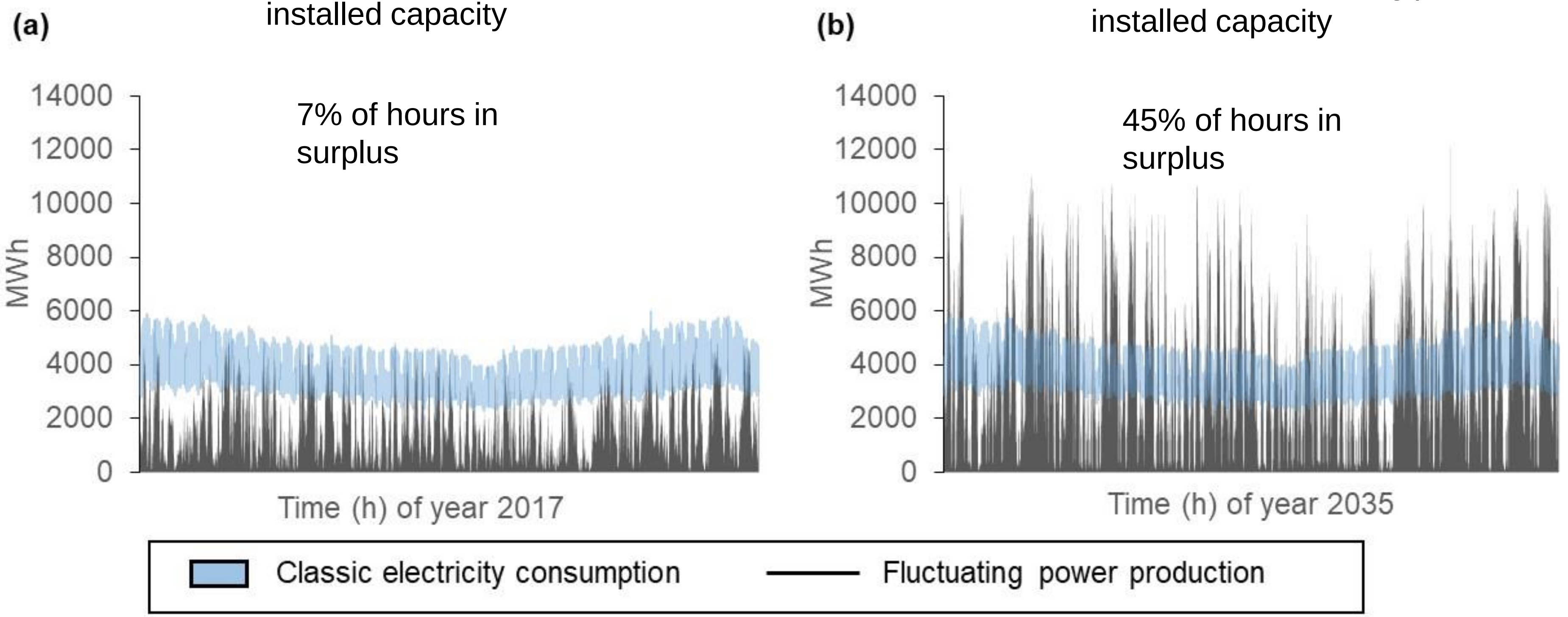
The opportunities of more fluctuating power

2017
6092 MW fluctuating power installed capacity

2035
13,409 MW fluctuating power installed capacity

7% of hours in surplus

45% of hours in surplus



Source: Hamelin et al. 2021. https://doi.org/10.1016/j.rser.2020.110506

France: from 20-65% fluctuating power in 2050 (Ademe, 2017)

