



list

LIST DAYS CONFERENCE

10 et 11 juin 2026



université
PARIS-SACLAY





list



LIST DAYS CONFERENCE

**Piloter la performance de circularité et
de soutenabilité de son organisation :
verrous scientifiques et enjeux
industriels et sociétaux**



Intervenant



Bernard YANNOU

*Directeur-adjoint de la
Recherche, CentraleSupélec*

université
PARIS-SACLAY


CentraleSupélec

LGi
Industrial Engineering Research Department

- Notre expérience
 - Analyse de Cycle de Vie
 - Intégration de l'écoconception dans les organisations
 - Indicateurs d'économie circulaire
 - Comparaison de scénarios : ACV + LCC + indicateurs EC
 - Modélisation de symbioses industrielles pour parcs éco-industriels
 - Modélisation de flux matière recyclée
 - Optimisation environnementale et résilience de chaîne d'approvisionnement
 - Désassemblage pour recyclage
- Notre constat
 - Difficulté d'élaborer une politique d'économie circulaire pour les organisations
 - Selon le Circularity Gap Report 2025, dégradation de la circularité :
 - 6,9% en 2025
 - 7,2% en 2023
 - 9,1% en 2018



CIRCULAR
LE NUMÉRIQUE AU SERVICE
DE L'ÉCONOMIE CIRCULAIRE

IT

<https://circularit.centralesupelec.fr/>


CentraleSupélec


université
PARIS-SACLAY


SystemX
INSTITUT DE RECHERCHE
TECHNOLOGIQUE

CIRCULAR-IT Alliance

Developing digital solutions for circular industrial and regional ecosystems

Researchers



Bernard Yannou
Full Professor
Chair holder



Ghada Bouillass
Assistant Prof.
Chair co-holder



Michael Saidani
Associate Prof. co-
associated to the LIST

LUXEMBOURG
INSTITUTE OF SCIENCE
AND TECHNOLOGY **LIST**



Marija Jankovic
Full Professor



François Cluzel
Associate Prof.



Tétiana Shevchenko
Assistant Prof.

Post-doctorates



Benoît Dabouis
Post-doctorate
MATIC post-
Marie-Lannelongue
Innovation Center

3A



Joris Nguyen

2A



Erwan Petit de
Bantel

2A



Thibault
Ronzaud

2A



Lauren
Durivault

2A



Maxime Royer

1A



Valentina
Calixto

1A



Sonali Patekar

Doctorates

Partners of the CIRCULAR-IT Alliance

MANITOU
GROUP

 GE HealthCare

mews
PARTNERS

PARIS
SACLAY
Communauté d'agglomération

som
Vallée de Chevreuse

CSTB
le futur en construction



The **CIRCULAR-IT Alliance** is an applied research chair whose objectives are to...

enable **industrial and regional organizations** to **measure** and **manage** their **circularity** and **sustainability** performance...



...through approaches to **data management, industrial management**, the definition of **indicators, action plans** and **strategies, simulation models**, and appropriate **governance** frameworks.

2 use cases



The industrial value chain



The territory (municipality, metropolitan area, region)



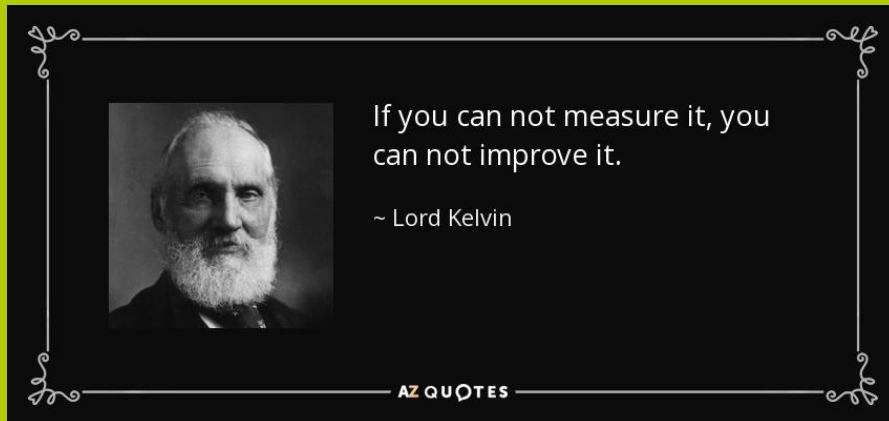
7 doctoral dissertations to aid in decision-making regarding **circular economy (CE) strategies or decarbonization initiatives within specific system boundaries, by involving **internal and external stakeholders** of the relevant organization.**



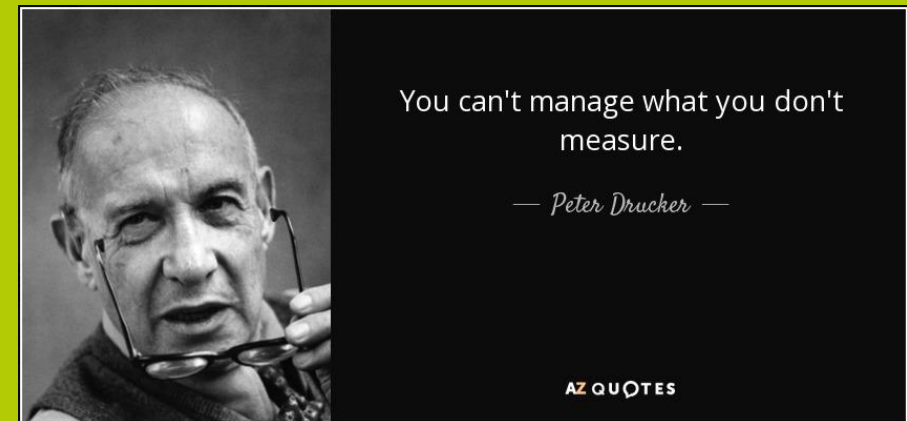
The sectors involved are:

- 1. the heavy-duty vehicle industry,**
- 2. decarbonization and circularity in the healthcare sector,**
- 3. reuse in construction,**
- 4. and regional contributions to climate and circular economy plans**

Measure and/or Take Action



Science



Management



CICULAR-IT Alliance aims to...

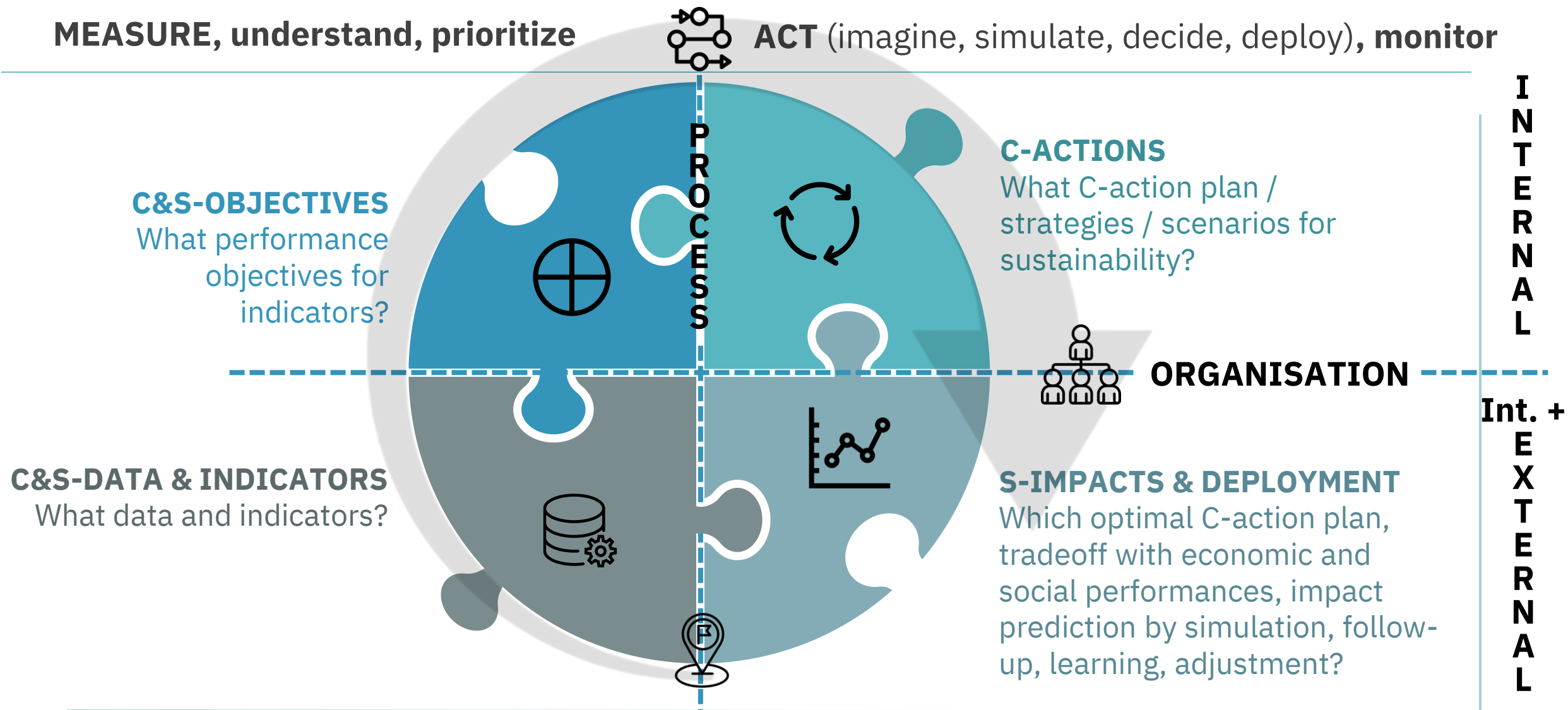
**develop methodological and
digital tools to enable
industrial and regional
organizations to manage their
circularity and sustainability
performance**

**Our goal is to create an integrated
framework for measuring and taking action:
the Circular Digital Cockpit**

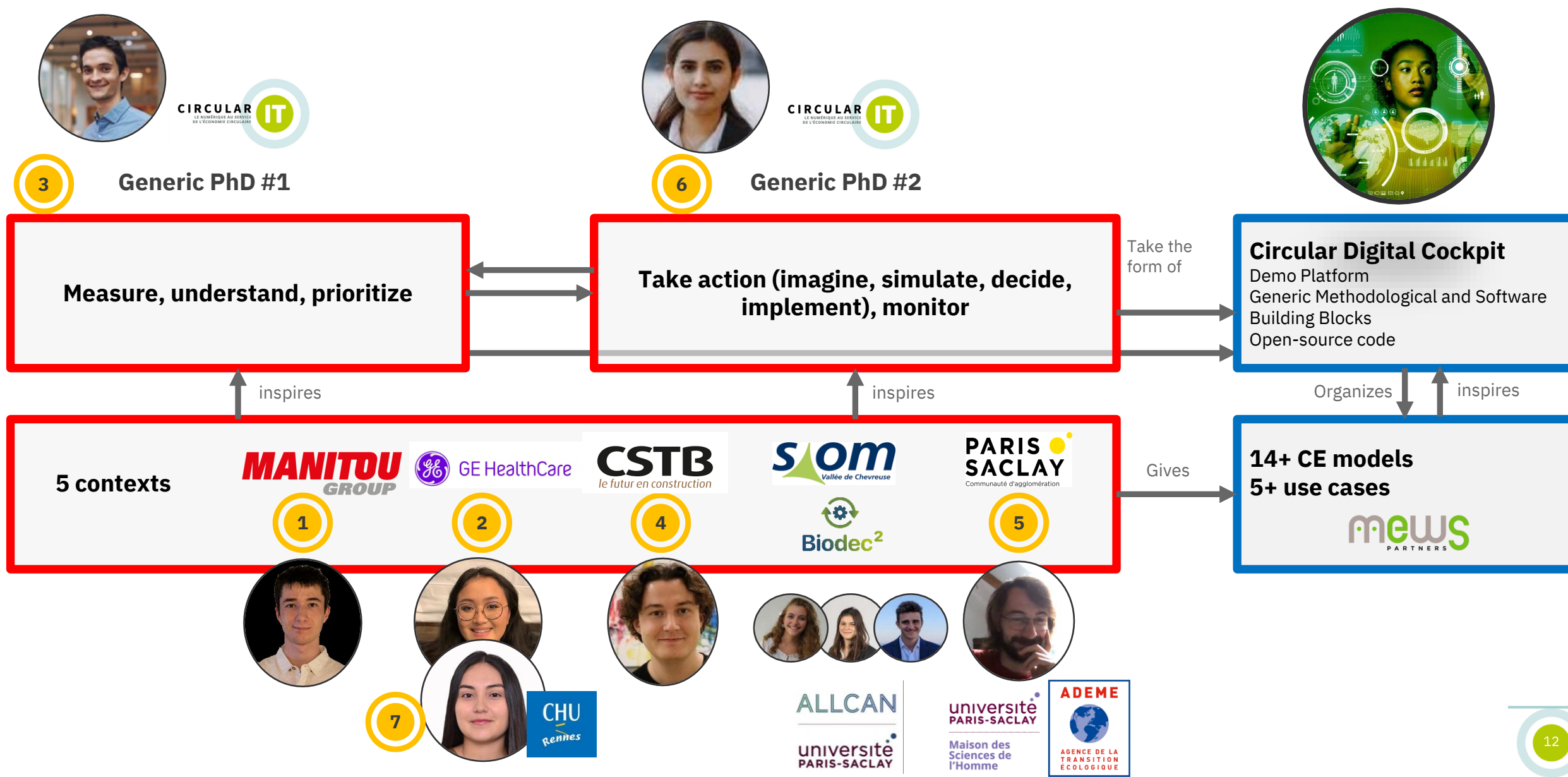


Circular Digital Cockpit

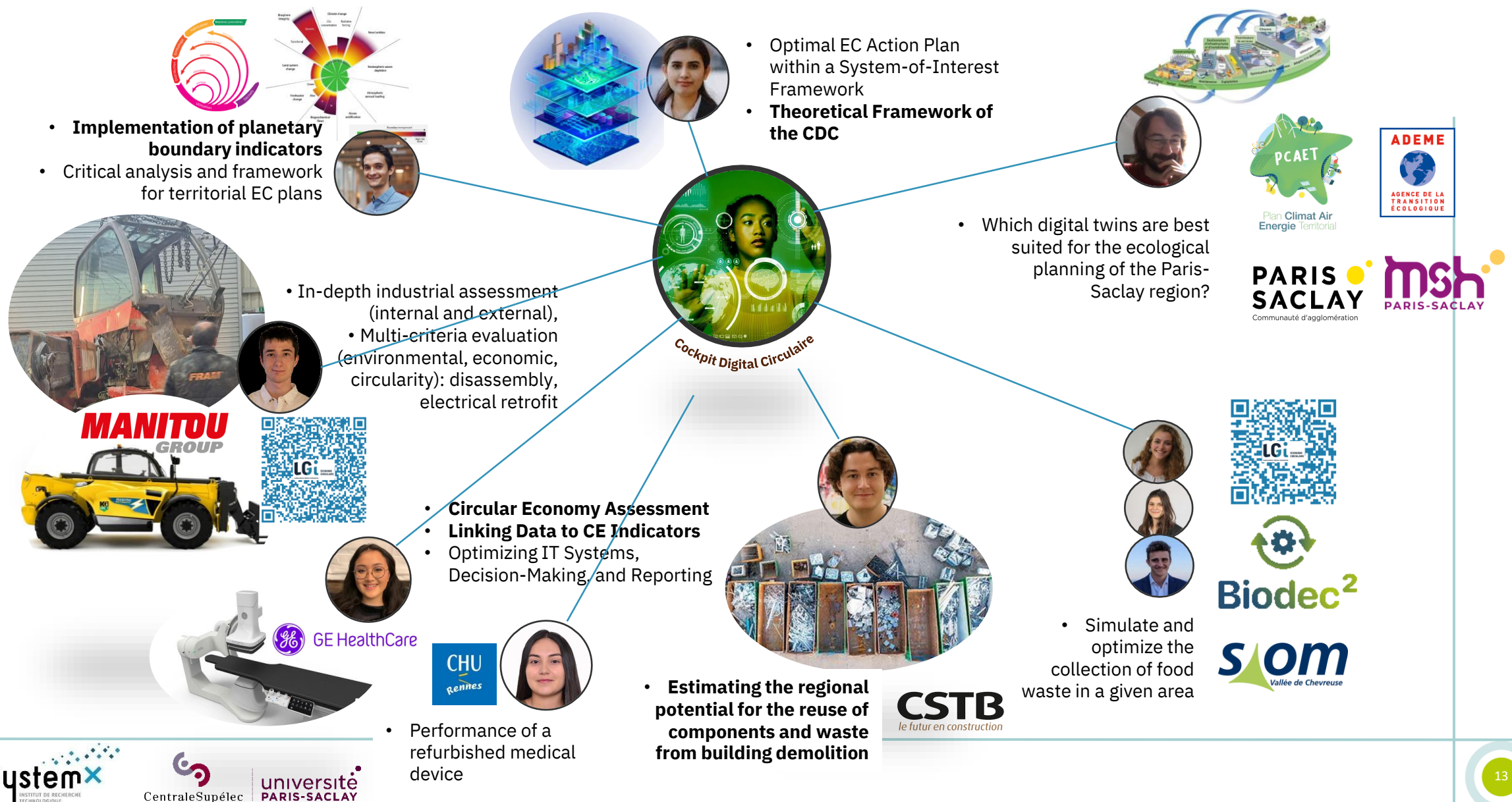
The simplified CDC



Overall structure: 2 theses on the generic model, 5 theses applied to use cases

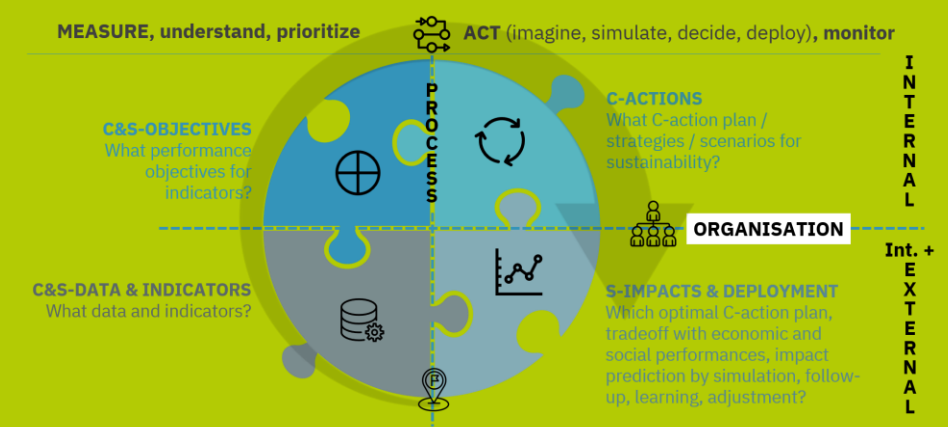


7 PhD theses in the CDC context





Summary of some PhD works in CircularIT Alliance (following the CDC process)



Data for Circularity Assessment: What, Where, and How?

Lauren Durivault ^{1,2}, Ghada Bouillass ¹, Michael Saidani ^{1,3}, Bernard Yannou ¹, Abdelhamid Boujarif ², Robert Heidsieck ²
(submitted to **Journal of Cleaner Production**)

¹ *Université Paris-Saclay, CentraleSupélec, Laboratoire Genie Industriel, Gif-sur-Yvette, France*

² *GE HealthCare, Circularity Innovation Lab, Buc, France*

³ *University of Quebec, ETS Montreal, Department of Systems Engineering, Montreal, Canada*

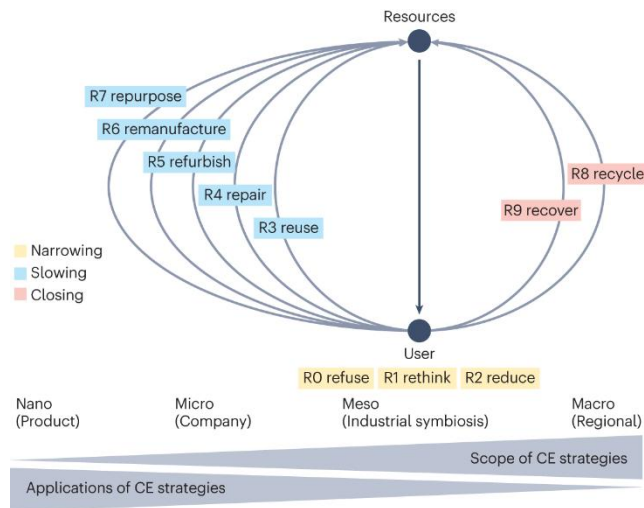


Lauren Durivault

Circular Economy

“CE is an economic system that uses a systemic approach to maintain a flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development”

ISO 59004:2024



S. Hellweg, E. Benetto, M. A. J. Huijbregts, F. Verones, and R. Wood, “Life-cycle assessment to guide solutions for the triple planetary crisis,” *Nat Rev Earth Environ*, vol. 4, no. 7, pp. 471–486, July 2023, doi: [10.1038/s43017-023-00449-2](https://doi.org/10.1038/s43017-023-00449-2).

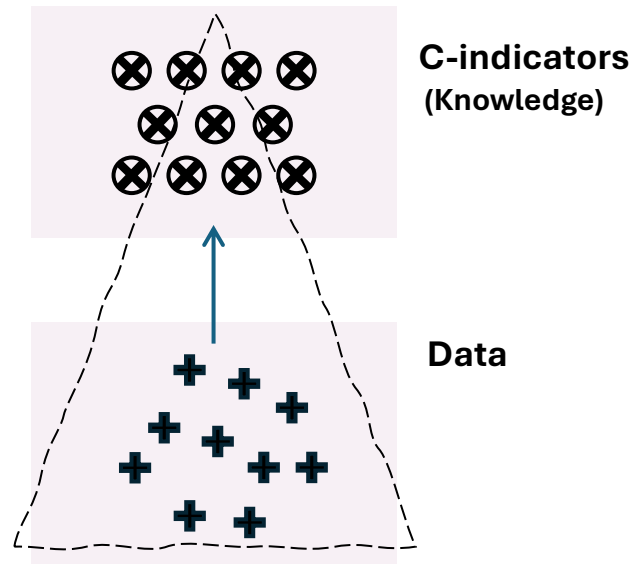
N. M. P. Bocken, I. de Pauw, C. Bakker, and B. van der Grinten, “Product design and business model strategies for a circular economy,” *Journal of Industrial and Production Engineering*, vol. 33, no. 5, pp. 308–320, July 2016, doi: [10.1080/21681015.2016.1172124](https://doi.org/10.1080/21681015.2016.1172124).

CE Assessment

“the **evaluation** and interpretation of results and impacts from a circularity measurement”

ISO 59004:2024

The research focuses on the data-driven computation of c-indicators



C. Zins, “Conceptual approaches for defining data, information, and knowledge,” *Journal of the American Society for Information Science and Technology*, vol. 58, no. 4, pp. 479–493, 2007, doi: [10.1002/asi.20508](https://doi.org/10.1002/asi.20508).

R. L. Ackoff, “From Data to Wisdom,” *Journal of applied systems analysis*, vol. 16, p. 8, Jun. 1989.

CE Assessment of an OEM

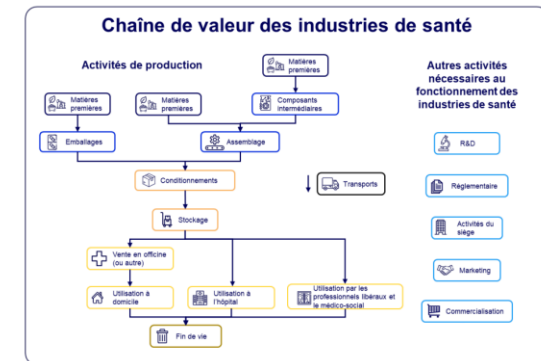
Case Study



Complex Systems

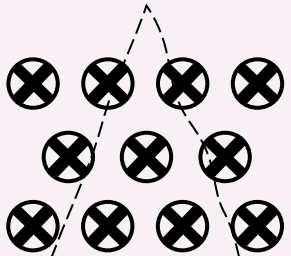


Complex Value & Supply chain



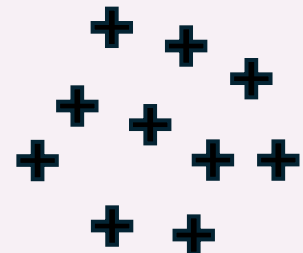
The Shift Project, “Decarbonons les industries des dispositifs médicaux,” Jun. 2025. Accessed: Apr. 13, 2026. [Online]. Available: <https://theshiftproject.org/app/uploads/2025/11/TSP-Decarbonons-les-industries-des-DM-RF.pdf>

What?



