Eco-conception de procédés de transformation

Caroline Pénicaud

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Séminaire InCoM 2016

CAROLINE PÉNICAUD

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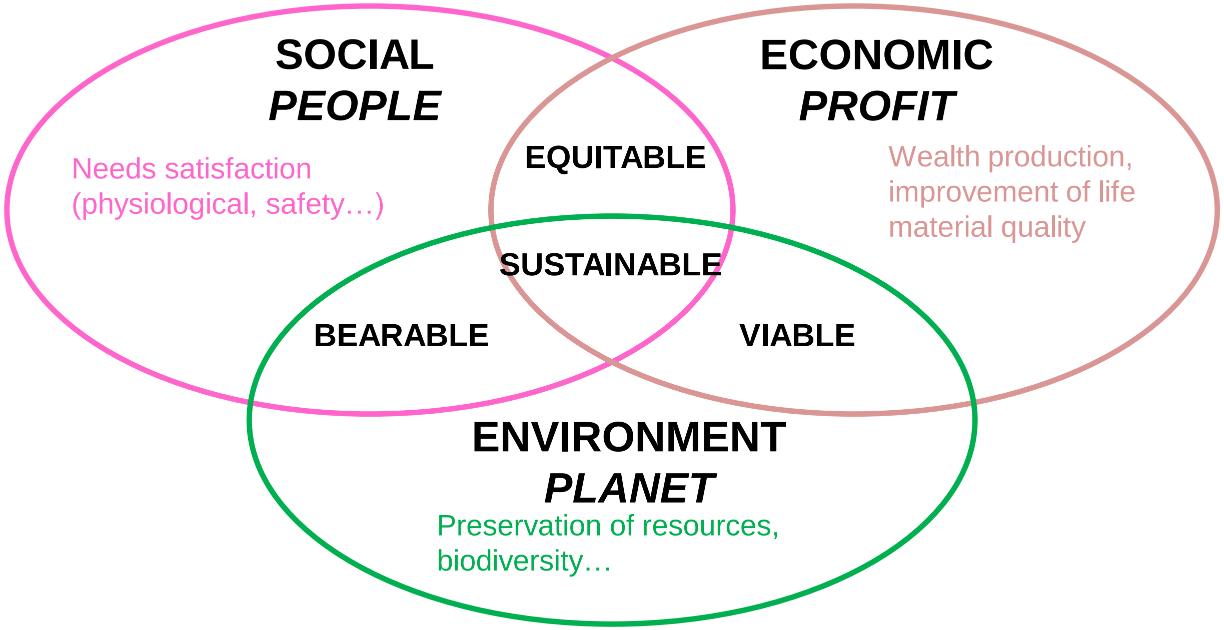
_01 CONTEXT

Sustainable Development

From Brundtland report 1987

- Development which
  - meets the needs of current generations without compromising the ability of future generations to meet their own needs
  - takes equally into account the following dimensions: ecology, economy, and social



Sustainable Development

IPAT principle

$$I = P \cdot A \cdot T$$

Weiszäcker 1995

IMPACT
resource depletion, waste accumulation…

PEOPLE
size of the human population

AFFLUENCE
level of consumption by that population

TECHNOLOGY
processes used to obtain resources and transform them into useful goods and wastes

$$\left.\begin{array}{l} P_{2030} = 2 \cdot P_{2008} \\ A_{2030} = 2 \cdot A_{2008} \end{array}\right\}$$