5

Cambioscop: what we do

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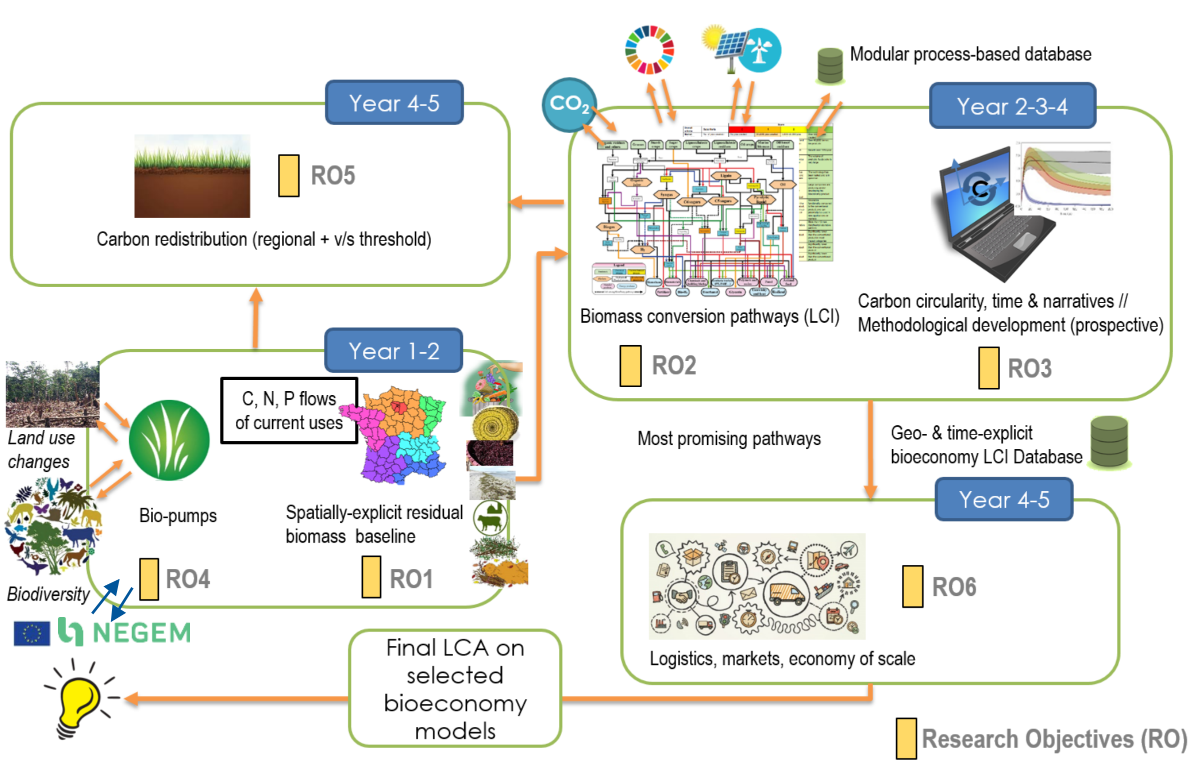


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French president's climate talent search nabs 18 foreign scientists