C-indicators

We don't know which **indicators** we need to measure, which are best fit for the **system-of-interest**



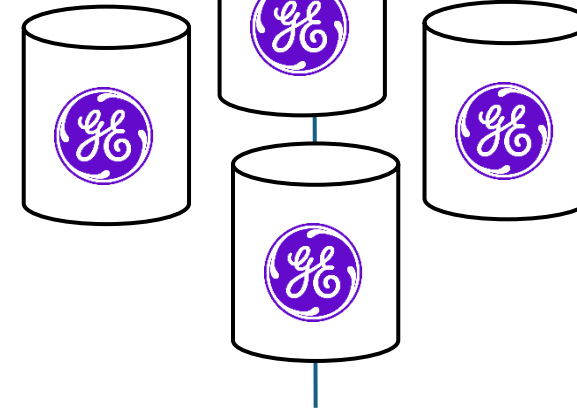
C-data

In the case we do know which **indicators** need to be measured, we don't know which **data points** are needed to measure them

Where?

Information Systems

In the case we do know which **data points** need to be collected, we don't know where it is in the companies **Information Systems**



How?

Data collection

How should the OEM tackle data collection?

- Which data points are most important?
- What is the least amount of data needed to compute a maximum number of indicators?

Data reconciliation

How can we structure the data points to facilitate indicator computation?

R. L. Ackoff, "From Data to Wisdom," *Journal of applied systems analysis*, vol. 16, p. 8, Jun. 1989.

J. Kirchherr, N.-H. N. Yang, F. Schulze-Spüntrup, M. J. Heerink, and K. Hartley, "Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions," *Resources, Conservation and Recycling*, vol. 194, p. 107001, Jul. 2023, doi: [10.1016/j.resconrec.2023.107001](https://doi.org/10.1016/j.resconrec.2023.107001).

M. Saidani, B. Yannou, Y. Leroy, F. Cluzel, and A. Kendall, "A taxonomy of circular economy indicators," *Journal of Cleaner Production*, vol. 207, pp. 542–559, Jan. 2019, doi: [10.1016/j.jclepro.2018.10.014](https://doi.org/10.1016/j.jclepro.2018.10.014).

D. Romero and F. Vernadat, "Enterprise information systems state of the art: Past, present and future trends," *Computers in Industry*, vol. 79, pp. 3–13, Jun. 2016, doi: [10.1016/j.compind.2016.03.001](https://doi.org/10.1016/j.compind.2016.03.001).

A. Polenghi, F. Acerbi, I. Roda, M. Macchi, and M. Taisch, "Enterprise information systems interoperability for asset lifecycle management to enhance circular manufacturing," *IFAC-PapersOnLine*, vol. 54, no. 1, pp. 361–366, Jan. 2021, doi: [10.1016/j.ifacol.2021.08.162](https://doi.org/10.1016/j.ifacol.2021.08.162).

T. Serody, J. Le Duigou, R. Gaha, and B. Eynard, "Preliminary Research Work for Sustainability Assessments Integrated Within Enterprise Information Systems," in *Product Lifecycle Management. PLM in the Age of Model-Based Engineering in Industry*, F. Mas, C. Del Valle, B. Eynard, L. Rivest, and A. Bouras, Eds., Cham: Springer Nature Switzerland, 2026, pp. 396–405. doi: [10.1007/978-3-032-09700-2_39](https://doi.org/10.1007/978-3-032-09700-2_39).

F. Acerbi, C. Sassanelli, and M. Taisch, "A conceptual data model promoting data-driven circular manufacturing," *Oper Manag Res*, vol. 15, no. 3, pp. 838–857, Dec. 2022, doi: [10.1007/s12063-022-00271-x](https://doi.org/10.1007/s12063-022-00271-x).

Proposed Top-Down Approach

Industrial Diagnosis

Why does the organization want to conduct CE assessment?

Method

Semi-structured interviews or other participatory approaches involving org. practitioners

Output

CE Assessment Rationale:

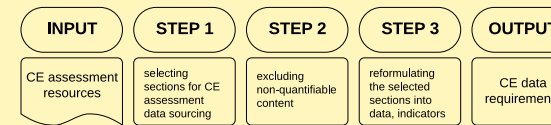
- Compliance
- CE strategy implementation
- Customer requirements

CE Assessment Scope:

- Supply chain
- Information Systems

Sense-making of CE assessment resources

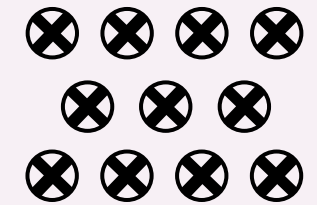
Method



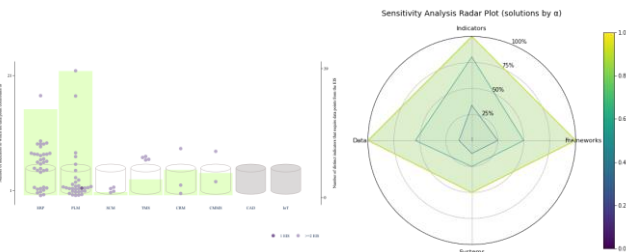
L. Durivault, G. Bouillass, M. Saidani, B. Yannou, A. Boujarif, and R. Heidsieck, "Bridging the gap between circularity assessment and data governance," in *Procedia CIRP - 33rd CIRP Conference on Life Cycle Engineering (LCE 2026)*, Kamakura, Japan, (accepted, to be published).

Output

A list of relevant c-indicators from regulations, standards, literature ...



Choice of a data collection strategy



Method

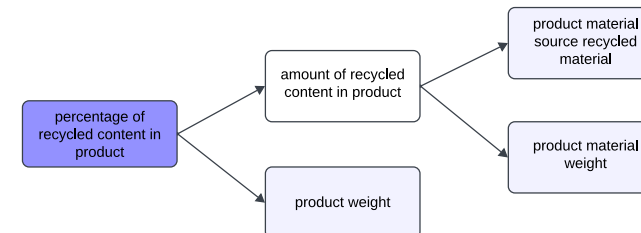
Mixed-Integer Linear Programming Problem Optimization

Output

A data collection strategy, minimizing implementation effort and maximizing CE assessment coverage

Links information systems, data points, c-indicators, and CE assessment objectives

Breaking down c-indicators into c-data

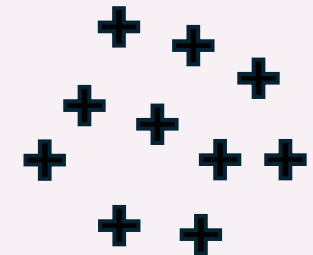


Method

Directed Acyclic Graphs implemented in software of choice

Output

A list of data points which need to be collected to compute the c-indicators



Perspective #1: Automation of sense-making method

Objective

Facilitate the understanding and implementation of CE requirements from policymakers, consumers, and rest of the market.

Target User

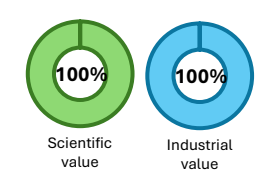
Employees working on ESG/compliance (non-coders)

Functionality

- Import a new document (CE assessment resource)
- Export clean, standardized CE data requirements

Expected Output

Corpus easing the update of the data-to-indicator model with new CE/sustainable data requirements



Perspective #2: CE compliance tool

Objective

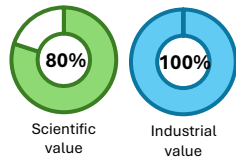
Assess an organization’s alignment relative to CE and sustainability regulations or standards by comparing required vs. available data.

Target User

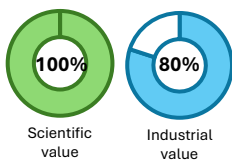
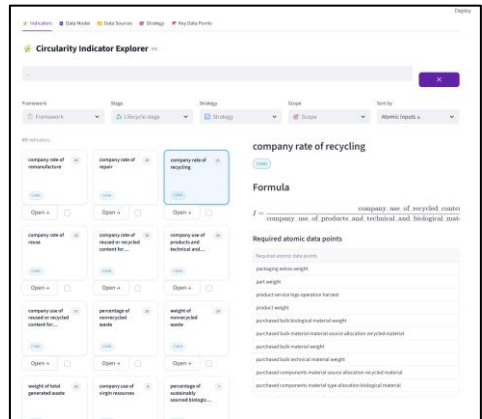
Employees working in ESG reporting, regulatory compliance, or sustainability governance.

Functionality

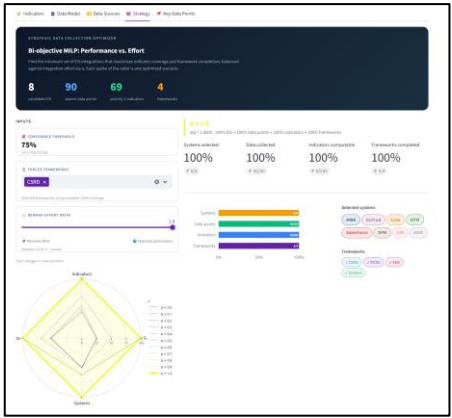
- Select a corpus of CE data requirements linked to a compliance framework and assess the organization’s progress in terms of alignment and data availability.
- Compare two or more frameworks to cross-check required indicators against available data and those defined in the model
- Visualize compliance overlap and identify missing data points across frameworks to guide data sourcing and reporting efforts.



Perspective #4: Open-source CE assessment toolkit



An all-rounder tool helping organizations manage their c-indicators and their data collection for CE assessment

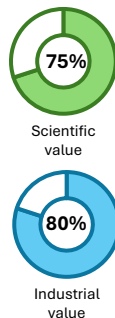
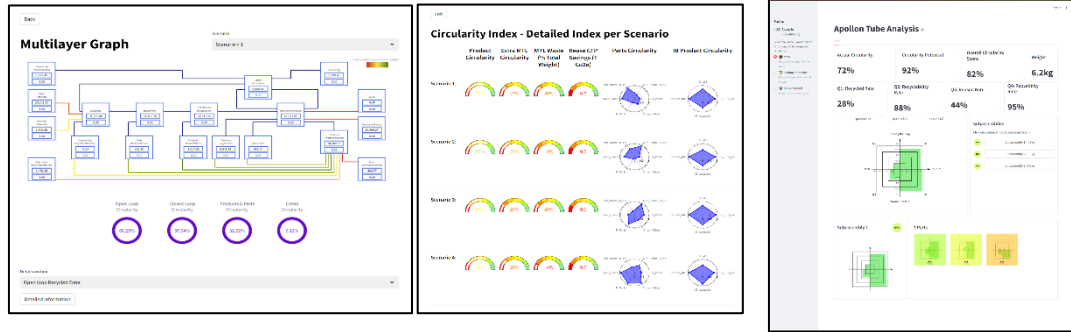


Target User

Data scientists and data engineers conducting CE assessments

Perspective #3: indicator-based decision-making tools

Linking c-indicators with CE strategies to identify hotspots in the organization



Measuring and Enhancing Circularity of the Healthcare Sector: The Circularity Model of Products & Spare Parts, El Bechari et al., 2024
T. Shevchenko, L. Durivault, B. Yannou, R. Heidsieck, M. Saidani, M. Ranjbari, and G. Bouillass, “Circular economy of complex medical devices: developing a novel assessment tool,” Business Strategy and the Environment, 2026.

Modeling reuse potential of building end-of-life components: a territorial approach

Thibault Ronzaud



Ronzaud, Thibault, Edouard Sorin, Ghada Bouillass, et Bernard Yannou. « Modeling reuse potential of building end-of-life components: a territorial approach ». **Design Conference**, Croatia. May 18-21 2026.



New taxonomy introduced in France in 2020

Products, equipment, materials and waste (PEMW)

Deconstruction site



Generates

Products



Windows



Doors



Staircases

Equipements



Sanitary appliances



Radiators



Power generator

Materials



Bricks



Steel beams



Tiles

Waste



Unsorted



Sorted

Reconditioning platforms



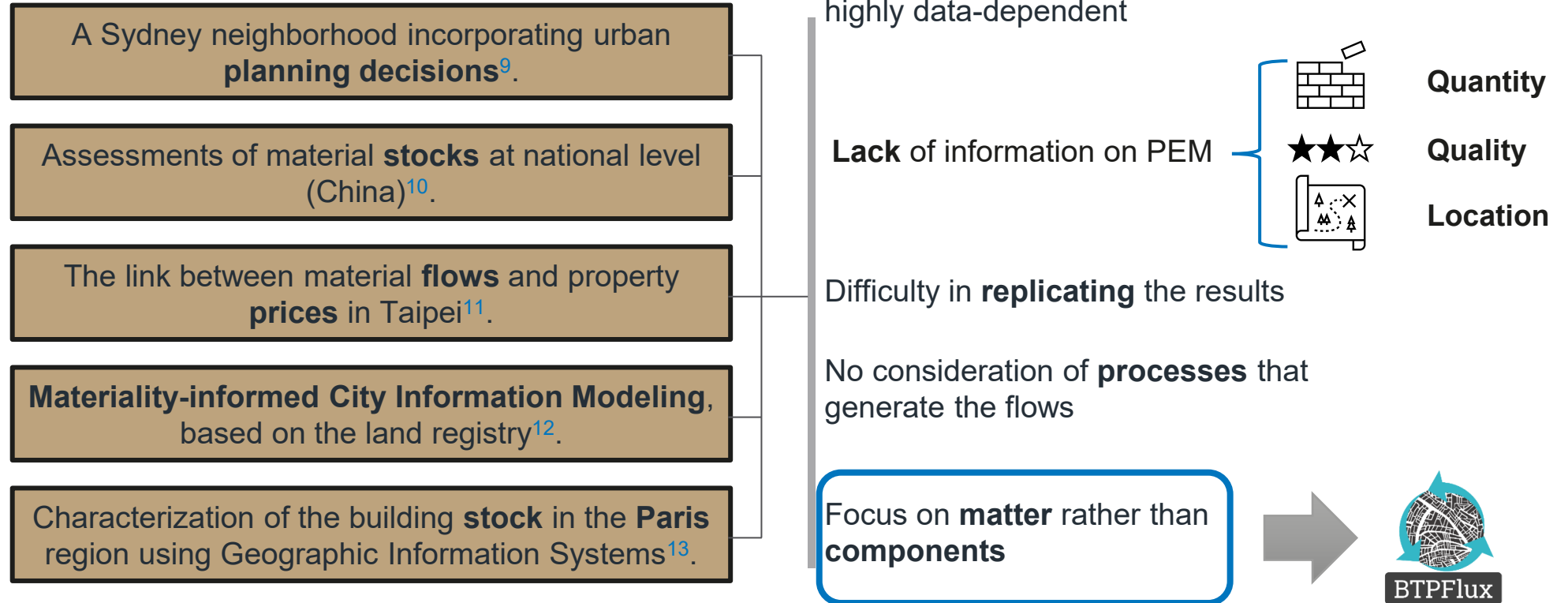
Reusable

Non reusable / recyclable

Source of photos : Opalis website <https://opalis.eu/en>

Literature review: findings

Flow prediction models



[9] H. Schandl, R. Marcos-Martinez, T. Baynes, Z. Yu, A. Miatto, and H. Tanikawa, "A spatiotemporal urban metabolism model for the Canberra suburb of Braddon in Australia," *Journal of Cleaner Production*, doi: 10.1016/j.jclepro.2020.121770.

[10] Z. Huang et al., "Resilience assessment of tunnels: Framework and application for tunnels in alluvial deposits exposed to seismic hazard," *Soil Dynamics and Earthquake Engineering*, vol. 162, 2022. doi: 10.1016/j.soildyn.2022.107456.

[11] Y.-M. Wang, J.-X. Ding, and X.-H. Wei, "Measurement of eco-efficiency of the construction of circular economy in Shandong province," *Journal of Ecology and Rural Environment*, vol. 29, no. 4, pp. 460–465, 2013.

[12] E. Sahebzamani and N. Forcada, "Enhancing sustainable construction decisions: integrating BIM and VR for circular economy assessment," *Building Research and Information*, 2025. doi: 10.1080/09613218.2024.2449441.

[13] V. Augiseau and E. Kim, "Spatial characterization of construction material stocks: The case of the Paris region," *Resources, Conservation and Recycling*, vol. 170, p. 105512, July 2021, doi: 10.1016/j.resconrec.2021.105512.

Structure of BTPFlux model

Sorin, E., Tirado, R., Gully, E., Louërat, M., & Laurenceau, S. (2022). *BTPFlux: A building material flow analysis model to enhance the urban metabolism on French territories*. IOP Conference Series: Earth and Environmental Science, 1078(1), 012027. <https://doi.org/10.1088/1755-1315/1078/1/012027>



Selecting a site or a complex of buildings

- France
- Region
- Department
- Local authorities
- Development project



Building stock dynamics

- Project-specific
- Statistics for a specific area
- Breakdown by building category
- Rate of demolition
- Rate of renovation
- Rate of construction

Localized estimation of component stocks

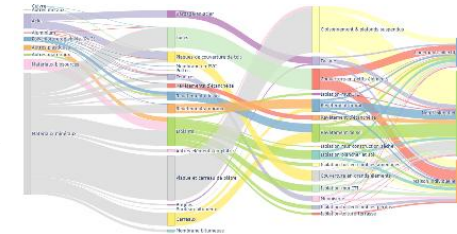


Materiality of future buildings



Materiality of renovation work

Materiality of buildings to be deconstructed



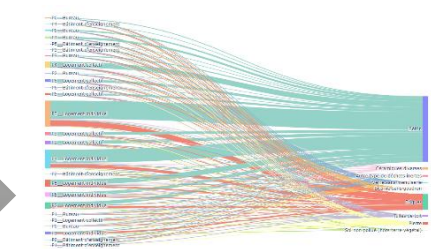
DEMAND

Incoming material flow

- CPE (construction Product and Equipment)
- Materials



Circular Economy



RESOURCES

Outgoing material flow

- PEM components
- Waste

Simplified representation of the reuse activity performances



Visual inspection



Dismantling



Hygrometry test



Assessment of cracks



Eurocode



French norms

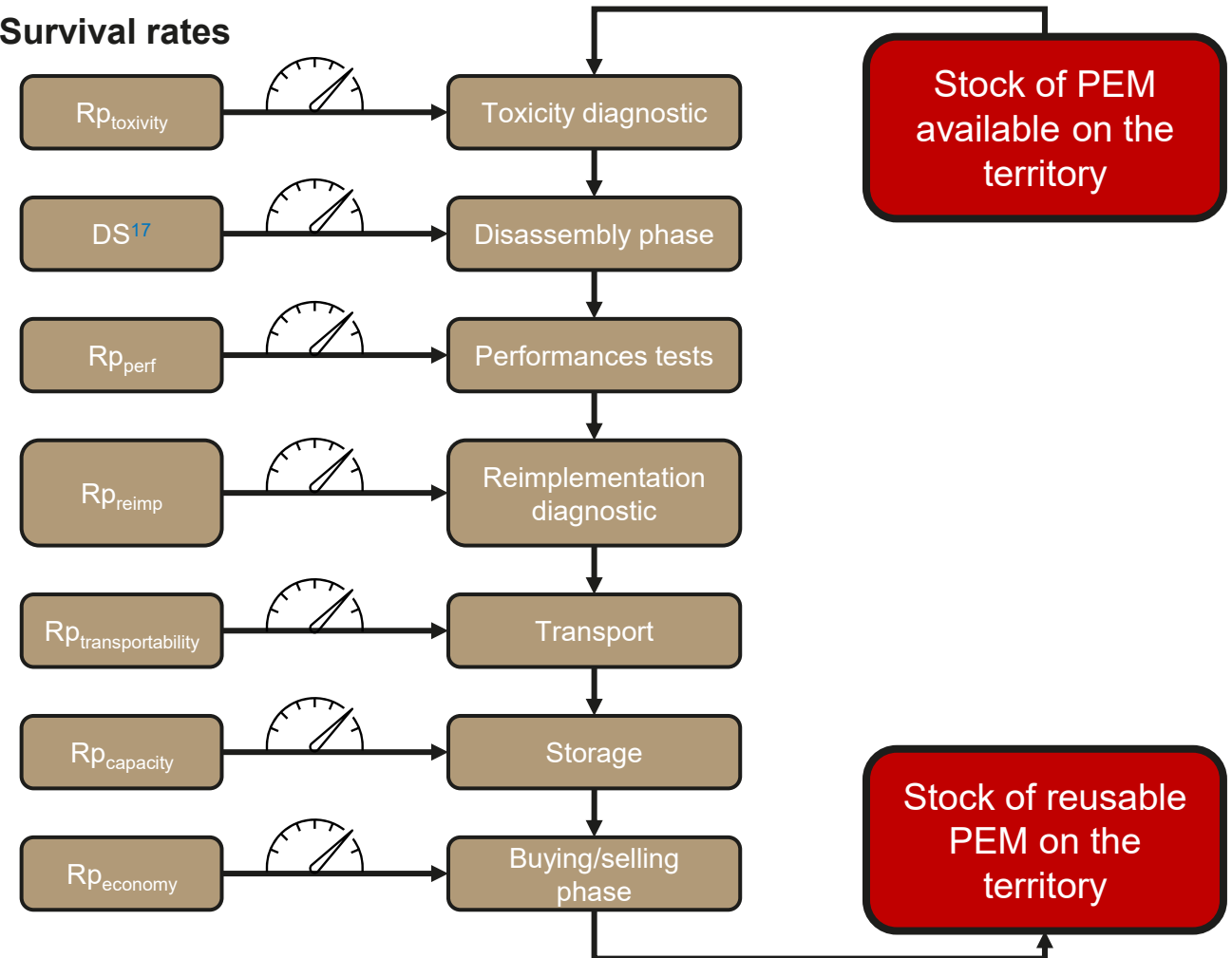


Transport



Storage

Survival rates



[17] Durmisevic, E., Ciftcioglu, Ö., & Anumba, C. J. (2003). Knowledge model for assessing disassembly potential of structures. Deconstruction and Materials Reuse Proceedings of the 11th Rinker International Conference. Photos : Interreg FCRBE REUSE TOOLKIT.

Presentation of the Territorial Reuse Architecture Model

Example using bathroom facilities



Average probability of a component to be toxic (%)
0 10 20 30 40 50 60 70 80 90 100 1

Average component disassembly score (%)
0 10 20 30 40 50 60 70 80 90 100 95

Average probability of the component to have satisfying performances (%)
0 10 20 30 40 50 60 70 80 90 100 95

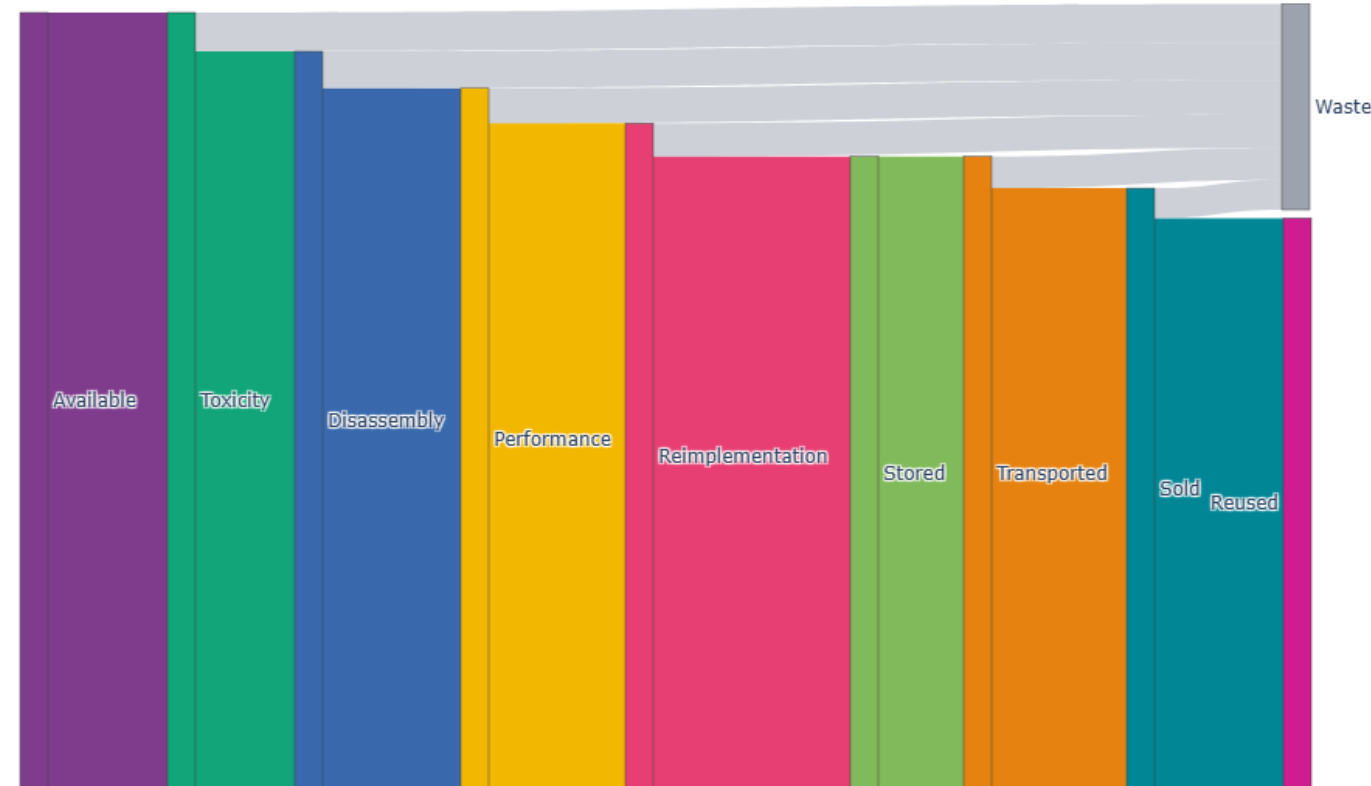
Component reimplementation ease (%)
0 10 20 30 40 50 60 70 80 90 100 95

Storage capacity of the considered territory (Nb)
- 1000 +

Average transportability of the component (%)
0 10 20 30 40 50 60 70 80 90 100 95

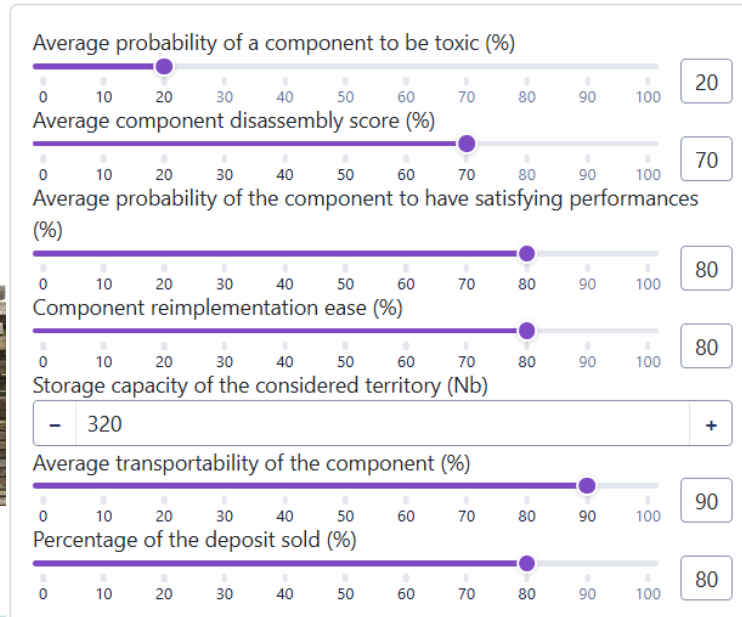
Percentage of the deposit sold (%)
0 10 20 30 40 50 60 70 80 90 100 95

Sankey diagrams

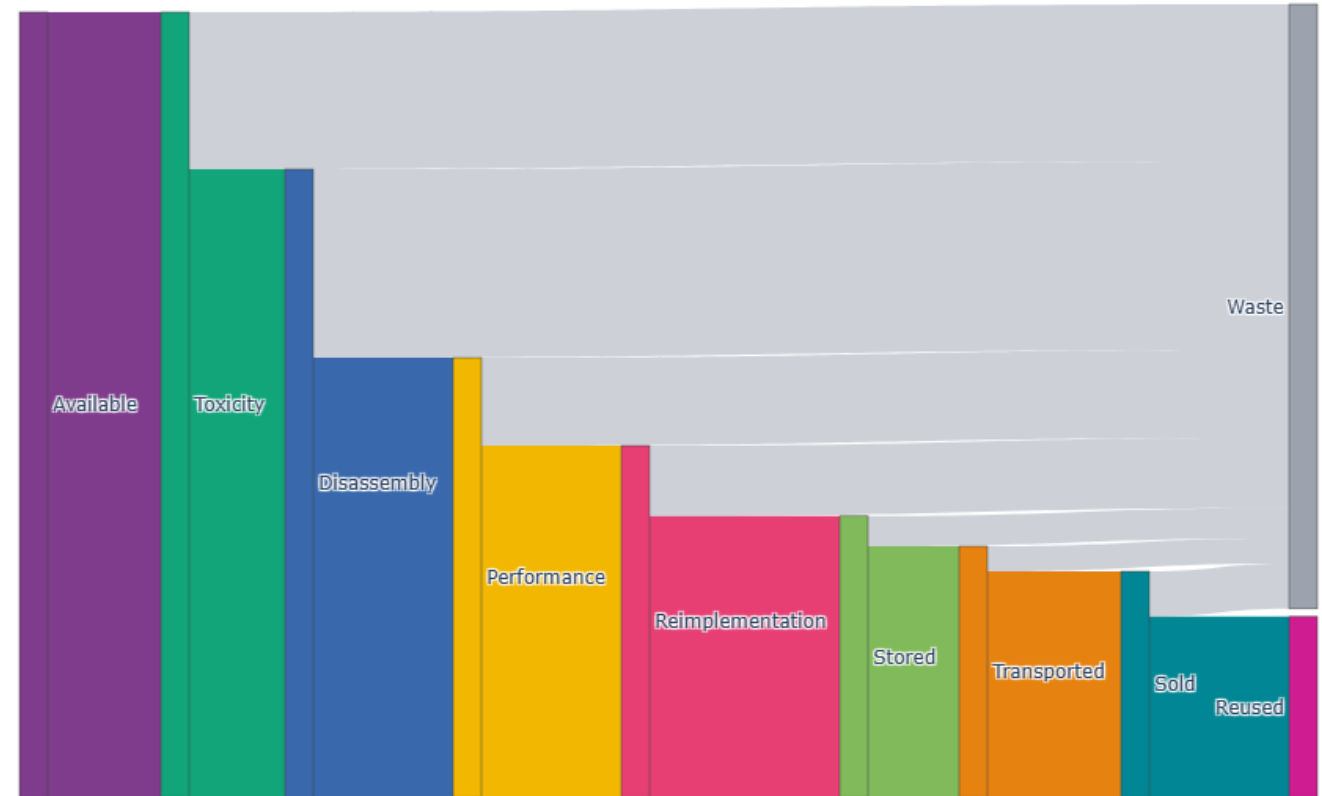


Presentation of the Territorial Reuse Architecture Model

Example using timber frame



Sankey diagrams



Rebuilding Ukraine using waste and reusable materials while minimizing the carbon footprint



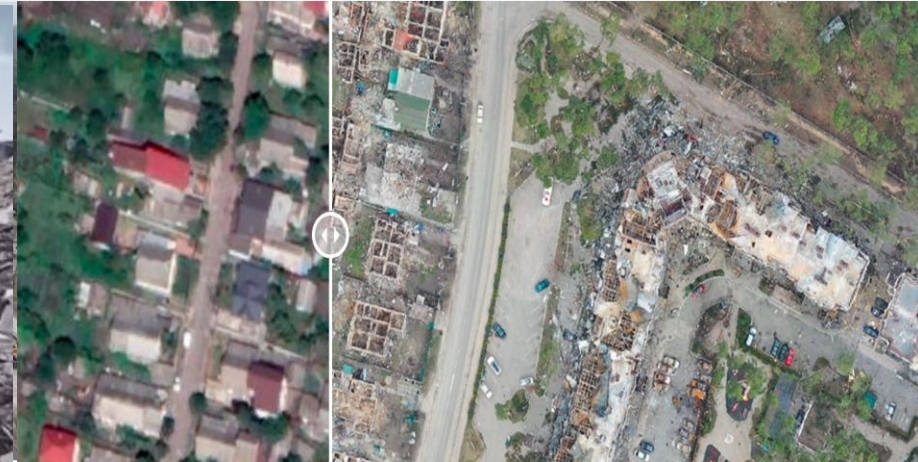
CRebuild4P-D: The framework for circular and climate-neutral post-disaster reconstruction: the case of Ukraine

The CRebuild4P-D project aims at developing and deploying a generic framework for the circular and climate-neutral reconstruction of a post-disaster territory and, on its basis, proposing a Strategy for reconstruction of post-war Ukraine to facilitate the recovery of regions by circular construction initiatives towards carbon-neutral Europe.

- ❑ Shevchenko, Tetiana, Michael Saidani, Bernard Yannou, Sultan Çetin, et Julian Kirchherr. « [A dual circular strategies hierarchy as a guiding framework for post-disaster recovery and reconstruction: Focus on Ukraine](https://doi.org/10.1016/j.jclepro.2025.146478) ». *Journal of cleaner Production*, n° 524 (2025): 146478. <https://doi.org/10.1016/j.jclepro.2025.146478>.
- ❑ Shevchenko, Tetiana, Bernard Yannou, et Michael Saidani. « [“Build Back Better” for war-torn Ukraine: dual strategies for integrating circularity in post-disaster recovery](https://doi.org/10.1017/pds.2025.10096) ». Article de colloque presented sur International Conference on Engineering Design (**ICED**), Dallas, Texas. 2025. <https://doi.org/10.1017/pds.2025.10096>.



Destruction in
Bakhmut,
Donetsk
region, July
2023





Understand EC indicators and their drivers, set objectives

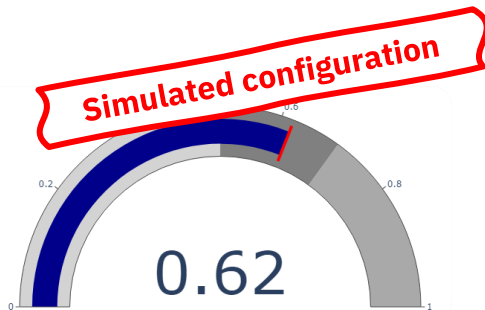
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DE L'ÉCONOMIE CIRCULAIRE



Need for a novel CMMP indicator (Circularity Model of Products & Spare Parts) to reflect progresses in repairing and packaging

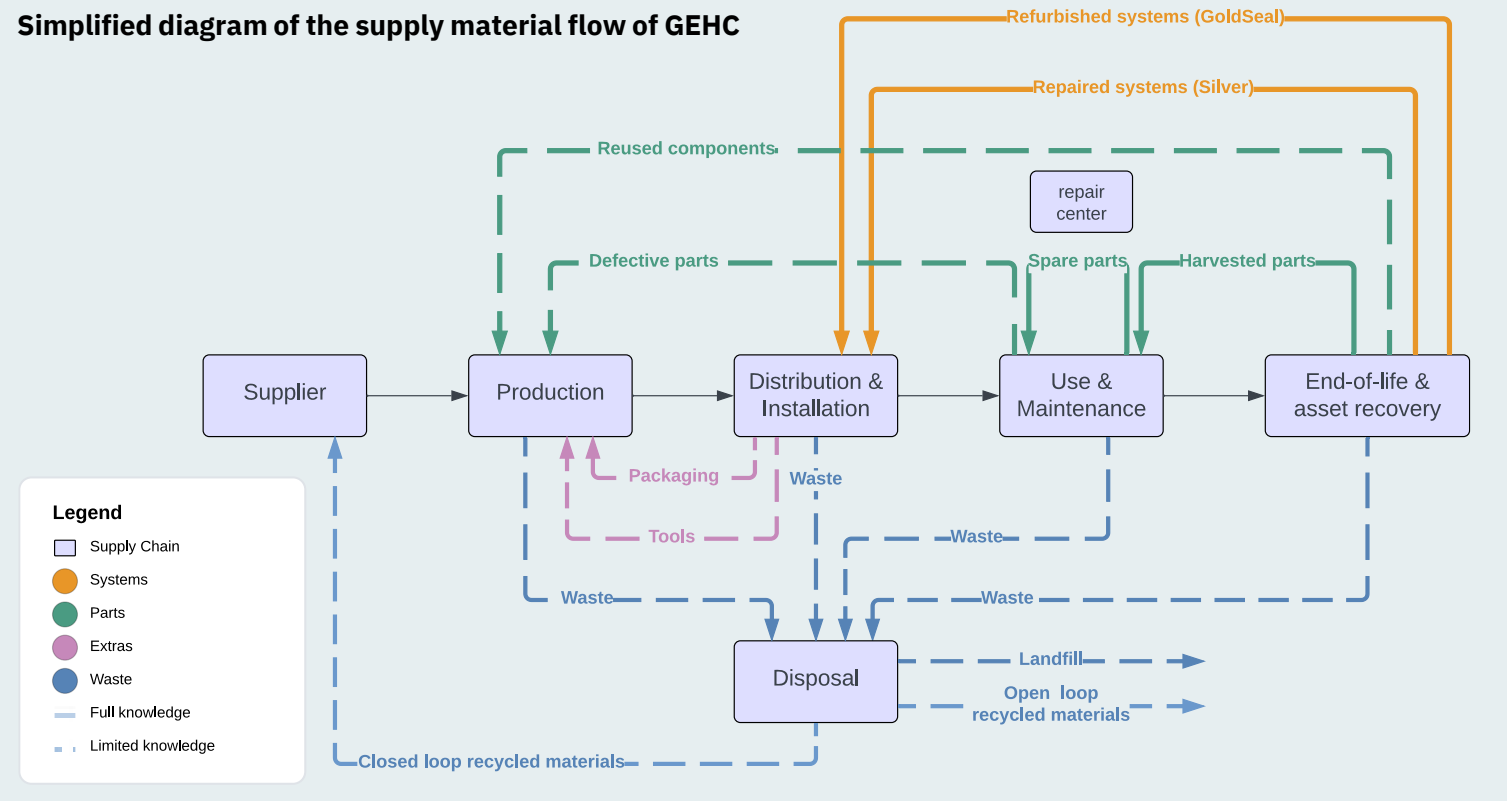


IGS 5 (Interventional Image Guided Systems)



Simulation of the circularity performance

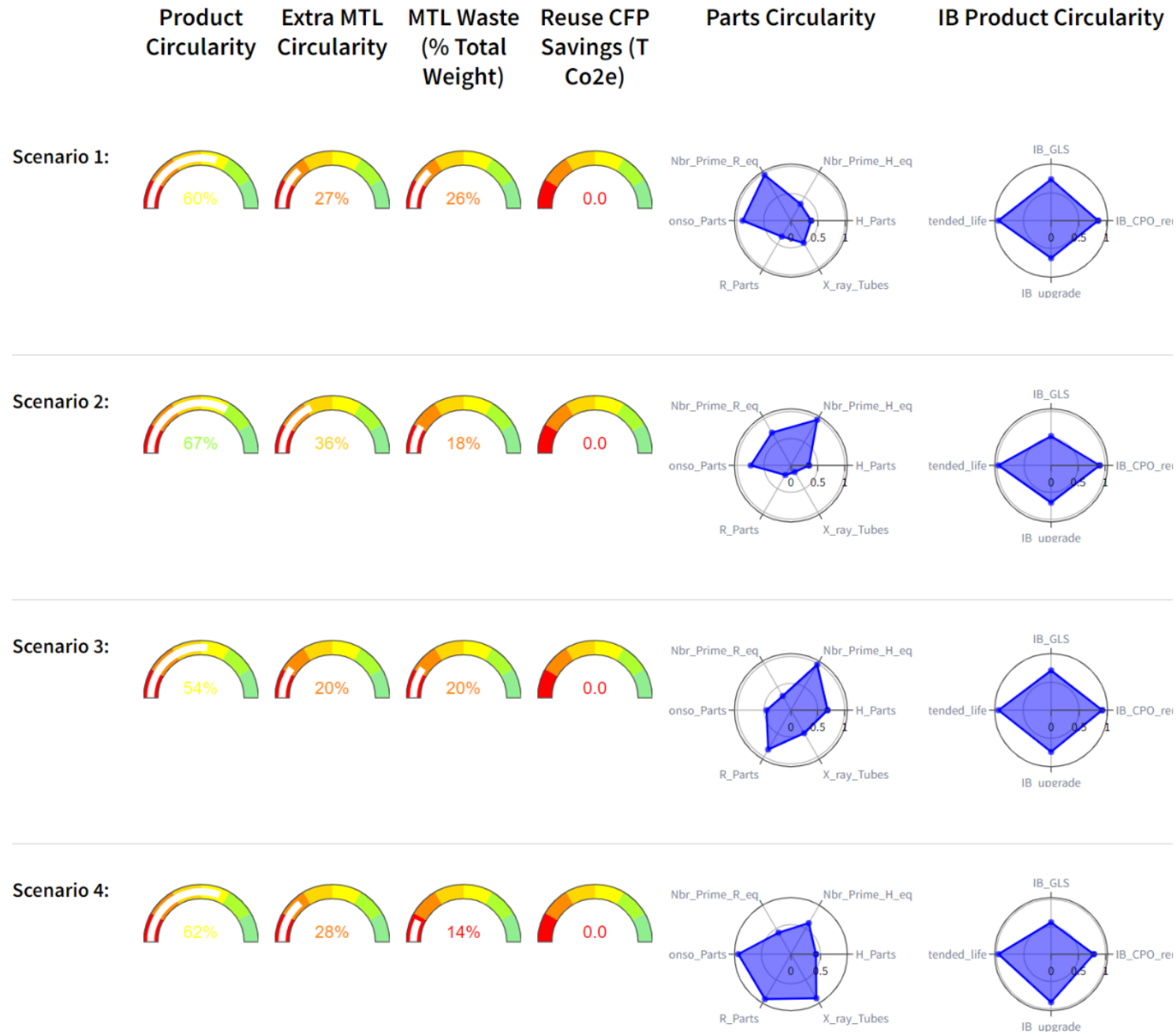
Simplified diagram of the supply material flow of GEHC



□ El Bechari, S., Bouillass, G., Yannou, B., Saidani, M., Volansch, A., & Heidsieck, R. (2024). [Measuring and Enhancing Circularity of the Healthcare Sector: The Circularity Model of Products & Spare Parts](#). Paper presented at the 33th International Association For Management of Technology (IAMOT) Conference, Porto, Portugal.

For each scenario:
visualization of various
KPIs and spider graphs

Circularity Index - Detailed Index per Scenario



Need of a novel CE product indicator, as a comprehensive circularity footprint along the BoM tree



Senographe Pristina
Mammography System

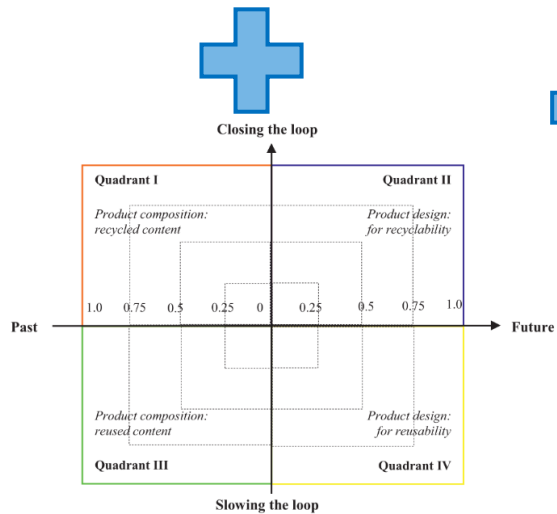


GE HealthCare

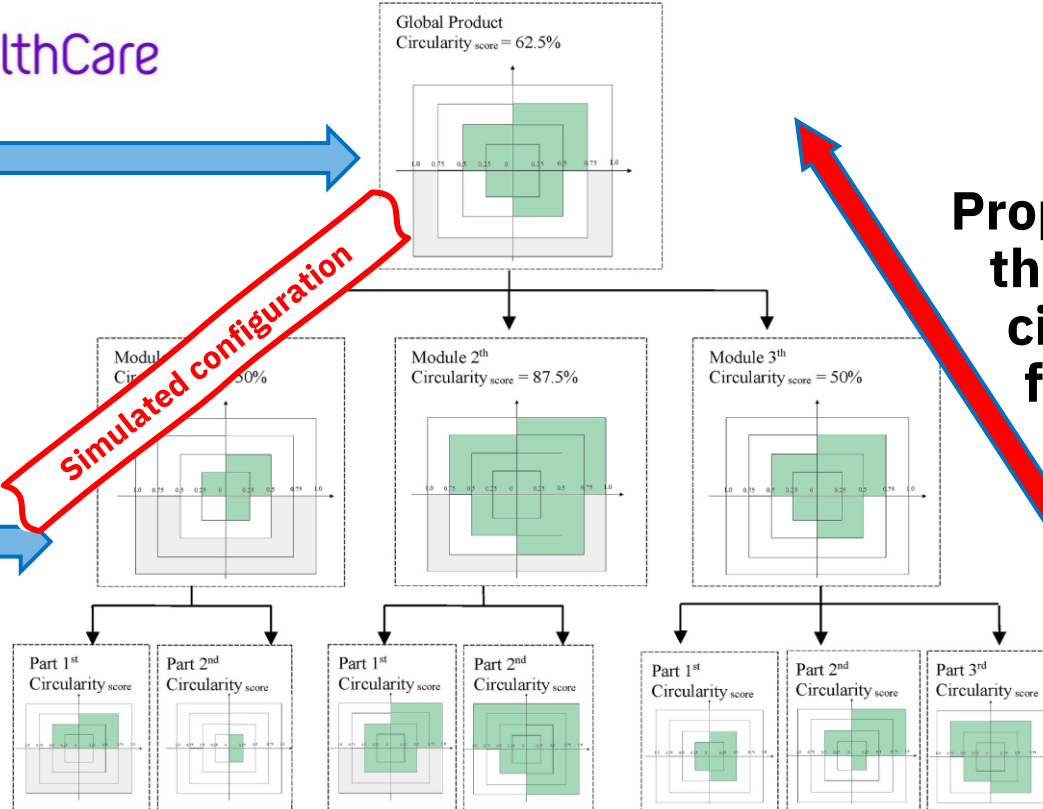


Simulated configuration

Propagation of
the product
circularity
footprint



Model of the “Closing–Slowing
Future–Past” quadrant



- ❑ Shevchenko, T., Cluzel, F., Yannou, B., Ranjbari, M., Esfandabadi, Z. S., Saidani, M., & Danko, Y. (2024). [Completing the design for product circularity toolkit with hierarchical computation of circularity maturity diagram and redesign circular strategies](#). *Journal of cleaner Production*, 437. doi:10.1016/j.jclepro.2024.140742
- ❑ Shevchenko, T., Yannou, B., Saidani, M., Cluzel, F., Ranjbari, M., Esfandabadi, Z. S., . . . Leroy, Y. (2022). [Product-level circularity metrics based on the “Closing–Slowing Future–Past” quadrant model](#). *Sustainable Production and Consumption*, 34, 395–411. doi:10.1016/j.spc.2022.09.024

Exploration dashboard for the CFSP model

Factor

☐ Factor in unavailability

Select the unit you want to factor in to compute child-to-parent circularity:

- ☒  **Mass**
Factor in the weight of the parts
- ☐  **Carbon Footprint**
Factor in the environmental impact
- ☐  **Simple model**
All parts considered equal

Apollon Tube Analysis ↗

2025

Actual Circularity

72%

Circularity Potential

92%

Overall Circularity Score

82%

Weight

6.2kg

Q1: Recycled Rate

28%

Q2: Recyclability Rate

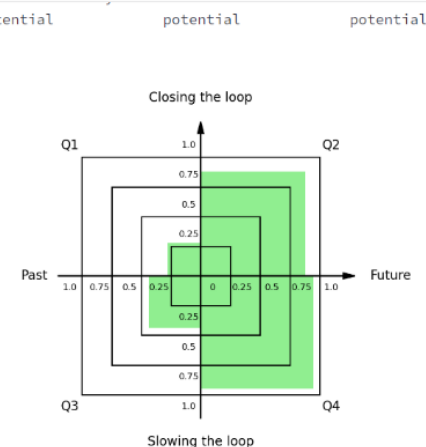
88%

Q3: Reused Rate

44%

Q4: Reusability Rate

95%



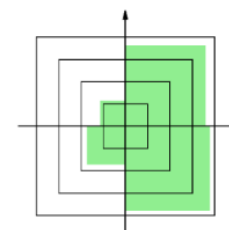
Subassemblies

Click on a subassembly to see more details

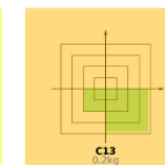
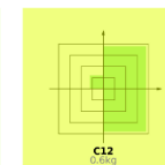
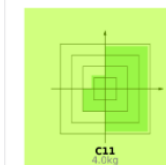
- 64%** Subassembly 1 - 4.9kg
- 61%** Subassembly 2 - 1.0kg
- 62%** Subassembly 3 - 0.3kg

Subassembly 1

64%



3 Parts





To what extent can the circular economy help ensure that planetary boundaries are respected?