By Elisabeth Pain | Dec. 11, 2017 , 2:00 PM

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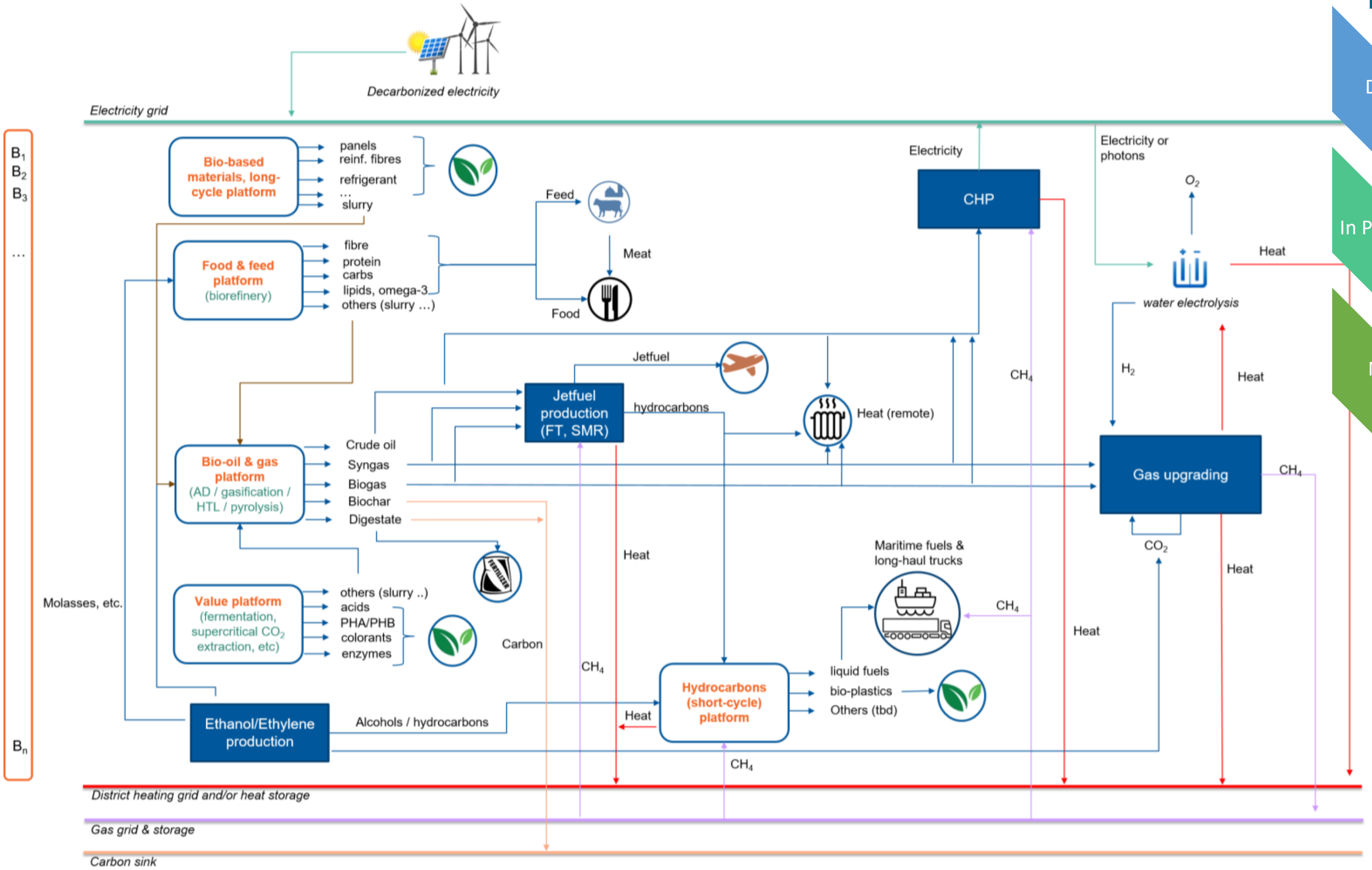
The interconnected vision of our economic systems



Done
- Residual biomass baseline
- Carbon sequestration platform

In Progress
- Waste-to-nutrition platform
- Bio-oil platform
- Bio-based gas platform
- Aviation fuels platform

Next
- Aggregation at national level, for an overall low environmental impact

Final task: Putting values on all flows

Disclaimer

- **Not only C**
- **Not only climate change (but all 16 environmental impacts of the Environmental Footprint life cycle impact assessment method)**

Take home messages

- **Biotech has a role in making it possible to keep fossil C in the ground**

  => and environmental scientists to properly account for it! (July 4th)

- **Biotech has a role in improving its processes:**

  => developping more efficient processes using C as efficiently as possible

  => processes using less water

  => processes using less energy

- **Beware what you put in:**

  => No free lunch! Even residual biomasses generate land use change. Consider what would have otherwise happened to the feedstock!

  => Avoid Haber-Bosch! Recovering/recycling nutrients to the extent possible

- **Transport is often meaningless!**

Cambioscop publications

1. Brassard P, Godbout S, Hamelin L (2021). Framework for the consequential Life Cycle Assessment of pyrolysis biorefineries: A case study for the conversion of primary forestry residues. *Renewable & Sustainable Energy Reviews*, 110549. DOI: 10.1016/j.rser.2020.110549

2. Gomez-Campos A, Vialle C, Rouilly A, Hamelin L, Rogeon A, Hardy D, Sablayrolles C. Natural Fiber Polymer Composites – A game changer for the aviation sector? (2021) *Journal of Cleaner Production*, 124986. DOI: 10.1016/j.jclepro.2020.124986

3. Gomez-Campos A, Vialle C, Rouilly A, Sablayrolles C, Hamelin L (2021). Flax fiber for technical textile: a consequential life cycle inventory. *Journal of Cleaner Production*, 125177. DOI: 10.1016/j.jclepro.2020.125177