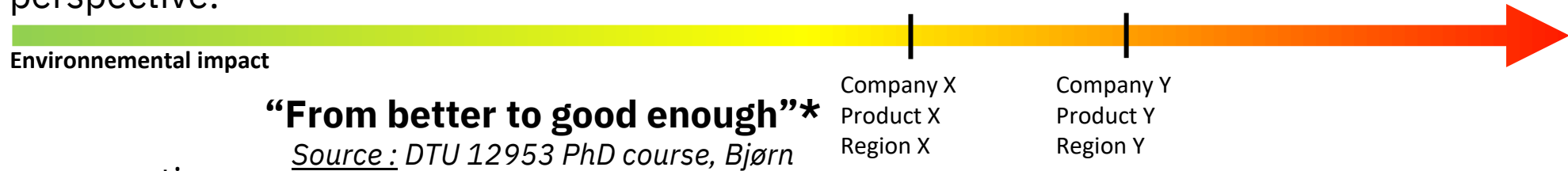
CIRCULAR
LE NUMÉRIQUE AU SERVICE
DE L'ÉCONOMIE CIRCULAIRE



E. de Bantel, M. Jankovic, G. Bouillass, B. Yannou

The AESA framework is a paradigm shift for us

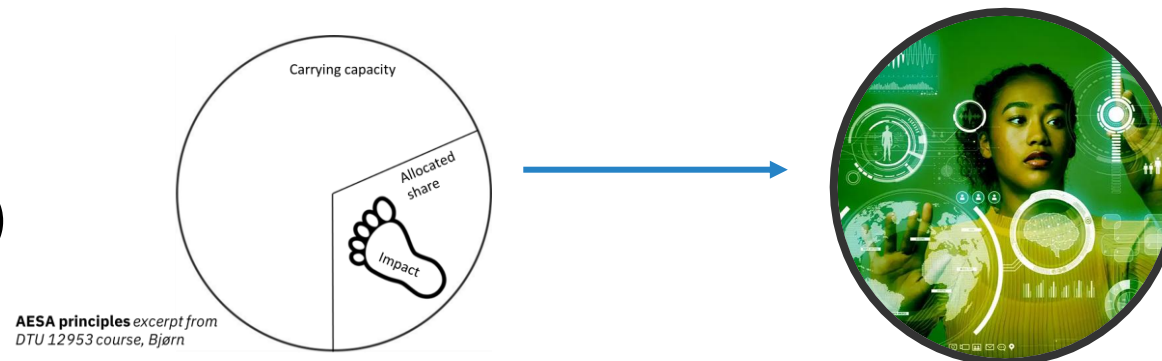
➤ Relative perspective:



➤ Absolute perspective:



Integration of the AESA (Absolute Environmental Sustainability Assessment) framework in the CDC



UNCASExt:

Introducing a framework and software for systematic carrying capacity allocation under uncertainty in AESA* (for *retrospective* and *prospective* studies)

de Bantel, E. I.¹, Pirson, T.², Puig-Samper, G.³, Hartmann, J.⁴, Hauschild, M.^{5,6}, Bouillass, G.¹, Yannou, B.¹, Jankovic, M.¹
(forthcoming submission to **Sustainable Production and Consumption**)

¹ Université Paris-Saclay, CentraleSupélec, Laboratoire Genie Industriel, 91190 Gif-sur-Yvette, France

² ICTEAM, Université catholique de Louvain, Louvain-la-Neuve, Belgium

³ Luxembourg Institute of Science and Technology (LIST), 5 avenue des Hauts-Fourneaux, 4362 Esch-sur-Alzette, Luxembourg

⁴ Institute for Technical Thermodynamics, RWTH Aachen University, Aachen, Germany

⁵ Section for Quantitative Sustainability Assessment, Department of Environmental and Resource Engineering, Technical University of Denmark, Lyngby, Denmark

⁶ Centre for Absolute Sustainability, Technical University of Denmark, Lyngby, Denmark

&

Towards a *target-driven approach* to circular economy through AESA*

de Bantel, E. I.¹, Hauschild, M.^{2,3}, Bouillass, G.¹, Yannou, B.¹, Jankovic, M.¹

¹ Université Paris-Saclay, CentraleSupélec, Laboratoire Genie Industriel, 91190 Gif-sur-Yvette, France

² Section for Quantitative Sustainability Assessment, Department of Environmental and Resource Engineering, Technical University of Denmark, Lyngby, Denmark

³ Centre for Absolute Sustainability, Technical University of Denmark, Lyngby, Denmark

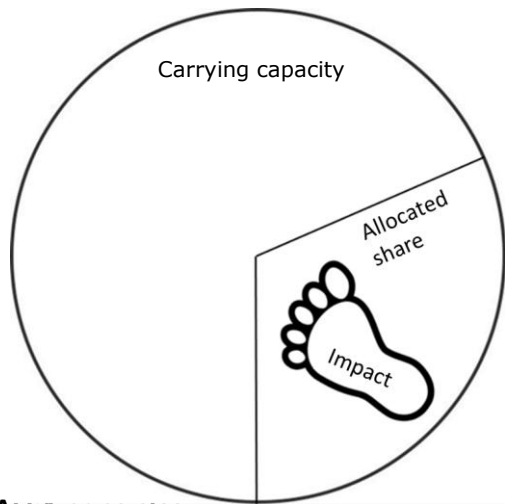
Erwan de Bantel



* *Absolute Environmental Sustainability Assessment*

Definition:

AESA is a methodology that evaluates whether human activities are environmentally sustainable by comparing their environmental impacts to environmental thresholds (Bjørn et al., 2020).



AESA principles

DTU 12953 PhD course, Bjørn

Absolute Sustainability Ratio (ASR)

Estimation of environmental burdens e

$\text{allocated Share of Carrying capacity (aSoCC}_e) \times CC_e$

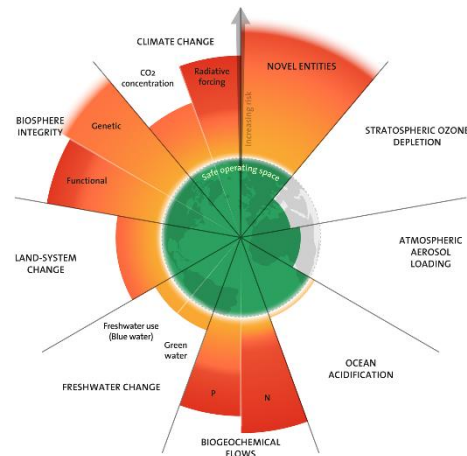
ASR ≤ 1: environmentally sustainable

ASR > 1: environmentally unsustainable

Definition:

Carrying capacities represent the maximum environmental burdens natural systems can sustain without triggering structural or functional changes that are irreversible or difficult to restore (Bjørn & Hauschild, 2015).

E.g.: Planetary boundaries framework



Sakschewski and Caesar et al. 2025

E.g.: Carrying capacities for EF 3.1. mid-point indicators

Sala et al. 2020

Bjørn and Hauschild 2015

Definition:

Allocated shares of carrying capacities represent the portion of carrying capacities assigned to a specific activity/territory based on explicit distribution justice principles (Puig-Samper et al., 2025).

List of the most mature allocation methods at country-level (L1) and sector-level (L2)*

Allocation level	SP(EM)	Definition	References
L1	$EG(\text{Pop})_r(t)$	Equal per capita allocation: all individuals worldwide receive the same share in year t .	[Lucas et al., 2020, Paulillo et al., 2026, Puig-Samper et al., 2025, Yang and Paulillo, 2025]
L1	$PR(\text{GDPcap})_r(t)$	Ability to pay: country share inversely proportional to GDP per capita in year t , reflecting ability to afford mitigation.	[Gebara and Laurent, 2023, Hjalsted et al., 2021, Paulillo et al., 2026, Puig-Samper et al., 2025, Verhaeghe et al., 2024, Yang and Paulillo, 2025]
L1	$PR\text{-}HR(Ecap, cum')_{e,r}(t)$	Historical responsibility: country share inversely proportional to cumulative per-capita environmental impacts over the responsibility period.	[Lucas et al., 2020, Paulillo et al., 2026, Yang and Paulillo, 2025]
L1	$AR(E')_{e,r}(t^{ar})$	Grandfathering: country share proportional to environmental impacts in a past reference year.	[Hjalsted et al., 2021, Lucas et al., 2020, Puig-Samper et al., 2025, van den Berg et al., 2020, Verhaeghe et al., 2024]
L1	$AR(Ecap')_{e,r}(t^{ar})$	Grandfathering (per-capita) in reference year t^{ar} , weighted by population at year t .	[Paulillo et al., 2026, Yang and Paulillo, 2025]
L2	$UT(\text{FD})$	FD as a proxy for the welfare that an industry provides to the population.	[Ryberg et al., 2018a, Hjalsted et al., 2021, Puig-Samper et al., 2025]
L2	$UT(\text{GVA})$	GVA as a proxy for the welfare that an industry provides to the population.	[Ryberg et al., 2018a, Hjalsted et al., 2021, Puig-Samper et al., 2025]
L2	$AR(E_e)$	Grandfathering: industry share proportional to environmental impacts in a past reference year.	[Lucas et al., 2021, Bjørn et al., 2025, Puig-Samper et al., 2025]

SP = sharing principle; EM = enacting metric; EG = egalitarian; PR = prioritarian; AR = acquired rights (grandfathering); HR = historical responsibility; Pop = population; cap = per-capita; cap,cum = cumulative per-capita; FD = final demand; GVA = gross value added.

* Sector-level methods (L2) can be applied in one-step or in combination with any country-level methods (L1)

Bjørn, A., Chandrakumar, C., Boulay, A.-M., Doka, G., Fang, K., Gondran, N., Hauschild, M. Z., Kerkhof, A., King, H., Margni, M., McLaren, S., Mueller, C., Owsianiak, M., Peters, G., Roos, S., Sala, S., Sandin, G., Sim, S., Vargas-Gonzalez, M., & Ryberg, M. (2020). Review of life-cycle based methods for absolute environmental sustainability assessment and their applications. *Environmental Research Letters*, 15(8), 083001. <https://doi.org/10.1088/1748-9326/ab89d7>

Bjørn, A., & Hauschild, M. Z. (2015). Introducing carrying capacity-based normalisation in LCA: Framework and development of references at midpoint level. *The International Journal of Life Cycle Assessment*, 20(7), 1005–1018. <https://doi.org/10.1007/s11367-015-0899-2>

B. Sakschewski, L. Caesar, et al. 'Planetary Health Check 2025: A Scientific Assessment of the State of the Planet', Potsdam Institute for Climate Impact Research (PIK), Sept. 2025. doi: 10.48485/PIK.2025.017.

Sala, S., Crenna, E., Secchi, M., & Sanyé-Mengual, E. (2020). Environmental sustainability of European production and consumption assessed against Planetary Boundaries. *Journal of Environmental Management*, 269, 110686. <https://doi.org/10.1016/j.jenvman.2020.110686>

Puig-Samper, G., Owsianiak, & Gondran, N. (2025). Quantifying uncertainties in absolute environmental sustainability assessment: A general framework applied to French electricity production. *Sustainable Production and Consumption*, 54, 12–24. <https://doi.org/10.1016/j.spc.2024.12.013>

UNCASExt:

Introducing a framework and software for systematic carrying capacity allocation under uncertainty in AESA (for *retrospective* and *prospective* studies)

UNCASExt framework

(A) Estimate environmental burdens

(A.1) Goal and scope of the Life Cycle Assessment (LCA)

- Set accounting approach to attributional
- Define the functional unit
- Define the system boundaries
- Define spatial variations
- Define temporal variations

(A.2) Parameterized inventory

- Collection of primary & secondary data

Spatial variability

- Development of LCA models

(i) Retrospective (ii) Prospective

- Foreground system

- Define parameters

- Define scenarios

- Background system

- Static (ecoinvent)

- Select PREMISE scenarios (IAM-SSP-climate pathway)

- LCI (environmental flows)

- match SSP per iteration

- match LCIA method

- PB-LCIA EF3.1

- GWP100 (IPCC) PB-IA ...

- LCIA method selection

- (A.3) Impact assessment (LCIA)

- Characterize environmental flows

- Propagate uncertainties with Monte Carlo simulation

- Test convergence on N_{mc}

- (A.4) Uncertainty analysis

(B) Allocate carrying capacities

(B.1) Quantification of carrying capacities

- Quantify carrying capacities Carrying capacity (CV) selection
- Define carrying capacity distribution (min/max)
- Dynamic carrying capacities (e.g. carbon budgets)

- Carrying capacity (CV) estimation

- Level of acceptable risk

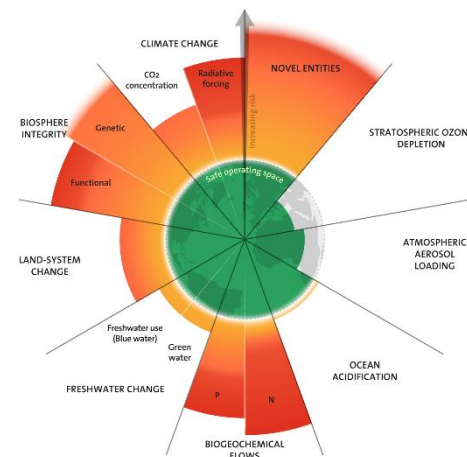
- Temporal variability

Carrying capacities covered by UNCASExt (+ software)

Static – All impact categories
yearly carrying capacity threshold level is constant over time

Dynamic - Climate Change
IPCC AR6 pathways, i.e. cumulative budget distributed over years by transition scenarios

E.g.: Planetary boundaries framework

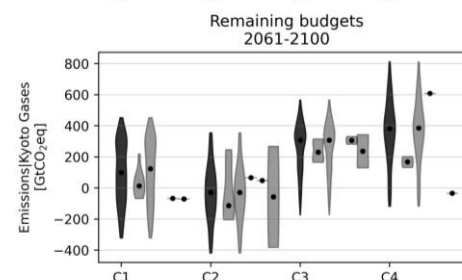
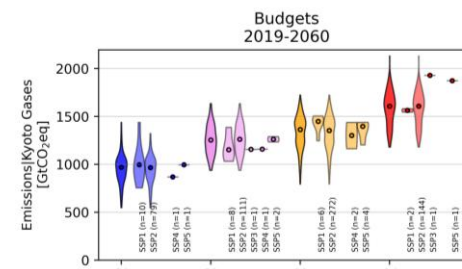
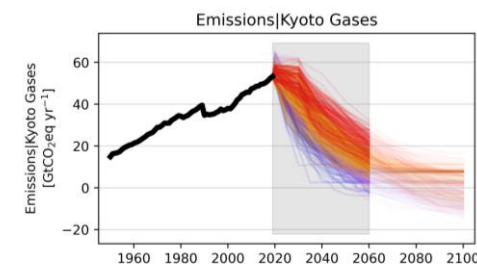


Sakschewski and Caesar et al. 2025

E.g.: Carrying capacities for EF 3.1. mid-point indicators

Sala et al. 2020

Bjørn and Hauschild 2015

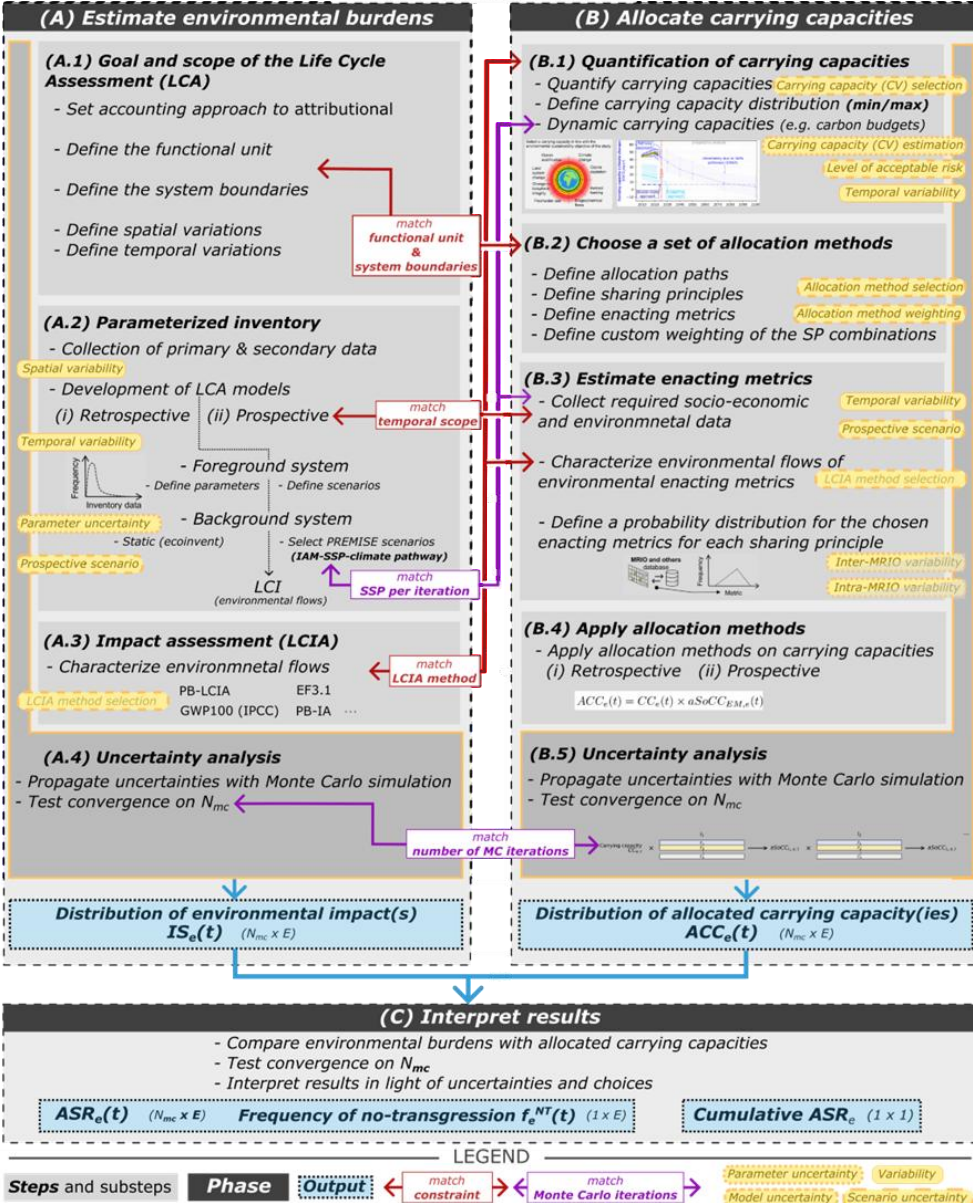


LEGEND

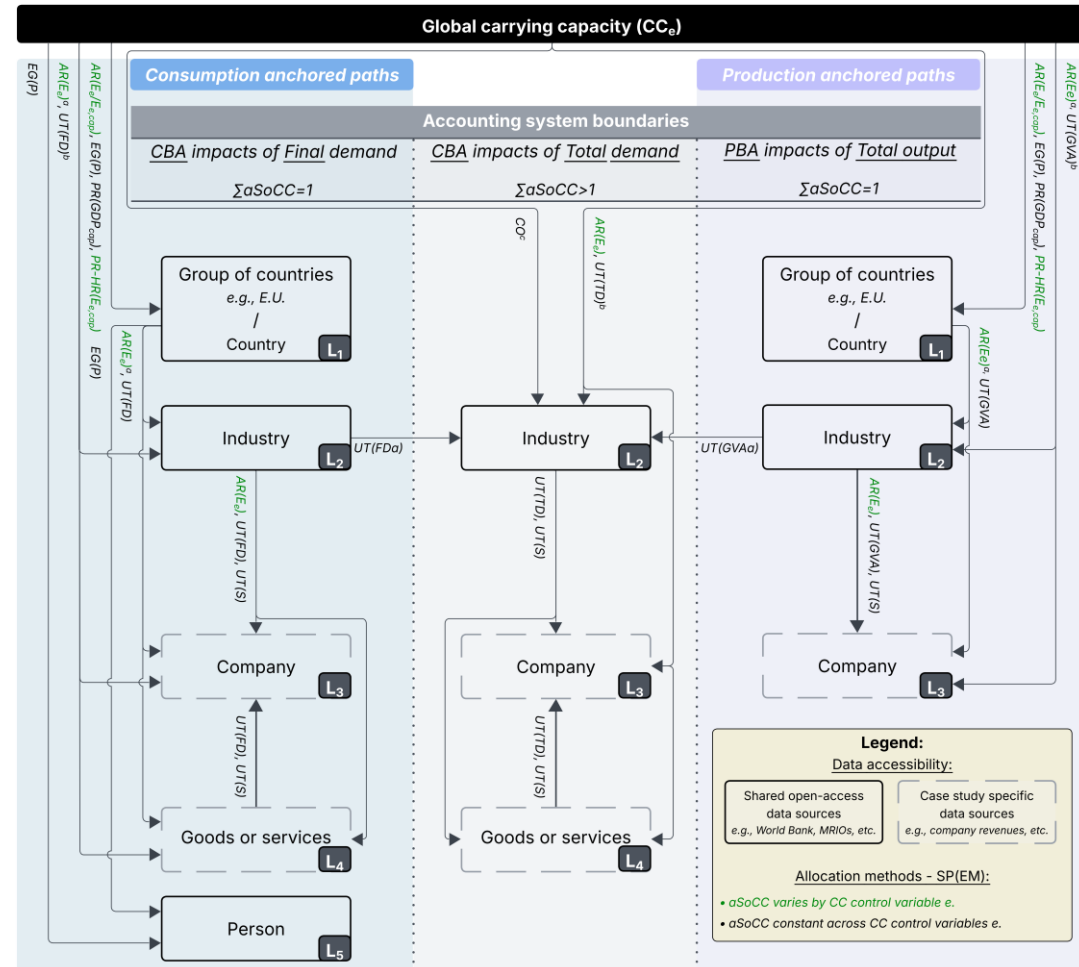
UNCASExt:

Introducing a framework and software for systematic carrying capacity allocation under uncertainty in AESA (for *retrospective* and *prospective* studies)

UNCASExt framework



Allocation methods covered by UNCASExt (+ software for L1 & L2)

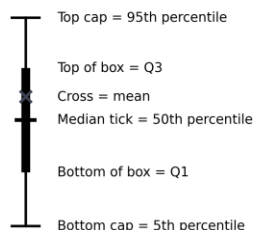


Software (PyAESAs Python package):

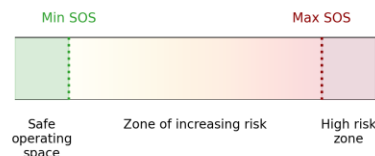
- Python package available to implement all listed country-level (L1) and sector-level (L2) allocation methods and functional units.
 - Use of open-access data sources, including the World Bank, International Monetary Fund, (EE)-MRIOs (e.g., EXIOBASE; Stadler et al., 2018; OECD ICIO), and IPCC AR6.
- PyAESAs v2 will extend the software coverage to company-level (L3) and product-level (L4).
 - For these levels, however, users will need to provide their own data sources, as no homogeneous open-access datasets currently provide the necessary information at such resolution.

PyAESAs output examples

ASR whisker key

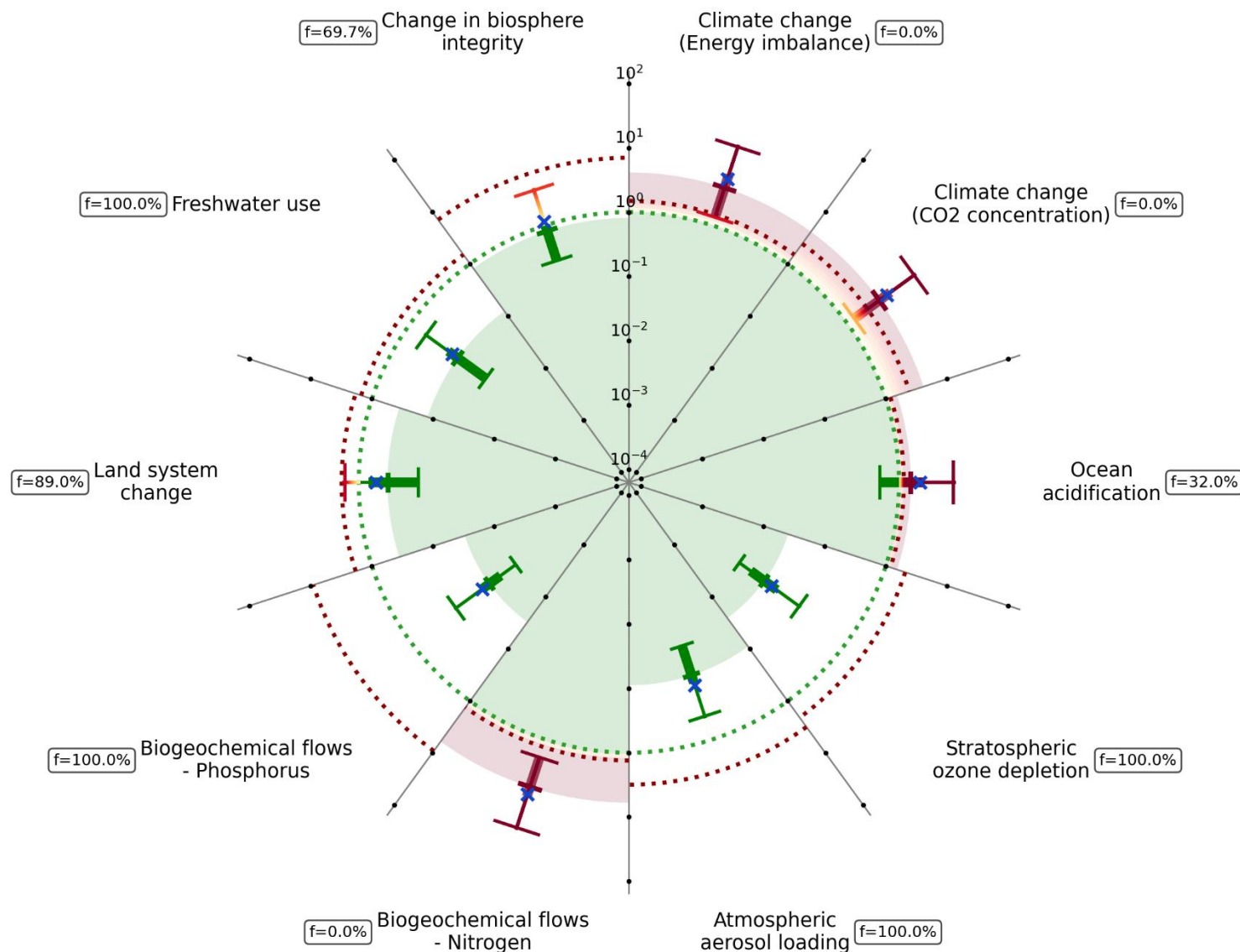


Risk level color scale



f = frequency of no transgression of Min SOS (ASR ≤ 1)

Absolute Sustainability Ratios (ASRs): i_p=Health and social work (85) r_c=FR YEAR=2019



Next step: Towards a *target-driven approach to circular economy* through AESA

To what extent and under which conditions can CE strategies enable to meet absolute sustainability thresholds (Country + Sector levels)?

- **PyAESA** (de Bantel et al., 2026)
- + • **Pycirk** (Donati et al., 2020, 2021): a Python package designed to implement circular economy strategies in EE-MRIOS (Exiobase)

Methodological note:

An Input-Output LCA approach will be followed for the study, but the method can be reproduced with process-based LCAs (with however limitations regarding prospective scenario-based allocated shares).

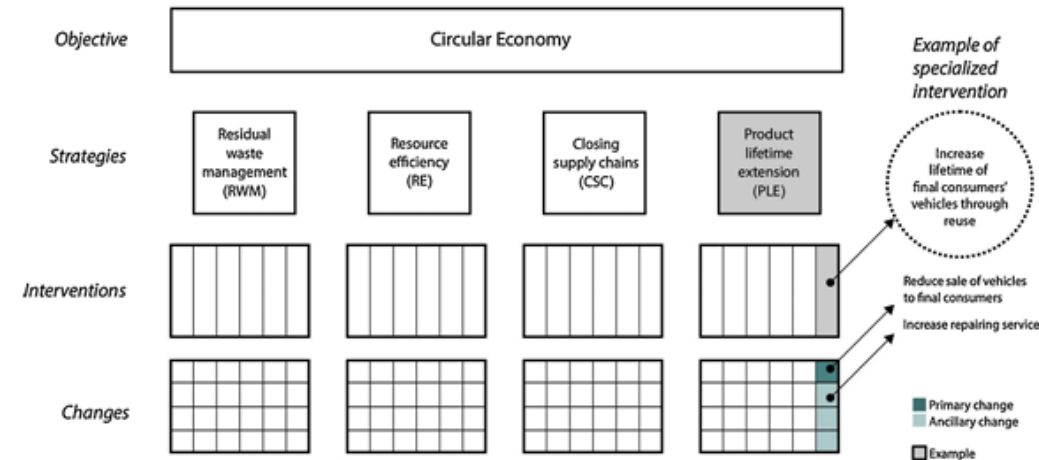
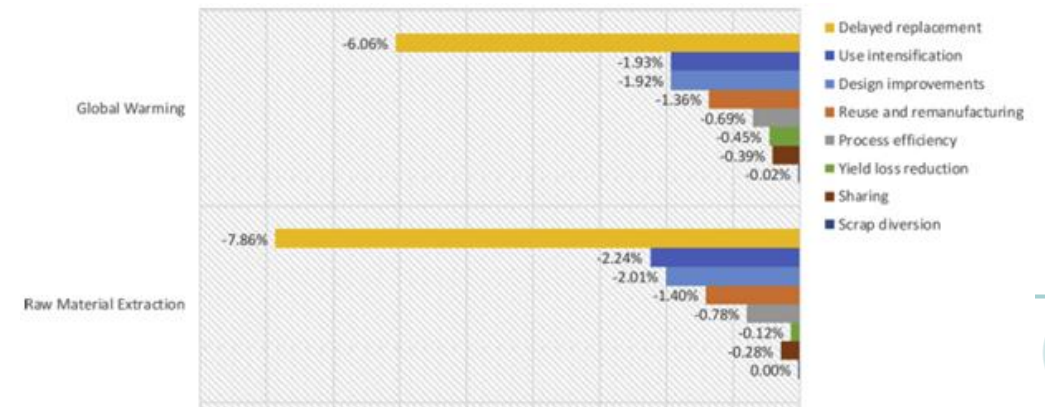


Fig. 1. CE policy modeling framework.

Examples of policies that can be modelled through the software:

- sharing
- recycling
- life extension
- rebound effects
- substitution
- market and value added changes
- efficiency

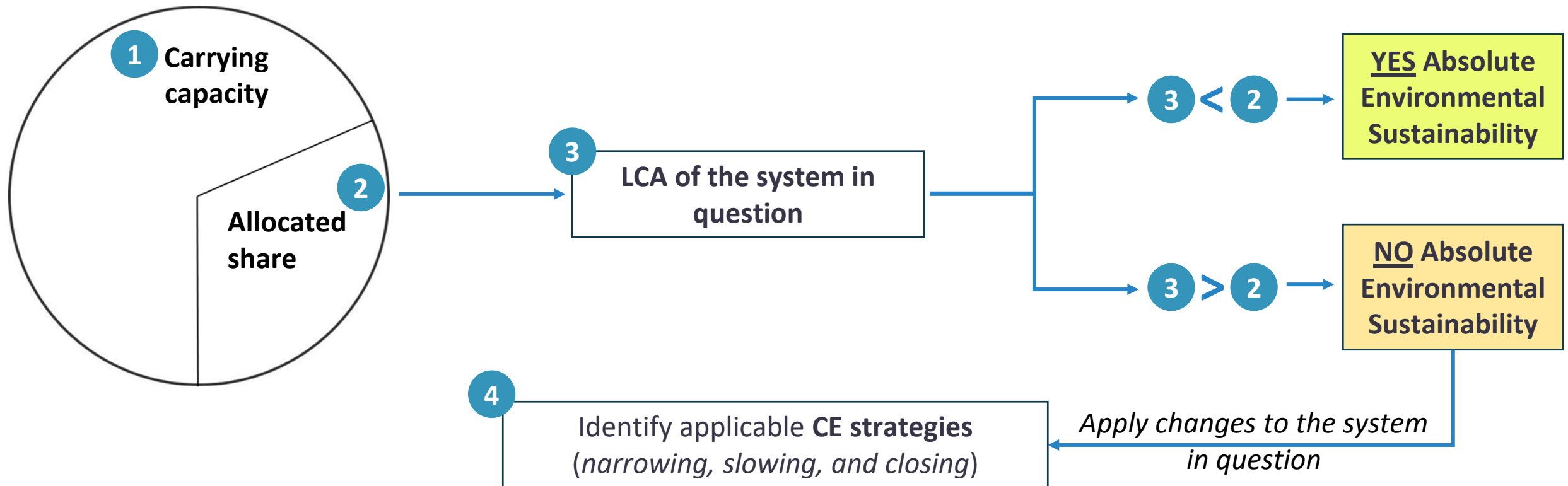
Strategy (Intervention)	Specialized intervention	Change type	Product category	Consumption activity	Technical Change (%)	Market penetration (%)	Substitution (SWK) (%)
Product lifetime extension (Delayed replacement)	Increase average lifetime of office buildings in constructions 1.5 times	Primary	Construction work	Final consumption expenditure (except households)	- 60	32.1	
Product lifetime extension (Delayed replacement)	Increase average lifetime of vehicles 2.3 times	Ancillary	Construction work	Construction work	60	22.7	
		Primary	Motor vehicles, trailers and semi-trailers	All final demand categories	- 50.7	100	
		Ancillary	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories	Motor vehicles, trailers and semi-trailers	50.7	100	
Resource Efficiency (Use intensification)	Increase 2.5 times the intensity of use of vehicles due to higher occupancy	Primary	Motor vehicles, trailers and semi-trailers	All final demand categories and all product categories	- 60	33	
		Proportional reduction to the above change	Other land transportation services	All final demand categories			- 30
		Ancillary	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories	All final demand categories and all product categories	120	33	
Product lifetime extension	Increase average life time of electrical machineries and	Primary	Electrical machinery and apparatus n.e.c.	All final demand categories	- 75	100	



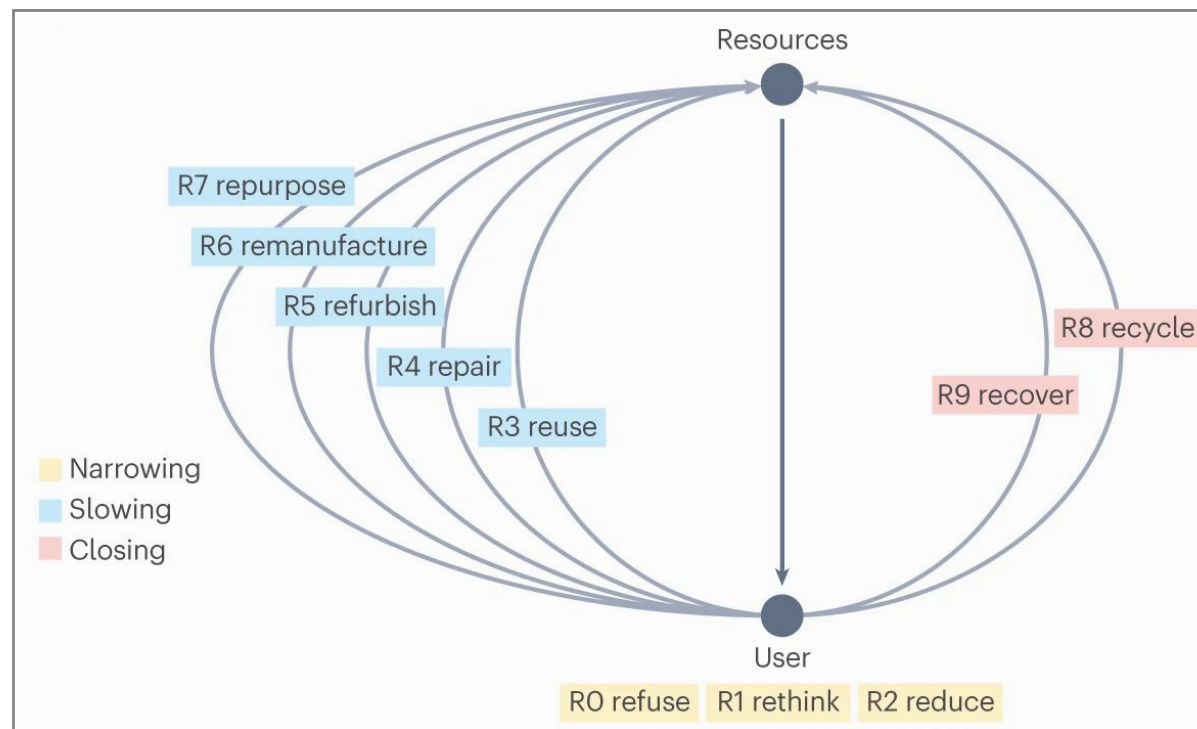
Donati, F., Aguilar-Hernandez, G. A., Sigüenza-Sánchez, C. P., de Koning, A., Rodrigues, J. F. D., & Tukker, A. (2020). Modeling the circular economy in environmentally extended input-output tables: Methods, software and case study. *Resources, Conservation and Recycling*, 152, 104508. <https://doi.org/10.1016/j.resconrec.2019.104508>

Donati, F., Nicolson, S., de Koning, A., Daniels, B., Christis, M., Boonen, K., Geerken, T., Rodrigues, J. F. D., & Tukker, A. (2021). Modeling the circular economy in environmentally extended input-output: A web application. *Journal of Industrial Ecology*, 25(1), 36–50. <https://doi.org/10.1111/jiec.13046>

How can we link circular economy (CE) strategies with planetary boundaries (via the AESA)?



How can we link circular economy (CE) strategies with planetary boundaries (via the AESA)?



Source : Hellweg et al., 2023.

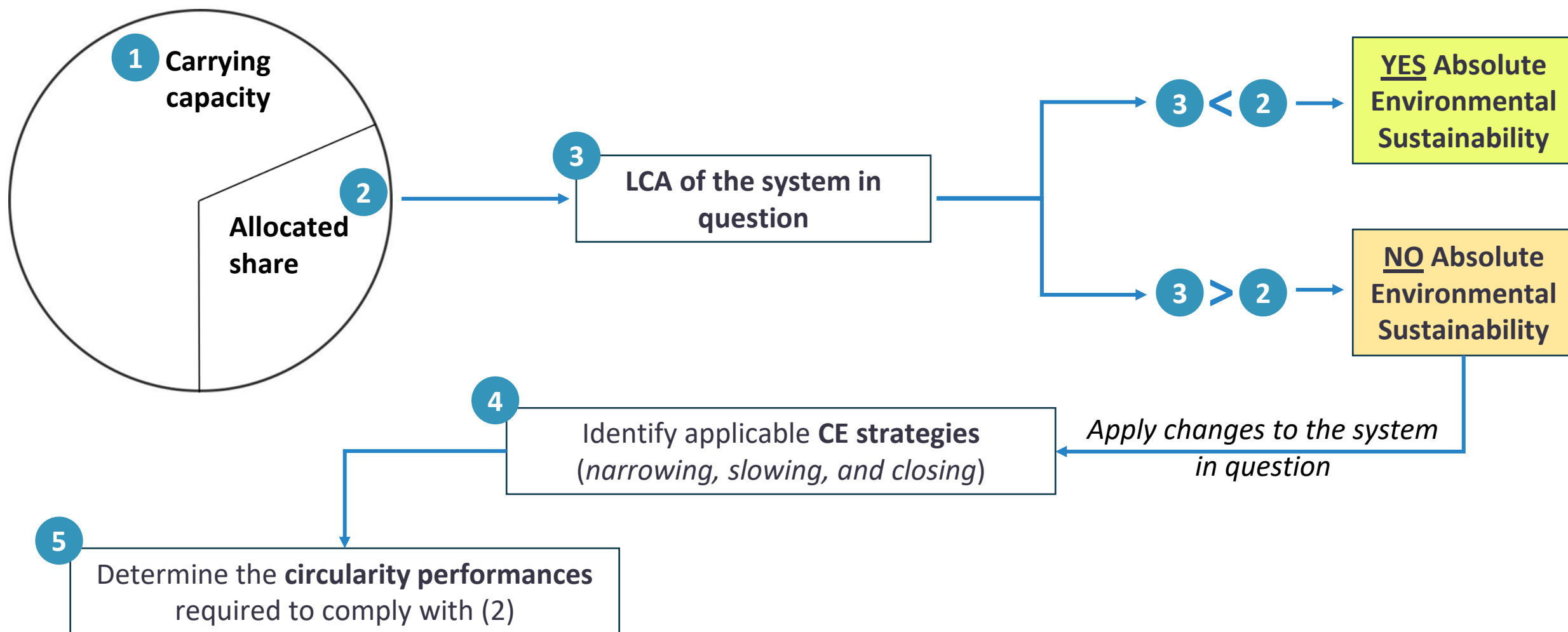
4

Identify applicable **CE strategies**
(*narrowing, slowing, and closing*)

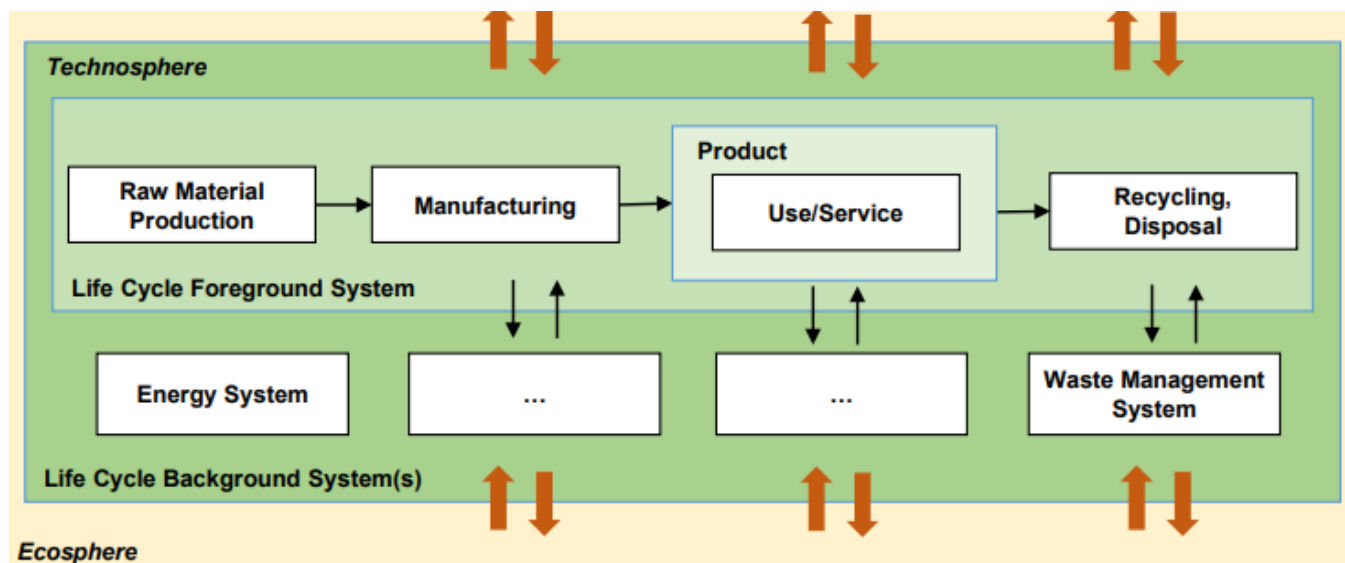


Ex: RMI system
(R5) Refurbishing machines to give them a second life (or a third, or a fourth?)

How can we link circular economy (CE) strategies with planetary boundaries (via the AESA)?



How can we link circular economy (CE) strategies with planetary boundaries (via the AESA)?



Source : Kara et al. , 2023.



Circularity performances:

- % recycled
- % reused
- tons-kilometers of reverse logistics
- Lifespan
- Etc.

The LCA results for these CE strategies depend on the Background system :

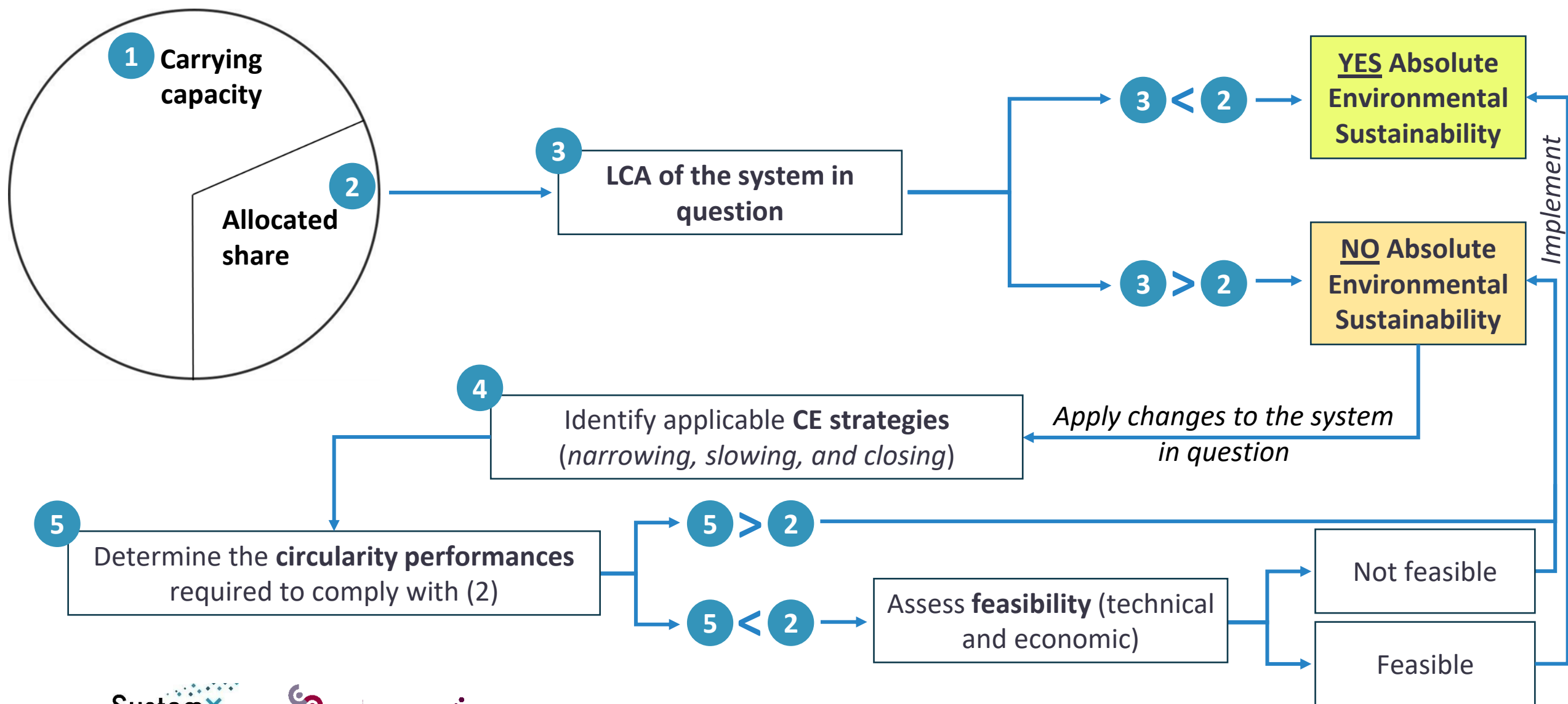
- Energy mix
- Transportation technologies
- Etc.

5

Determine the **circularity performances** required to comply with (2)

Prospective modeling

How can we link circular economy (CE) strategies with planetary boundaries (via the AESA)?





CIRCULAR
LE NUMÉRIQUE AU SERVICE
DE L'ÉCONOMIE CIRCULAIRE



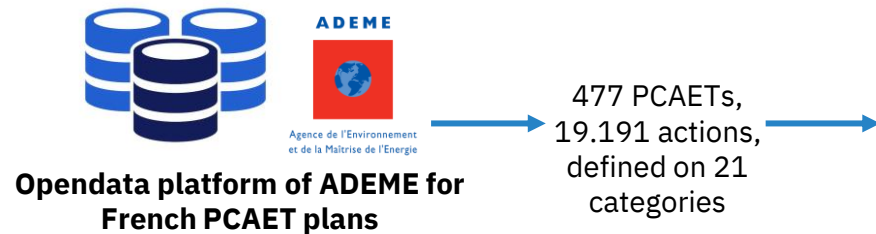
Regarding the CE action plans

Analyze the quality of existing (regional/territorial) plans

We show that in France, the **Regional Climate, Air, and Energy Plans (PCAETs)** are **not ambitious enough in relation to the objectives of the National Low-Carbon Strategy**



- ❑ Bouillass, G., Baltazar, J., & Yannou, B. (2024). *On the Path towards Carbon Neutrality? A Comprehensive Analysis of Local Climate Plans* in France. *Renewable and Sustainable Energy Reviews*, 212, 115240. <https://doi.org/10.1016/j.rser.2024.115240>



- **Uneven thematic coverage**
- **Diverse plans** (cross-cutting / sector-specific)
- **A wide variety of local approaches** (adaptation not well covered)

Part des collectivités locales ayant fixé des objectifs de réduction des émissions de GES pour les huit secteurs d'activités à l'horizon 2030 et 2050, sur un échantillon de 477 collectivités.