4. Hamelin L, Møller HB, Jørgensen U (2021). Harnessing the full potential of biomethane towards tomorrow's bioeconomy: A national case study coupling sustainable intensification, emerging biogas technologies and energy system analysis. *Renewable & Sustainable Energy Reviews,* 110506. DOI: 10.1016/j.rser.2020.110506

5. Hamelin L, Borzecka M, Kozak M, Pudelko R (2019). A spatial approach to bioeconomy: quantifying the residual biomass potential in Europe. *Renewable & Sustainable Energy Reviews,* 100, 127-142. DOI: 10.1016/j.rser.2018.10.017

6. Hansen JH, Hamelin L, Taghizadeh-Toosi A, Olesen JE, Wenzel H (2020). Agricultural residues bioenergy potential that sustain soil carbon depends on energy conversion pathways. *Global Change Biology Bioenergy 12*, 1002-1013. DOI: 10.1111/gcbb.12733

7. Javourez U, O'Donohue M, Hamelin L (2021). Waste-to-nutrition: a review of current and emerging conversion pathways. Biotechnology Advances 53, 107857. DOI: https://doi.org/10.1016/j.biotechadv.2021.107857

8. Karan SK, Hamelin L (2021). Crop residues may be a key feedstock to bioeconomy but how reliable are current estimation methods? *Journal of Resources, Conservation and Recycling 164,* 105211. DOI: 10.1016/j.resconrec.2020.105211

9. Karan SK, Hamelin L (2020). Towards local bioeconomy: A stepwise framework for high-resolution spatial quantification of forestry residues. *Renewable & Sustainable Energy Reviews 134,* 110350. DOI: 10.1016/j.rser.2020.110350

10. Lakshman V, Brassard P, Hamelin L, Raghavan V, Godbout S (2021). Pyrolysis of Miscanthus: Developing the mass balance of a biorefinery through experimental tests in an auger reactor. *Bioresource Technology Reports*, 100687. DOI: 10.1016/j.biteb.2021.100687

11. Shapiro-Bengsten S, Hamelin L, Bregnbaek LM, Zhou L, Munster M (2022). Should Residual Biomass be used for Fuels, Power and Heat, or Materials? Assessing Costs and Environmental Impacts for China in 2035. *Energy & Environmental Science.* DOI: 10.1039/D1EE03816H

12. Teigiserova DA, Hamelin L, Titura-Barna L, Ahmadi A, Thomsen M (2022). Circular bioeconomy: Life Cycle assessment of scaled-up cascading production from orange peel waste under current and future electricity mixes. *Science of the Total Environment,* 812, 152574. DOI: 10.1016/j.scitotenv.2021.152574

13. Teigiserova D, Barna L, Ahmadi A, Hamelin L, Thomsen M (2021). *A step closer to circular bioeconomy for citrus peel waste: a review of yields and technologies for sustainable management of essential oils. Journal of Environmental Management, 812, 152574. DOI:* 10.1016/j.scitotenv.2021.152574

14. Teigiserova D, Hamelin L, Thomsen M (2020). Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy. *Science of the Total Environment,* 706, 136033. DOI: 10.1016/j.scitotenv.2019.136033

15. Teigiserova D, Hamelin L, Thomsen M (2019). Review of high value food waste and food residues biorefineries with focus on unavoidable waste from processing. *Journal of Resources, Conservation and Recycling,* 149, 413-426. DOI: 10.1016/j.resconrec.2019.05.003

16. Shen Z, Tiruta-Barna L, Hamelin L (2022). Simultaneous carbon storage in arable land and anthropogenic products (CSAAP): Demonstrating an integrated concept towards well below 2°C. *Journal of Resources, Conservation and Recycling,* 182, 106293. DOI: 10.1016/j.resconrec.2022.106293

What do you think are the greatest challenges ahead?

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https://www.youtube.com/channel/UCvWM2__5hSWN1zujJ4vEZNA

Video on the project on the MOPGA channel:
https://www.youtube.com/watch?v=0I7VkgHM9lw&list=UUegK_BEcsgqJt1YOeFsenNg&index=12&ab_channel=MakeOurPlanetGreatAgain

Note: all of our data are publicly available when ready, on the Cambioscop website and/or as SI of our papers and/or as preprints and/or on data repository

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