Sectors	Number of local authorities that have settled GHG reduction targets (N=477)			
	By 2030	%	By 2050	%
Residential	444	93%	219	46%
Tertiary	445	93%	213	45%
Road transport	446	94%	219	46%
Other transports	245	51%	95	20%
Agriculture	435	91%	215	45%
Waste	322	68%	123	26%
Industry w/o energy	426	89%	208	44%
Energy industry	151	32%	68	14%



- Axes stratégiques**
- Bâtiment (19 actions),
 - Mobilité (27 actions),
 - Gestion des déchets et économie circulaire (26 actions),
 - Engagement des citoyens (12 actions),
 - Agriculture (11 actions),
 - Développement des ENR (8 actions),
 - Urbanisme (9 actions),
 - Services publics (8 actions),
 - Mise en oeuvre du plan climat et son évaluation (6 actions).

Structure	Nombre	Exemple
Axe stratégique	9	Réduire la consommation d'énergie des logements et locaux d'activité
Objectifs opérationnels	32	Sensibiliser et informer sur les économies d'énergie dans les logements
Actions	126	Repérer les ménages en situation de précarité énergétique et les accompagner dans leurs démarches d'économie d'énergie (SLIME)

The 7 factors that influence the quality of plans



Policy

Political will (awareness of climate issues—adaptation and mitigation—and the governance models adopted).



Legal

Consistent regulatory measures



Financial

Availability of funding (grants)



Methodology

Methods and tools for defining and evaluating actions
Methods that incorporate a systems-based approach to planning



Technology

Use of digital tools for modeling or monitoring the implementation of a plan.
Data management and challenges related to tool interoperability



Organizational

The local government's ability to coordinate the implementation of the plan across different departments



Stakeholder engagement

The local government's ability to coordinate the plan's implementation across different departments

- ☐ **A challenge to be addressed at the national level**
 - ☐ Toward a reference framework to clearly define PCAET actions and monitor their impacts across the region
- ☐ **The need to define the concept of plan quality**
 - ☐ Performance criteria for plans currently under development (use case with the Paris Saclay metropolitan area)

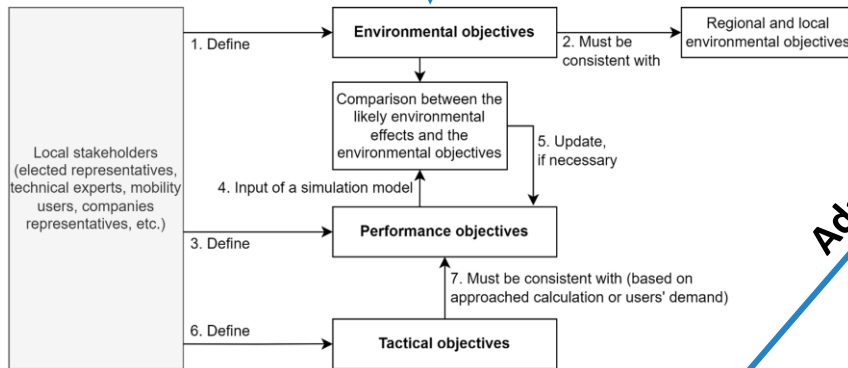
Analyze the quality of existing (regional/territorial) plans

Through a detailed **analysis of 13 Circular Economy plans**, we demonstrate that **the actions outlined in these plans are insufficiently aligned with sustainability goals**



Erwan De Bantel, Ghada Bouillass, Bernard Yannou, et Marija Jankovic. « **From ambition to impact? Assessing the quality of local circular economy plans** ». *Sustainable Cities and Society* 135 (2025): 107016. <https://doi.org/10.1016/j.scs.2025.107016>.

Change Theory



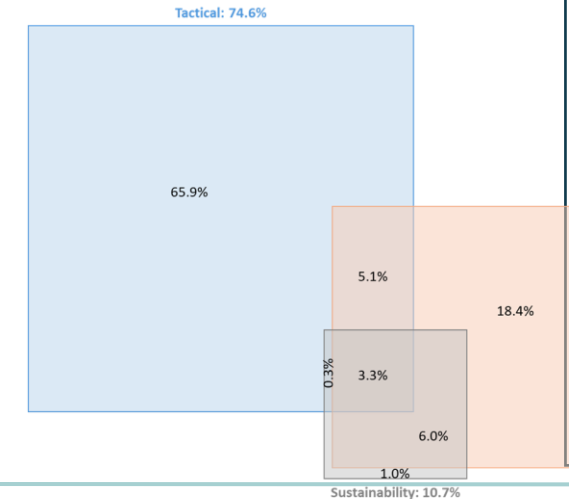
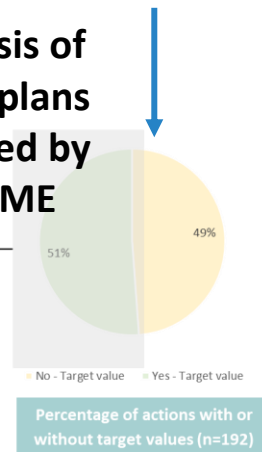
J. Baltazar, *Integrating environmental issues into territorial strategies: a methodological contribution to the design of mobility plans*, PhD thesis, Université Paris-Saclay (2024)

Adaptation

Analysis of 13 EC plans certified by ADEME



Legend:
▼: Objective n must be consistent with objective n+1



Example of an action with fully defined causal relationships

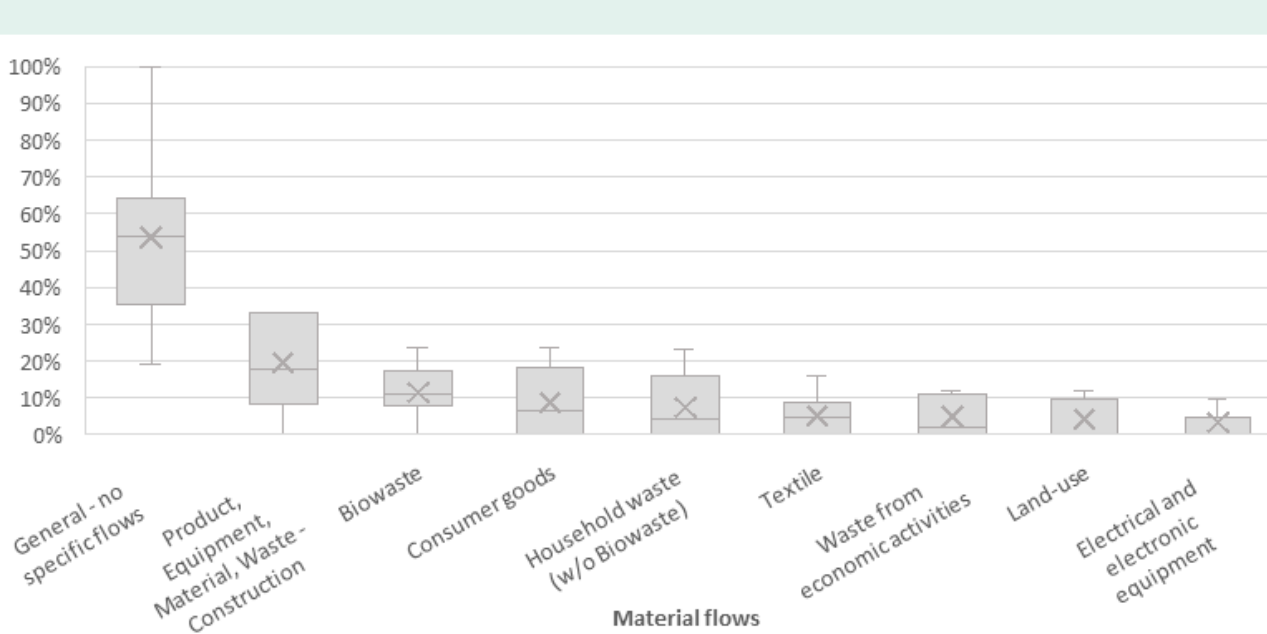
Action:
Promote the reuse of materials in land-use planning projects

Tactical:
x land-use planning projects funded for x thousand euros

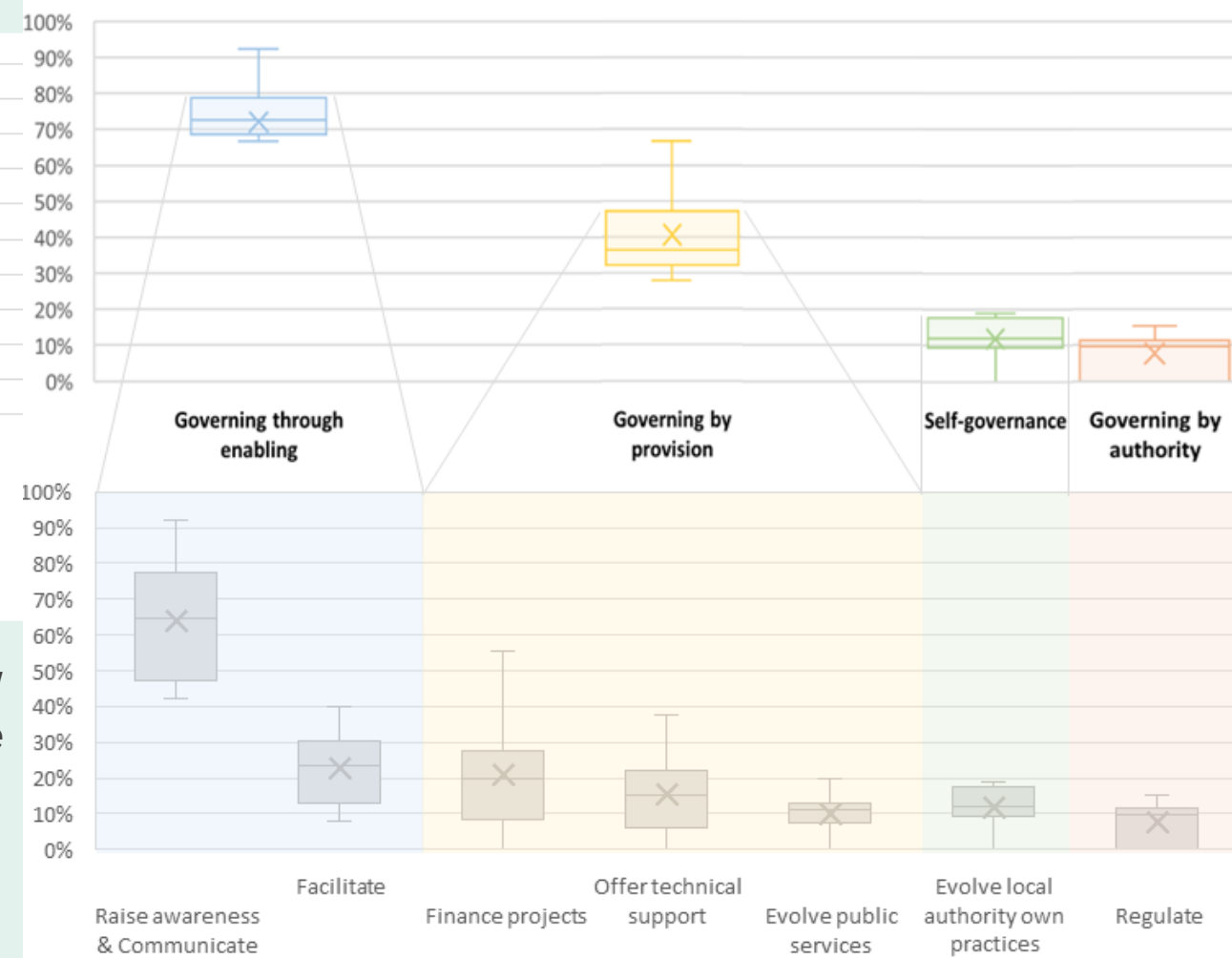
Circularity performance
x tons of construction materials reused

Sustainability / Environment
x% reduction in CO2eq & x jobs created

Percentage of actions with target values by corresponding objective level



Percentage of actions (n=237) focusing on each material flow ($j_1=9$). All material flows targeted by less than 1% of actions are excluded ($j_2=5$).



Percentage of actions (n=237) (a) mobilising each governance mode ($j_a=4$) and (b) corresponding means of action ($j_b=7$).

Develop a simulation model to assess the circularity and sustainability performance of a circularity action / strategy

Understand the relationships between an EC action / strategy and its sustainability performance through a **simulation model**



MANITOU
GROUP



Experiments to study the economic and circular performance of dismantling heavy machinery for reuse and recycling.



LCA, simplified MFA, and a cost model to assess the economic, environmental, and circular sustainability of electric retrofits.

Evaluating the effectiveness of an electrical retrofit for a thermal machine:

- Comparing the environmental performance of vehicles requires more accurate assumptions and an analysis of how factors such as the timing of the retrofit, used-vehicle costs, and the reuse of the internal combustion engine vary...
- The benefits of conversion are limited unless certain specific conditions are met.

Dismantling to understand and recommend effective circular economy strategies:

- Observation protocol
- 10 machines dismantled
- Analysis of factors and conditions conducive to reuse
- Recommendations for increasing refurbishment and further engaging in the circular economy
- Recommendations for a circular telescopic handler

- Nguyen, Joris, Emmanuel Pion, Ghada Bouillass, et al. « [Is the electric retrofit of a vehicle beneficial from an environmental, circularity, and economic point of view? A critical review and proposal](#) ». Submitted to **Renewable and Sustainable Energy Reviews**, 2026.
- Nguyen, Joris, Emmanuel Pion, Ghada Bouillass, et al. « [Is the electric retrofit of a vehicle beneficial from an environmental, circularity, and economic point of view? Methodology and case study of an off-road vehicle](#) ». Submitted to **Journal of Cleaner Production**, 2026.

Establish the theoretical foundations of the CDC and make it operational

Patekar, S., Yannou, B., Saidani, M., & Bouillass, G. (2026).
The Circular Digital Cockpit: A functional view – linking data, indicators and actions for circularity.
Circular Economy – Interdisciplinary Conference (CEIC 2026), Toulouse, France.

Patekar, S., Yannou, B., & Saidani, M. (2026).
Designing a Circular Digital Cockpit: A systems architecture approach for circular economy
MCV Management du Cycle de Vie (submitted) Lille, France



Sonali Patekar

What is a CE-Model?

1. Internal audit method to identify circularity levers based on EMF building blocks
2. External audit method to identify circularity levers
3. Model for assessing the impacts of equipment dismantling and subsequent component's reusing from a circularity and economic perspective
4. Model for assessing the impacts of electrical retrofitting of a thermal machine from a circularity, environmental and economic perspective
5. Local CE plans quality model
6. Target-Driven Circular Economy Model for Absolute Sustainability
7. Territorial Reuse Architecture Model (TRAM)
8. Sense-making approach for CE assessment resources
9. C-data to C-indicator model
10. The Circularity Model of Products & Spare Parts (CMPP)
11. The CSFD quadrant hierarchical metric
12. Governance rules for the effectiveness of local climate plans
13. Taxonomy of CE-indicators (updated version)
14. Circularity Potential Indicator for product development

A CE-Model is a resource/solution that contributes to achieving part of the CDC's overall objective, namely “**measuring the C&S indicators of a system of interest (SoI) in order to improve the sustainability of the organization.**”

They are the computing engines of the CDC.

Model Identity Card

Title		Fiche #x
Type Mapping / model	Graphical representation	
Interest / goal		
Context		
Who?	Inputs / Data needed	
Research Questions	Outputs / Meet the operational need(s)	
Genericity	Originality	Location.s on the CDC

Internal audit method to identify circularity levers based on EMF building blocks

Fiche #1

Type Method / Framework	Graphical representation 	Who? Product and service managers, decision makers
Interest / goal Identify circularity levers to activate and barriers to the circular economy for an OEM. Especially if the literature for the business segment is lacking.	Inputs / Data needed Data from interviews	Research Questions How to identify actions to develop a circular economy from an industrial diagnosis?
Context Performed in a case study company (OEM, Manitoux). Limited to a singular company.	Outputs / Meet the operational need(s) List of barriers and levers to activate related to the circularity	Genericity Any manufacturing company. Circular economy only.
Originality In-depth diagnosis of a single company X framework focused on which activity to act X circularity framework design to primarily identify circularity levers from field-based information	Location.s on the CDC 7	

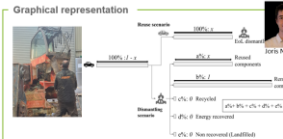
External audit method to identify circularity levers

Fiche #2

Type Method	Graphical representation 	Who? Product and service managers, distributors, decision makers
Interest / goal Provide different insights to identify relevant circularity levers to activate compared to an internal diagnosis or a multi-OEM diagnosis. Also provide information of the current operation of the ecosystem regarding circularity.	Inputs / Data needed Data from interviews + grey literature (circular economy in the industry, stocks and flows of products in the industry)	Research Questions How to identify actions to develop a circular economy from an industrial diagnosis?
Context Diagnosis of an OEM's distributors to help an OEM to identify circularity levers	Outputs / Meet the operational need(s) List of barriers and levers to activate related to the circularity + Data on the stocks and flows of products	Genericity Application to external diagnosis or multi-manufacturers diagnosis
Originality (1) New parameters and method to identify them & (2) application to the heavy vehicle industry	Location.s on the CDC 7	

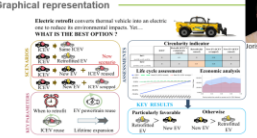
Model for assessing the impacts of equipment dismantling and subsequent component's reusing from a circularity and economic perspective

Fiche #3

Type Model	Graphical representation 	Who? Users (Research engineer to adapt the model to the specific case?), regulators and industrial decision makers
Interest / goal Assess under which condition a circularity strategy occurring during the lifetime of a product is beneficial from an economic, circularity and/or environmental point of view. Therefore, decision makers can decide if they want to activate the circularity levers	Inputs / Data needed For each product: assessment list of components, residual costs, dismantling time, historical mass, age, theoretical lifespan, for each component: mass, material, residual selling price, intermediate recyclability, residual value (book, EOL), for each EOL management pathway (per material type): invasion loops (%), selling price (\$/kg), Dismantling hourly cost and fixed costs, vehicles, transportation costs	Research Questions How to build a model to simulate the circularity, environmental and economic performances of a circularity strategy?
Context This model has been applied to an industrial case study. It is based on heavy vehicles' dismantling experiments performed by a professional dismantler. The model is limited to strategies applicable to a product during its lifetime.	Outputs / Meet the operational need(s) Recyclability and recoverability rate. Under which condition a dismantling met regulatory criteria in terms of recyclability and recoverability. Evaluation of the lifetime extended or prematurely destroyed in the process. Evaluation of the economic viability to dismantle depending on various conditions.	Genericity It can be applied with minor adaptations to other circularity levers activable during a product lifetime such as retrofit, upgrading, reconditioning,...
Originality (1) regarding the dismantling literature by varying several new parameters (2) by overlapping circularity/environmental/economic analysis, using in-depth analysis (such as LCA and LCC rather than experts' evaluations) compared to other scenarios and varying parameters (3) A new circularity indicator	Location.s on the CDC 10 - 12	

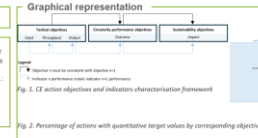
Model for assessing the impacts of electrical retrofitting of a thermal machine from a circularity, environmental and economic perspective

Fiche #4

Type Model	Graphical representation 	Who? Users (Research engineer to adapt the model to the specific case?), regulators and industrial decision makers
Interest / goal Assess under which condition a circularity strategy occurring during the lifetime of a product is beneficial from an economic, circularity and/or environmental point of view. Therefore, decision makers can decide if they want to activate the circularity levers	Inputs / Data needed For new electric, retrofitted and thermic vehicles: LCA data, vehicles' prices, residual values (whole vehicles, dismantled, materials), willingness to pay, lifetime expectancy, moment of the retrofit operation in the vehicle's lifetime.	Research Questions How to build a model to simulate the circularity, environmental and economic performances of a circularity strategy?
Context This model has been applied to an industrial case study. It is based on a real electric retrofit experiment accompanied by an LCA. The model is limited to strategies applicable to a product during its lifetime.	Outputs / Meet the operational need(s) Evaluation of the lifetime extended or prematurely destroyed in the process. Evaluation of the economic viability to retrofit depending on various conditions. Evaluation of the environmental impacts of retrofitting depending on various conditions.	Genericity It can be applied with minor adaptations to other circularity levers activable during a product lifetime such as retrofit, upgrading, reconditioning,...
Originality (1) regarding the electric retrofit literature by measuring and discussing the circularity of the lever and by varying several new parameters (2) by overlapping circularity/environmental/economic analysis, using in-depth analysis (such as LCA and LCC rather than experts' evaluations) compared to other scenarios and varying parameters (3) A new circularity indicator	Location.s on the CDC 10 - 12	

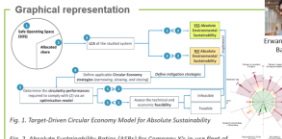
Local CE plans quality model

Fiche #5

Type Methodology	Graphical representation 	Who? Local authority CE officer/local planning officer to guide the local CE planning process and ensure that the considered objectives, indicators and actions do correspond to the criteria set by the Local CE plans quality model.
Interest / goal The objective of this methodology is to assess the quality of local CE plans regarding their formulation of objectives and their reporting of indicators to monitor progress. The analysis aims to determine whether the causal chain of objectives is respected, from tactical objectives (e.g., set to lead innovation projects) to circularity performance objectives (e.g., x of material reused), and ultimately to sustainability objectives (e.g., -x% leCO2 reduced). Ensuring consistency across these levels is essential to verify that achieving objectives at one level contributes to reaching those at the next, and therefore that the actions listed in local CE plans effectively support improvements in sustainability.	Inputs / Data needed Formulation of CE plan actions, indicators, and objectives to be manually assessed using the proposed quality model (de Bartol et al., 2025, in review).	Research Questions What are the current planning processes and types of action, objectives and indicators?
Context The methodology is designed to be applied only at local authority level.	Outputs / Meet the operational need(s) During the design of local CE plans, the proposed approach enables verification that the selected objectives and indicators form a complete causal chain. This ensures that plans are designed in a way that can genuinely contribute to achieving ultimate environmental and socio-economic sustainability objectives.	Genericity The causal chain logic could be applied to an industrial context, however it is not an option currently explored.
Originality First proposed local CE plans quality model. Based on previous work by Balzacq (2024) on mobility plans.	Location.s on the CDC 4, 6, 8, 9, 10, 11, 12	

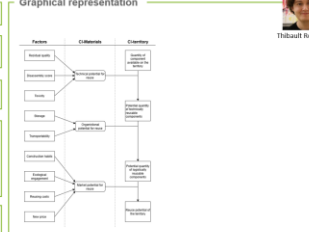
Target-Driven Circular Economy Model for Absolute Sustainability

Fiche #6

Type Model	Graphical representation 	Who? It is designed for multiple users from the strategic level to product designers.
Interest / goal This model enables the adoption of a systematic target-driven life cycle engineering approach to support company decision-making. The model sets absolute sustainability thresholds for products or services to determine whether they are absolutely sustainable. If not, it identifies the best combination of strategies, including circular economy options, that could enable compliance. By projecting future changes in background systems such as energy mixes and transport technologies, it accounts for the fact that strategies unsustainable today may become viable tomorrow, and vice versa, thereby providing essential guidance for decision-makers.	Inputs / Data needed World bank, International Monetary fund, Input-Output tables (Exiobase 3.9.6.), National and industry databases (Eurostat, OECD) + pymrio and premise python libraries + ecosystem + usual data needs for LCA	Research Questions How to set absolute environmental thresholds and assess the extent to which and the parameters within which circularity strategies may (or not) contribute to complying with the set thresholds?
Context The model is designed to be applied at the company level to any type of product or service. It is being tested on MPF scanners and Wind turbines.	Outputs / Meet the operational need(s) Set absolute environmental thresholds for a company's products + define CE parameters (% recycling/reuse/repair, Lvm, etc.) to comply with set thresholds	Genericity An extension to local authorities could also be envisaged, as the model is able to define absolute sustainability thresholds for any function/infrastructure/human needs. It could therefore be applied, for example, at the scale of local authorities to domains such as transport, housing, etc.
Originality This model builds on the first systematic function-based absolute sustainability framework, which enables the projection of absolute sustainability thresholds into the future under conditions of uncertainty. It also constitutes the first optimization model designed to identify circular economy parameters that can enable a system to achieve absolute sustainability.	Location.s on the CDC 1, 2, 4, 5, 6, 7, 8, 10, 11, 12	

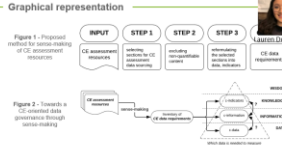
Territorial Reuse Architecture Model (TRAM)

Fiche #7

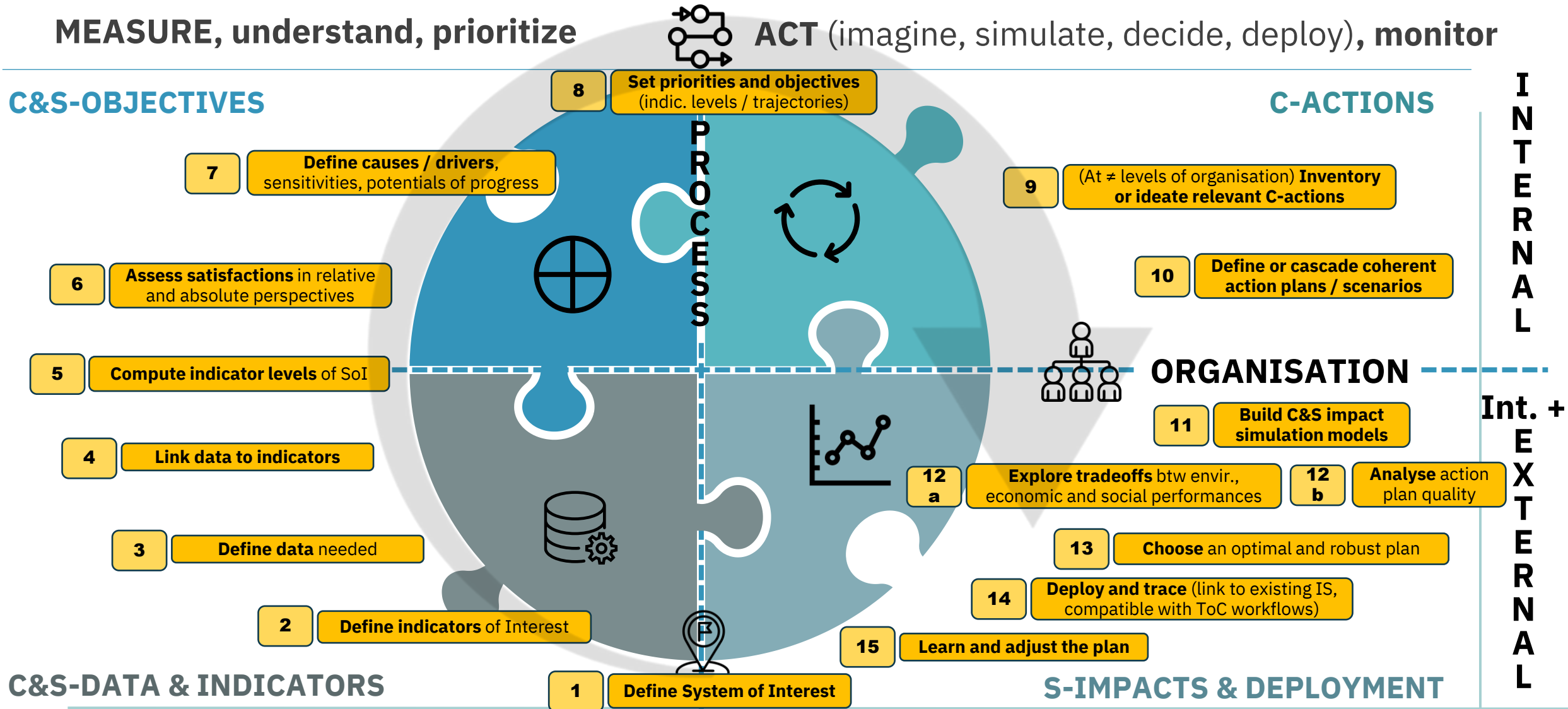
Type Model & Indicators	Graphical representation 	Who? Different actors stand to benefit from the use of reuse-oriented indicators. Component and new material producers can improve design strategies by integrating reuse potential early on, while policymakers and public authorities can use these insights to develop better guidelines, identify reuse bottlenecks, and support emerging markets. Local authorities are better equipped to plan infrastructure and compare reuse potential with actual practices, and storage platform owners gain clarity on component-specific storage requirements.
Interest / goal Provide an overview on the processes that occur during the reuse process of a component and measure its impacts on circularity performances.	Inputs / Data needed Only at territorial scale (commune, department, region). Local authorities and territorial actors' scope.	Research Questions How can material stock modelling be adapted to work with limited data across different territories? How can territorial activities be considered in a model to simulate reuse of building components? To what extent can such a model support decision-making in circular urban transitions?
Context Only at territorial scale (commune, department, region). Local authorities and territorial actors' scope.	Outputs / Meet the operational need(s) The process of linking activities with the reuse potential could be adapted to a specific product at company's level.	Genericity The process of linking activities with the reuse potential could be adapted to a specific product at company's level.
Originality Includes reuse activities in the circularity measurement. Multi scale aggregation: from component to territory. Modelling of circularity processes impact on circularity	Location.s on the CDC 1, 2, 3, 4	

Sense-making approach for CE assessment resources

Fiche #8

Type Approach	Graphical representation 	Who? The approach should support CE practitioners, sustainability managers, data scientists, and engineers in companies who need to measure CE for reporting or decision-making across the product lifecycle.
Interest / goal Translate heterogeneous CE assessment resources into clear and operational CE data requirements that support corporate data sourcing, indicator implementation, and CE monitoring.	Inputs / Data needed CE assessment resources: documents that are produced by CE-enablers (academia, policymakers, industry). Examples range from academic frameworks to grey literature, including regulations, standards, certifications, and corporate documents.	Research Questions How can existing CE assessment resources be leveraged to facilitate corporate data sourcing for CE monitoring?
Context Industries face increasing regulatory and strategic pressures to measure circularity, but existing CE frameworks offer limited guidance on identifying the specific data required. CE assessment resources contain valuable guidance but are not structured for data sourcing purposes.	Outputs / Meet the operational need(s) CE data requirements: identified data points to collect or indicators to facilitate corporate data sourcing to measure CE.	Genericity The approach has been applied to the CE assessment resources, but broader testing is required since many documents with varied structure and content fall within this category. Additional validation is needed across sectors and document types.
Originality Sense-making has not been previously explored for Circular Economy in particular, as it was defined in the context of sustainability in a broader sense.	Location.s on the CDC 3, 1	

A functional view of the CDC

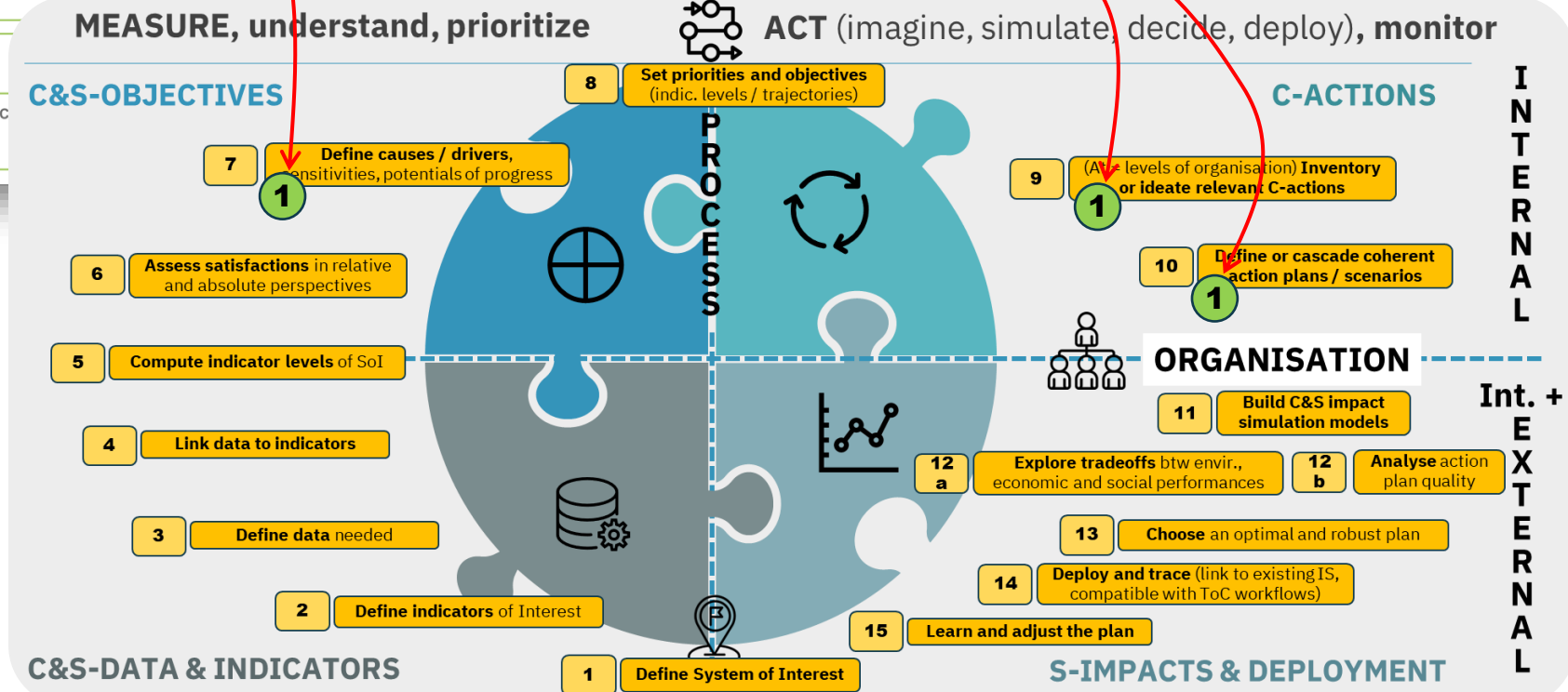


Locate 14 CE-models in relation to the 15 functions of the CDC

Internal audit method to identify circularity levers based on EMF building blocks

Fiche #1

Type Method / Framework	Graphical representation
Interest / goal Identify circularity levers to activate and barriers to the circular economy for an OEM. Especially if the literature for the business segment is lacking.	
Context Performed in a case study company (OEM: Manitou). Limited to a singular company.	Inputs / Data needed Data from interviews
Who? Product and service managers, decision makers	Outputs / Meet the operational need(s) List of barriers and levers to activate related to the circularity
Research Questions How to identify actions to develop a circular economy from an industrial diagnosis?	
Genericity Any manufacturing company. Circular economy only.	Originality In-depth diagnosis of a single company X framework focused on which activity to act X circularity framework design to primarily identify circularity levers from field-based information
Location.s on the CDC 7	



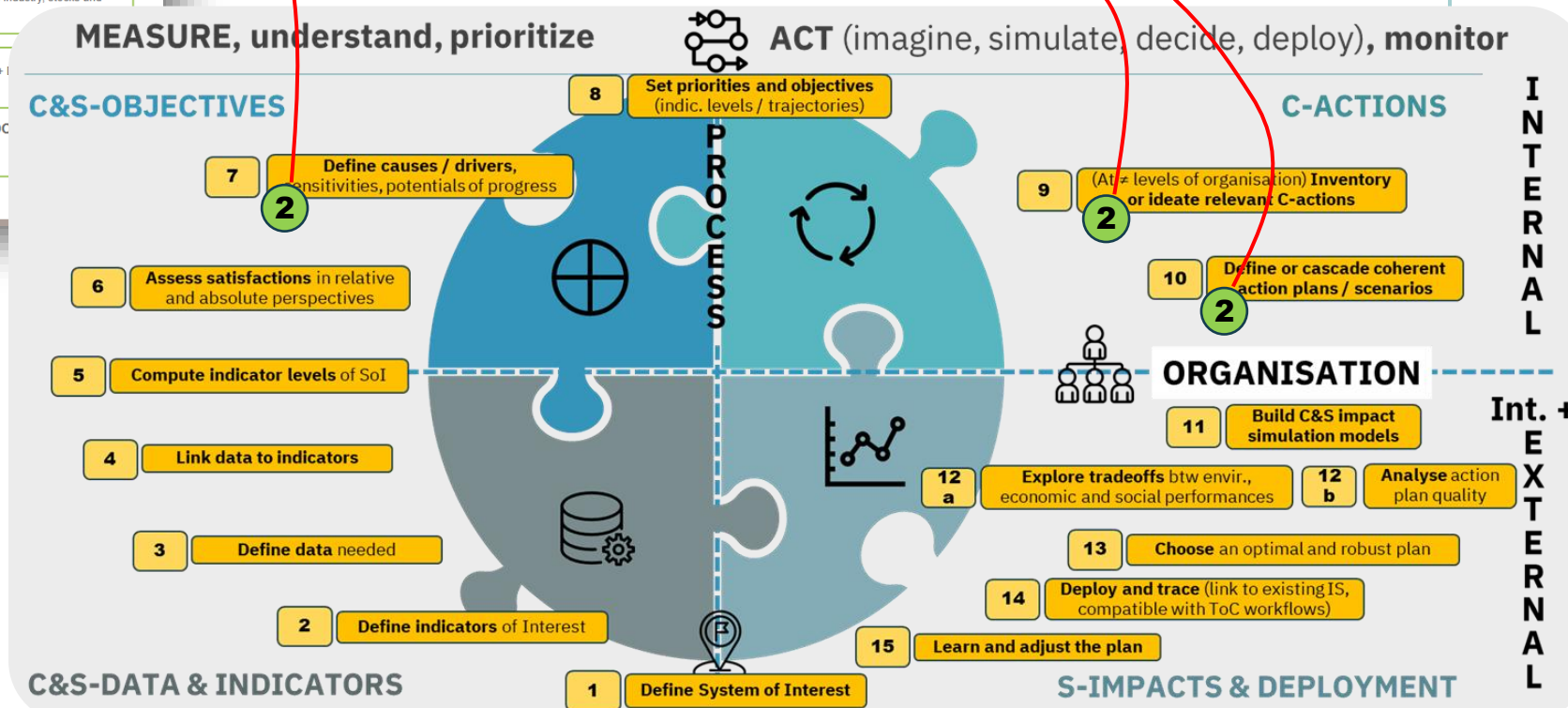
Locate 14 models in relation to the 15 functions of the CDC

External audit method to identify circularity levers

Fiche #2

Type Method	Graphical representation
Interest / goal Provide different insights to identify relevant circularity levers to activate compared to an internal diagnosis or a multi-OEM diagnosis. Also provide information of the current operation of the ecosystem regarding circularity.	
Context Diagnosis of an OEM's distributors to help an OEM to identify circularity levers	
Who? Product and service managers, distributors, decision makers	Inputs / Data needed Data from interviews + grey literature (circular economy in the industry, stocks and flows of products in the industry)
Research Questions How to identify actions to develop a circular economy from an industrial diagnosis?	Outputs / Meet the operational need(s) List of barriers and levers to activate related to the circularity + flows of products
Genericity Application to external diagnosis or multi-manufacturers diagnosis	Originality (1) New parameters and method to identify them & (2) application to the heavy vehicle industry
Location.s on the CDC 7	

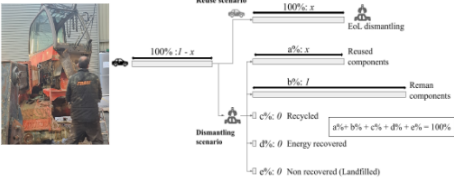
3

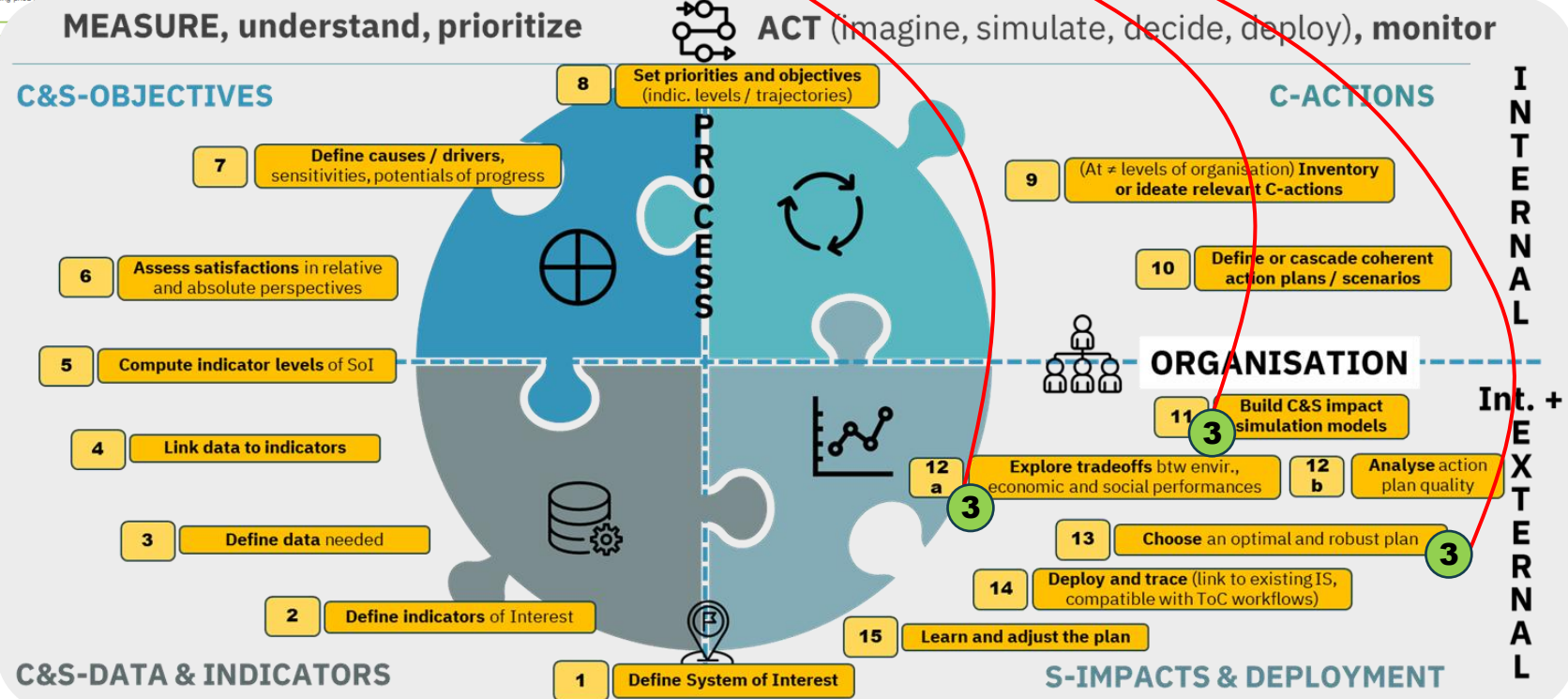


Locate 14 models in relation to the 15 functions of the CDC

Model for assessing the impacts of equipment dismantling and subsequent component's reusing from a circularity and economic perspective

Fiche #3

Type Model	Graphical representation 
Interest / goal Assess under which condition a circularity strategy occurring during the lifetime of a product is beneficial from an economic, circularity and/or environmental point of view. Therefore, decision makers can decide if they want/can to activate the circularity levers	
Context This model has been applied to an industrial case study. It is based on heavy vehicles' dismantling experiments performed by a professional dismantler. The model is limited to strategies applicable to a product during its lifetime.	
Who? Users (Research engineer to adapt the model to the specific case?), regulators and industrial decision makers	Inputs / Data needed For each product assessed: list of components, residual value, dismantling time, theoretical mass, age, theoretical lifespan. For each component: mass, materials, 2nd-hand selling price, remanufacturing, revaluation option (resale, EoL). For each EoL management pathway (per material type): revelation loops (%), selling price (€), hourly costs and fixed costs, subsidies, transportation costs.
Research Questions How to build a model to simulate the circularity, environmental and economic performances of a circularity strategy?	Outputs / Meet the operational need(s) Recyclability and recoverability rate. Under which conditions a dismantling criteria in terms of recyclability and recoverability. Evaluation of the life prematurely destroyed in the process. Evaluation of the economic value depending on various conditions.
Genericity It can be applied with minor adaptations to other circularity levers activable during a product lifetime such as retrofit, upgrading, reconditioning,....	Originality (1) regarding the dismantling literature by varying several new parameters (2) by overlapping circularity/environmental/economic analysis, using in-depth analysis (such as LCA and LCC rather than experts evaluation) compared to other scenarios and varying parameters (3) A new circularity indicator
	Location. 10 - 12



Locate 14 models in relation to the 15 functions of the CDC

Model for assessing the impacts of electrical retrofitting of a thermal machine from a circularity, environmental and economic perspective

Fiche #4

Type

Model

Interest / goal

Assess under which condition a circularity strategy occurring during the lifetime of a product is beneficial from an economic, circularity and/or environmental point of view. Therefore, decision makers can decide if they want/can to activate the circularity levers.

Context

This model has been applied to an industrial case study. It is based on a real electric retrofit experiment accompanied by an LCA. The model is limited to strategies applicable to a product during its lifetime.

Who?

Users (Research engineer to adapt the model to the specific case?), regulators and industrial decision makers

Research Questions

How to build a model to simulate the circularity, environmental and economic performances of a circularity strategy?

Genericity

It can be applied with minor adaptations to other circularity levers activable during a product lifetime such as dismantling, upgrading, reconditioning,...

Originality

(1) regarding the electric retrofit literature by measuring and discussing the circularity of this lever and by varying several new parameters (2) by overlapping circularity/environmental/economic analysis, using in-depth analysis (such as LCA and LCC rather than experts' evaluation) compared to other scenarios and varying parameters(3) A new circularity indicator

Location.s

10 - 12

Graphical representation

Electric retrofit converts thermal vehicle into an electric one to reduce its environmental impacts. Yet... WHAT IS THE BEST OPTION?

Circularity indicator

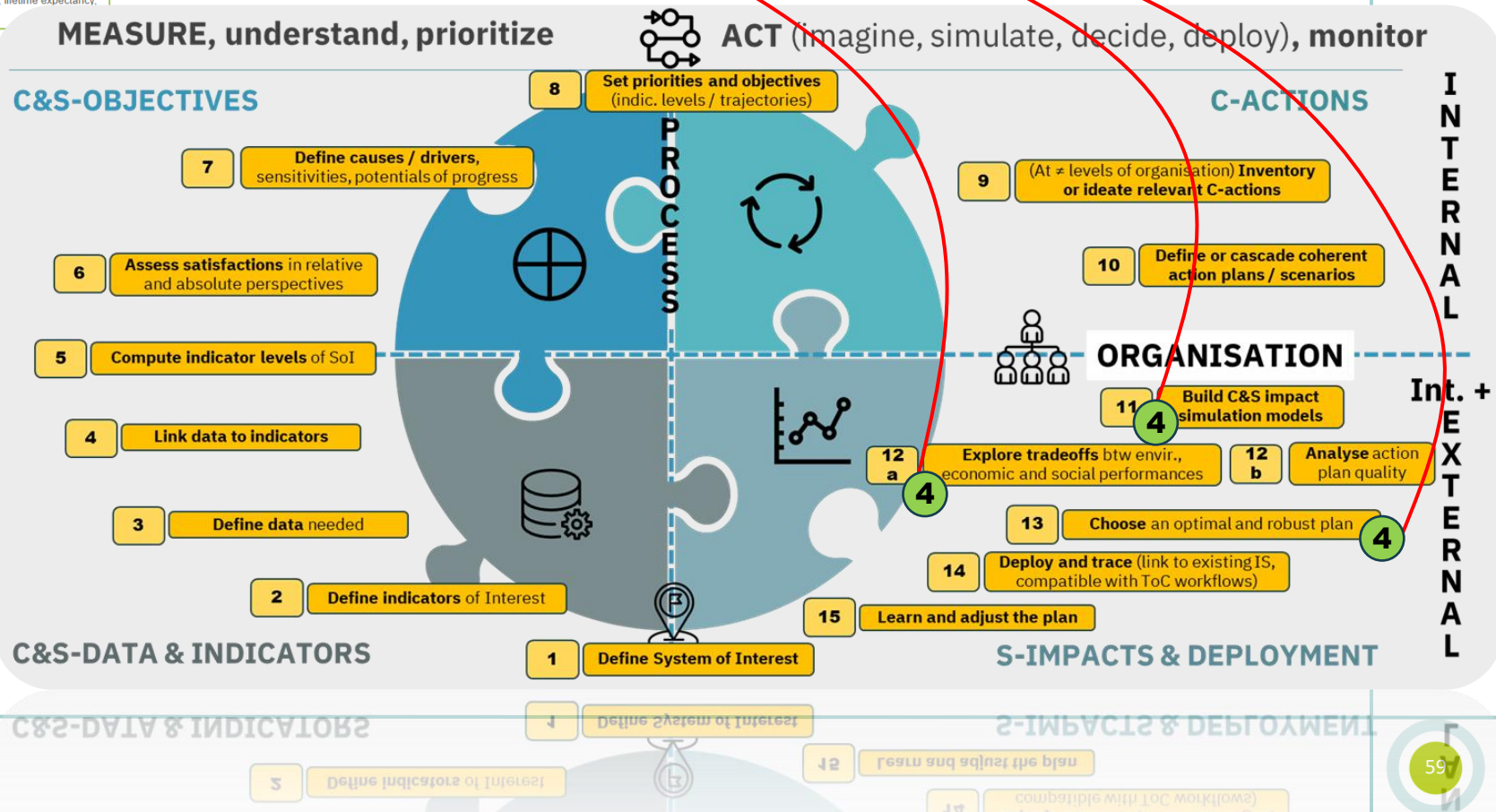
Scenario	Same ICEV	New ICEV	Retrofitted EV	New EV
Life cycle assessment	High	High	Low	Low
Economic analysis	High	High	Low	Low

KEY RESULTS

Particularly favorable: Retrofitted EV, New EV
Otherwise: New EV, Retrofitted EV

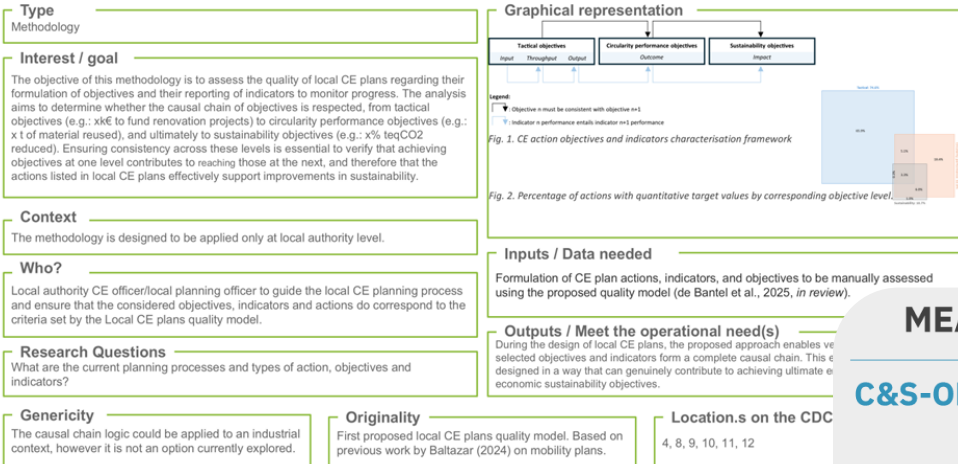
KEY PARAMETERS

When to retrofit: ICEV rise, EV powertrain rise, Lifetime expansion



Locate 14 models in relation to the 15 functions of the CDC

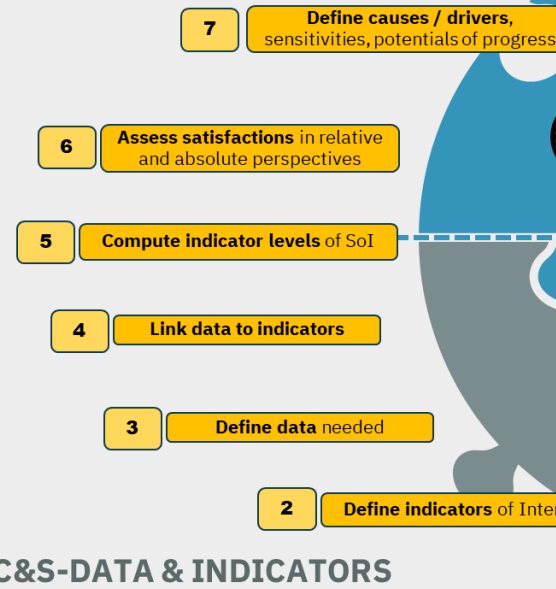
Local CE plans quality model



Fiche #5

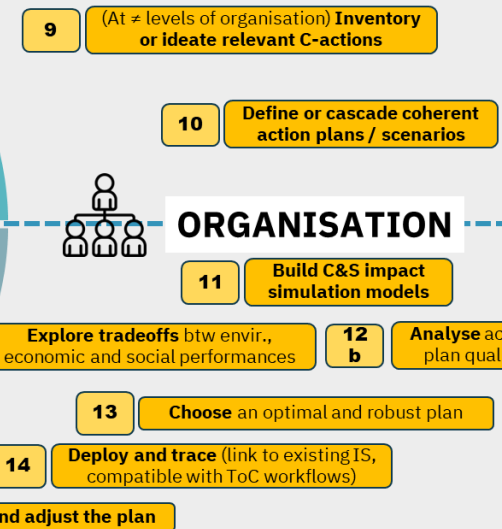
MEASURE, understand, prioritize

C&S-OBJECTIVES



ACT (imagine, simulate, decide, deploy), monitor

C-ACTIONS



ORGANISATION

INTERNAL
Int. + EXTERNAL

Locate 14 models in relation to the 15 functions of the CDC

Target-Driven Circular Economy Model for Absolute Sustainability

Fiche #6

Type
Model

Interest / goal

This model enables the adoption of a systematic target-driven life cycle engineering approach to support company decision-making. The model sets absolute sustainability thresholds for products or services to determine whether they are absolutely sustainable. If not, it identifies the best combination of strategies, including circular economy options, that could enable compliance. By projecting future changes in background systems such as energy mixes and transport technologies, it accounts for the fact that strategies unsustainable today may become viable tomorrow, and vice versa, thereby providing essential guidance for decision-makers.

Context

The model is designed to be applied at the company level to any type of product or service. It is being tested on MRI scanners and Wind turbines.

Who?

It is designed for multiple users from the strategic level to product designers.

Research Questions

How to set absolute environmental thresholds and assess the extent to which and the parameters within which circularity strategies may (or not) contribute to complying with the set thresholds?

Genericity

An extension to local authorities could also be envisaged, as the model is able to define absolute sustainability thresholds for any function fulfilling human needs. It could therefore be applied, for example, at the scale of local authorities to domains such as transport, housing, etc.

Originality

The model builds on the first systematic function-based absolute sustainability framework, which enables the projection of absolute sustainability thresholds into the future under conditions of uncertainty. It also constitutes the first optimisation model designed to identify circular economy parameters that can enable a system to achieve absolute sustainability.

Graphical representation

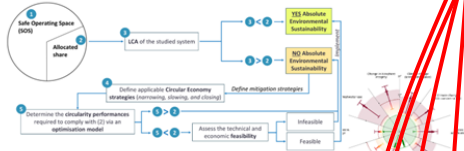


Fig. 1. Target-Driven Circular Economy Model for Absolute Sustainability

Fig. 2. Absolute Sustainability Ratios (ASRs) for Company X's in-use fleet of Product Y in Year N.

Inputs / Data needed

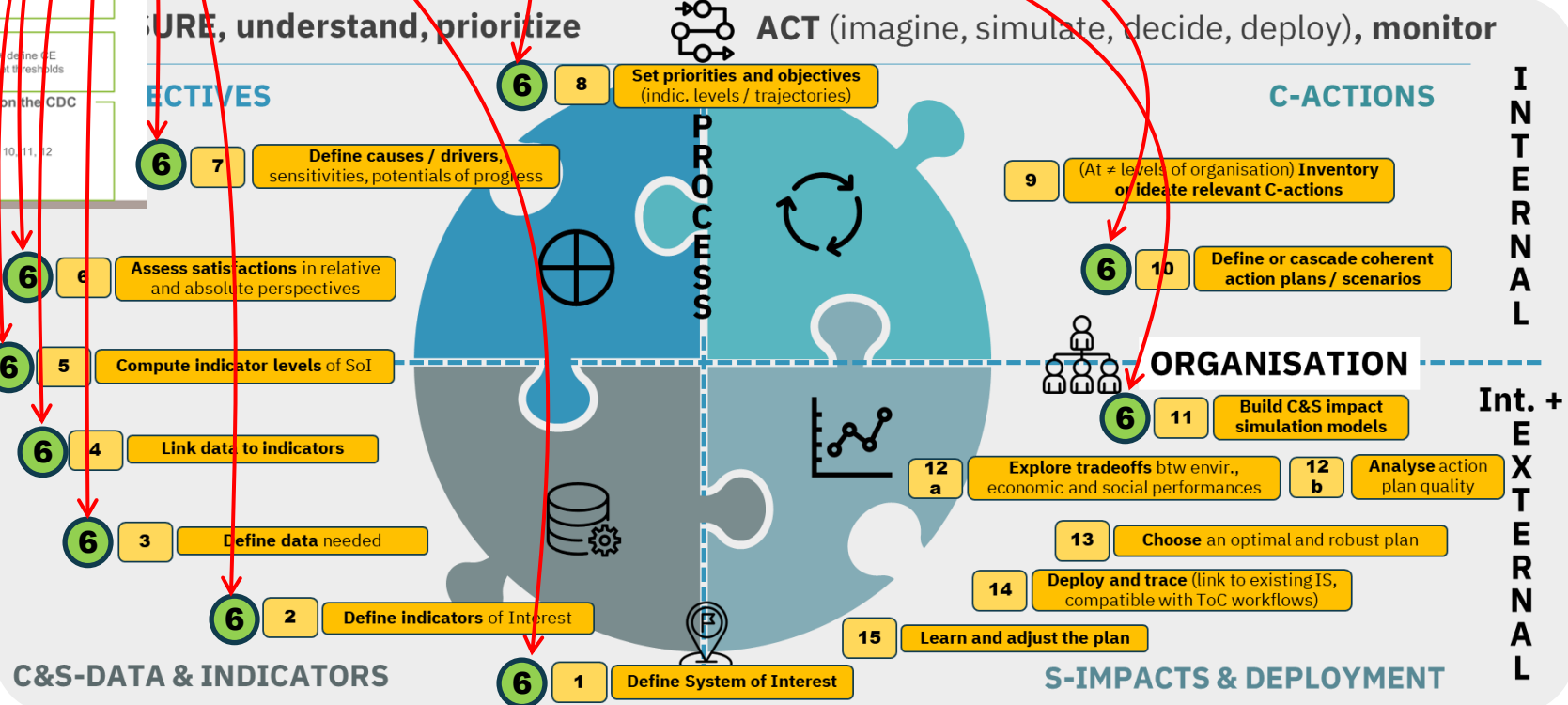
World bank, International Monetary fund, Input-Output tables (Exiobase 3.9.6), National and industry databases (Eurostat, OECD) + pymrio and promise python libraries + ecoinvent + usual data needs for LCAs

Outputs / Meet the operational need(s)

Set absolute environmental thresholds for a company's products + define CE parameters (% recycling/reuse/reman, Lkm, etc.) to comply with set thresholds

Locations on the CDC

1, 2, 4, 5, 6, 7, 8, 10, 11, 12



Fiche #7

- Originality**
 - Includes reuse activities in the circularity measurement.
 - Multi scale agrégation: from component to territory.
 - Modélisation of circularity processes impact on circularity

```

graph TD
    subgraph Factors
        P1[Product quality]
        P2[Discounting costs]
        P3[Toxicity]
        P4[Storage]
        P5[Transportability]
        P6[Distribution habits]
        P7[Ecological engagement]
        P8[Rising costs]
        P9[New price]
    end

    subgraph CIMaterials [CI Materials]
        M1[Technical potential for reuse]
        M2[Operational potential for reuse]
    end

    subgraph CITerritory [CI Territory]
        T1[Quantity of components in service]
        T2[Potential quantity of technology reusable components]
        T3[Potential quantity of materials reusable components]
        T4[Reuse potential of the territory]
    end

    P1 --> M1
    P2 --> M1
    P3 --> M1
    P4 --> M2
    P5 --> M2
    P6 --> M1
    P7 --> M1
    P8 --> M1
    P9 --> M1

    M1 --> T1
    M1 --> T2
    M1 --> T3
    M1 --> T4

    M2 --> T1
    M2 --> T2
    M2 --> T3
    M2 --> T4

    T1 --> T2
    T2 --> T3
    T3 --> T4
  
```

Location.s on the Cr

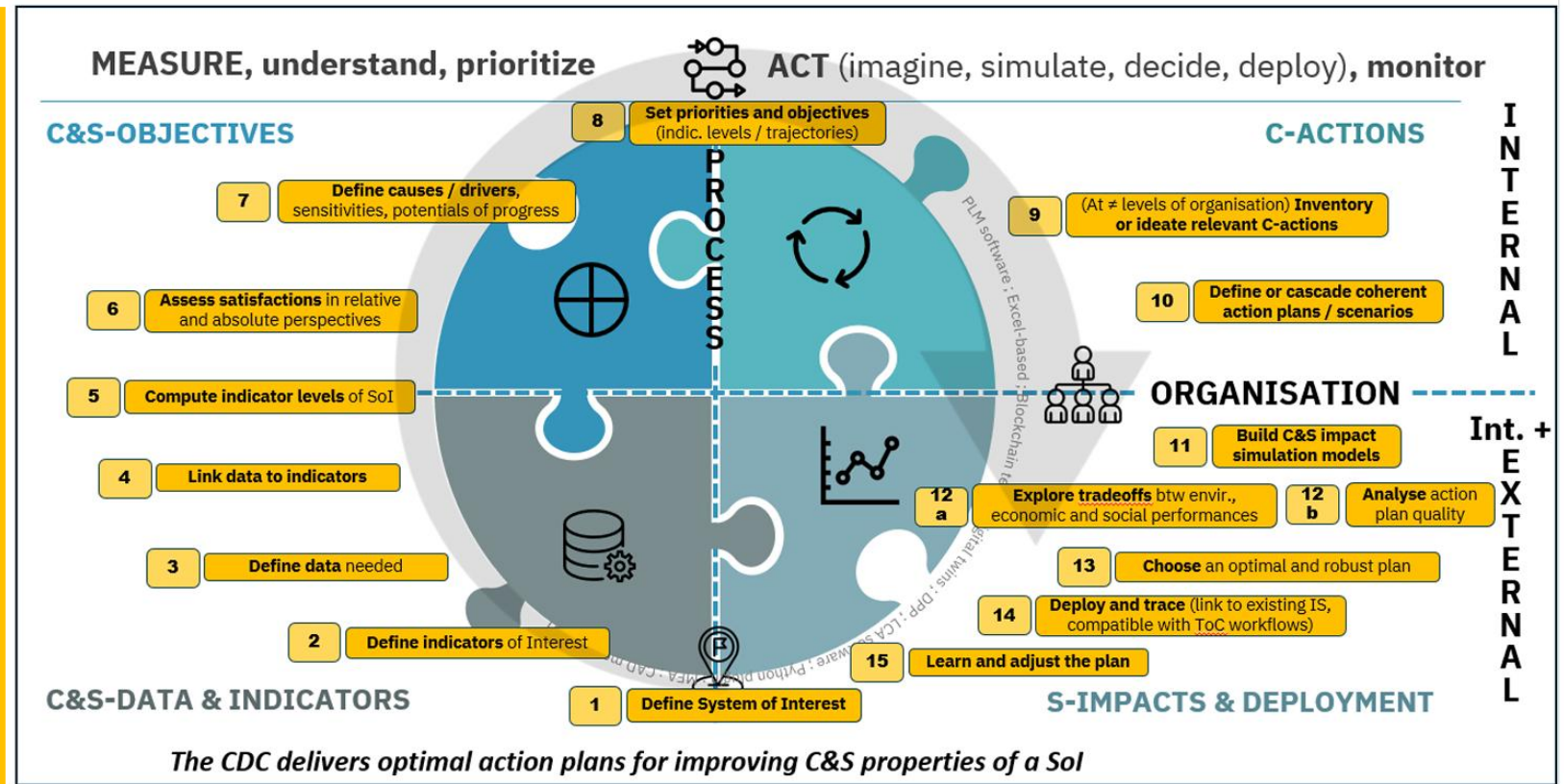


Starting with the 15-step functional view of the CDC

Structure the
Workflow of a
CDC study (SADT
representation)

Define an UML
Data Model

Generalize CE Models
and use them as
computing processes

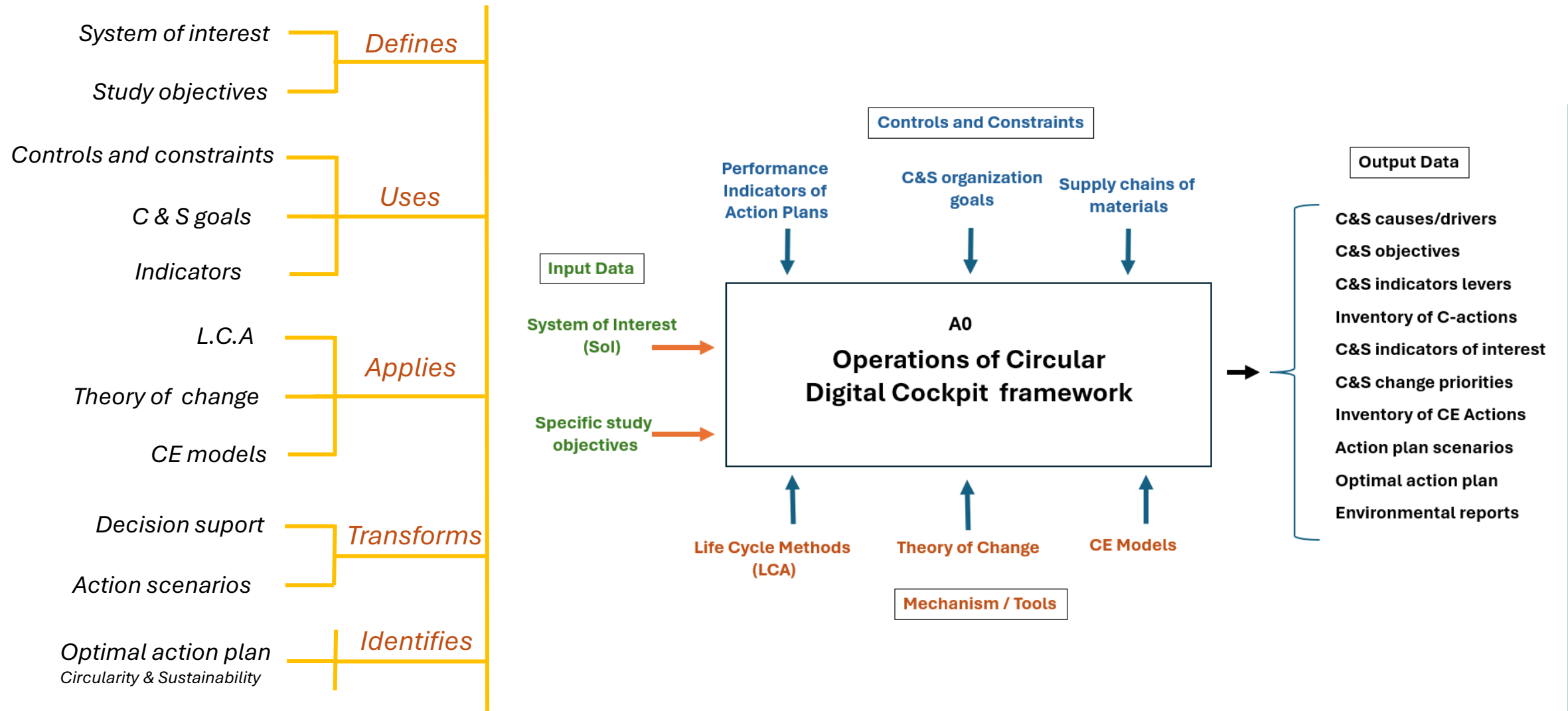


Goals

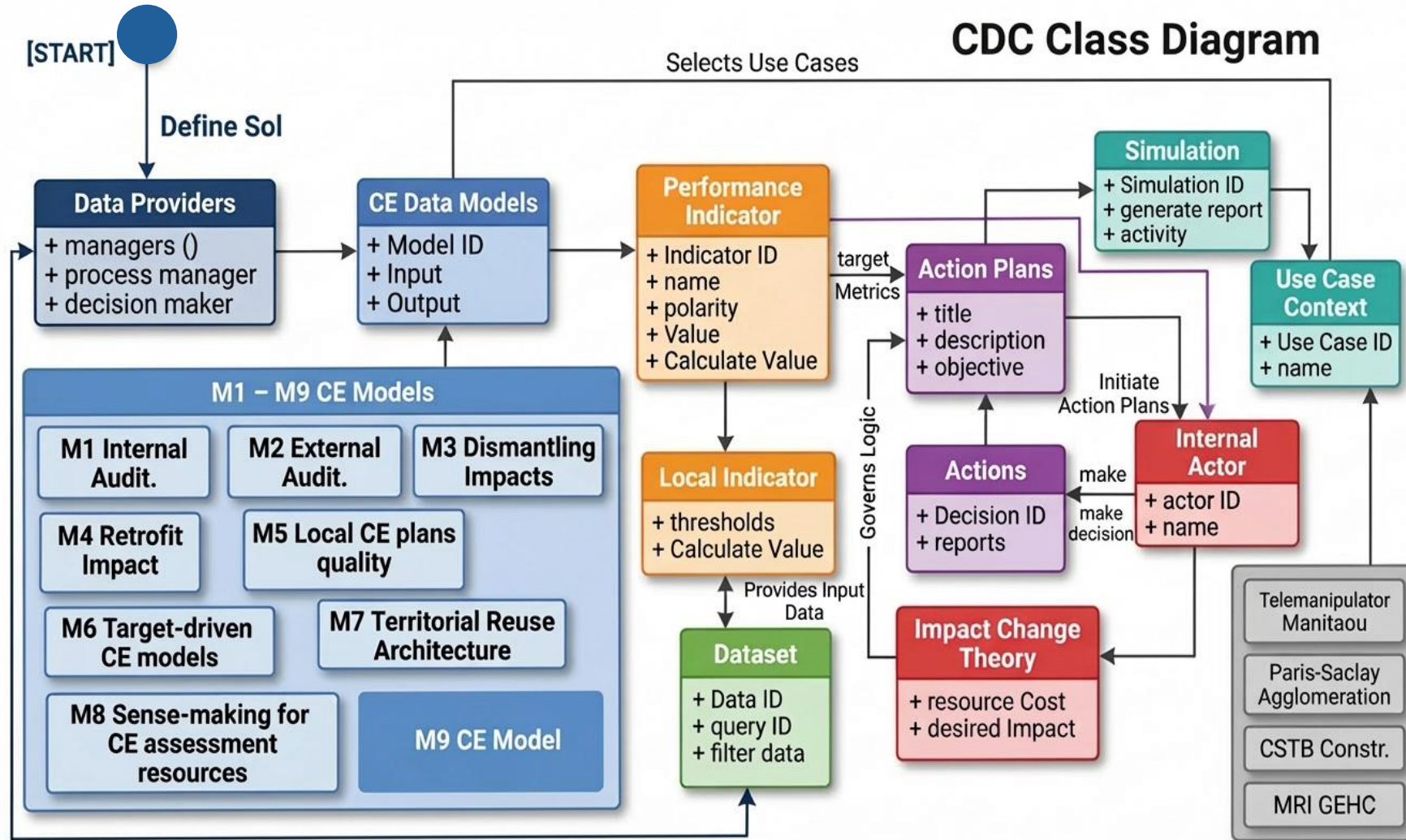
Test on diverse
use cases



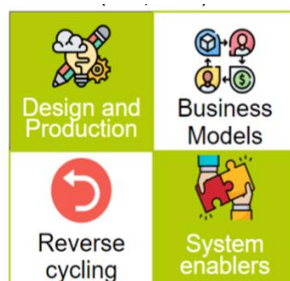
Structured Analysis and Design Technique (SADT) representation of the CDC 15 functional stages



UML Data Model (to evolve...)



Generalize CE Models in order to use them as computing processes of the CDC



1/ Internal audit



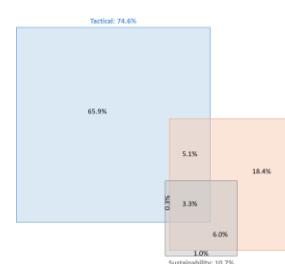
2/ External audit



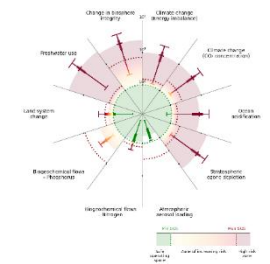
3/ Dismantling impacts



4/ Retrofit impacts



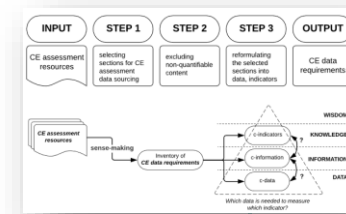
5/ Local CE plans quality



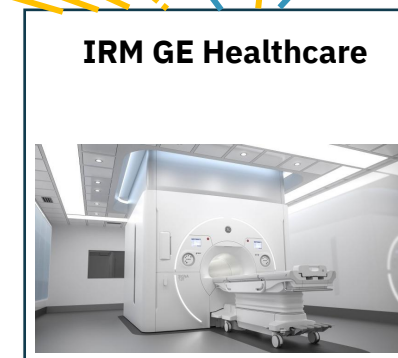
6/ Target-driven CE model for absolute sust.



7/ Territorial Reuse Architecture



8/ Sense-making for CE assessment resources



YES - possibly analyzing the best practices in terms of CE actions locally. Variants and invariants.

YES - Not a vehicle. Consider different types of upgrading, time to retrofit, extend the lifetime or not.

Quick check of causal link.

Allocation keys easy to compute.

In case a company wants to control the internal flow of certain parts or material.

Link local documents, call for tender, and CE&S indicators.

MSc projects

MSc information conditions in this sector.



Thank you

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