If $I_{2030} \sim I_{2008}$ => $T_{2030} = T_{2008} / 4$

↓ Reality

Technology is important! $T_{2030} = T_{2008} / 10$

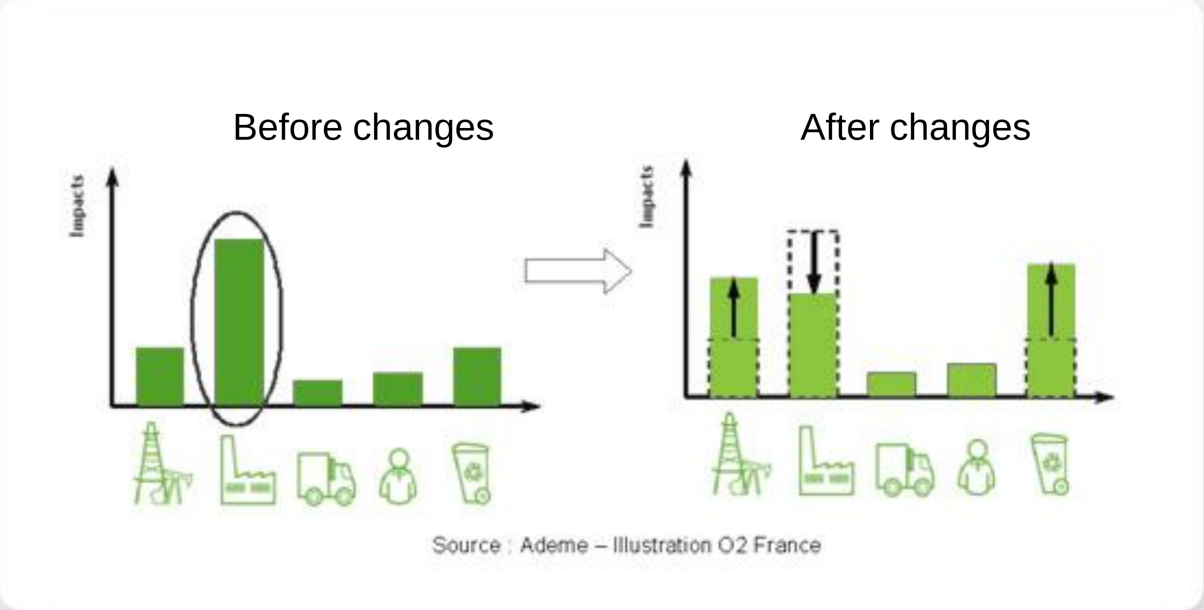
Life Cycle Thinking

- Considering all the phases of the product/service's life
  - « from cradle to grave »
  - « from cradle to cradle »
  - « from cradle to gate »

Life Cycle Thinking

Impact transfer

Impact transfer: Shift of impact from one life cycle stage to another(others) one(s).

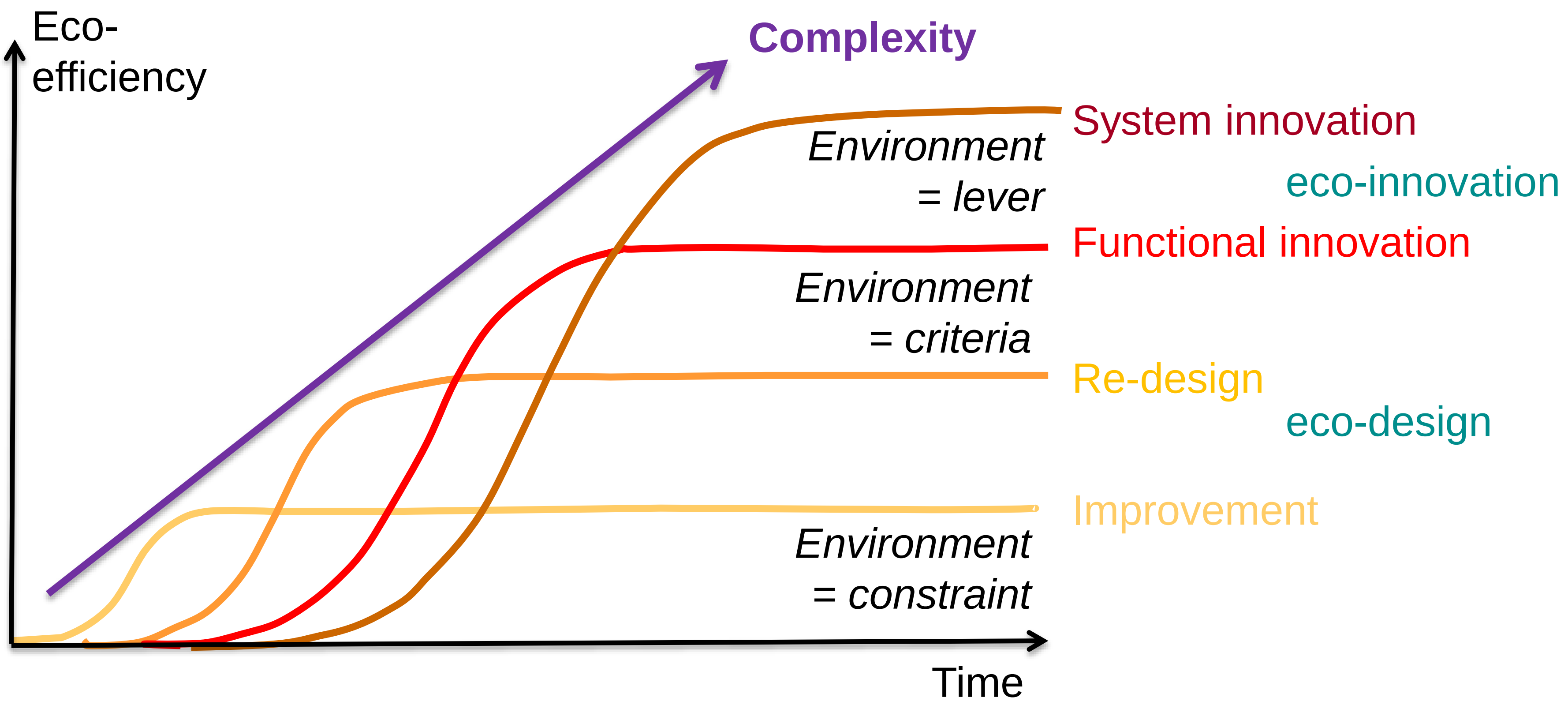


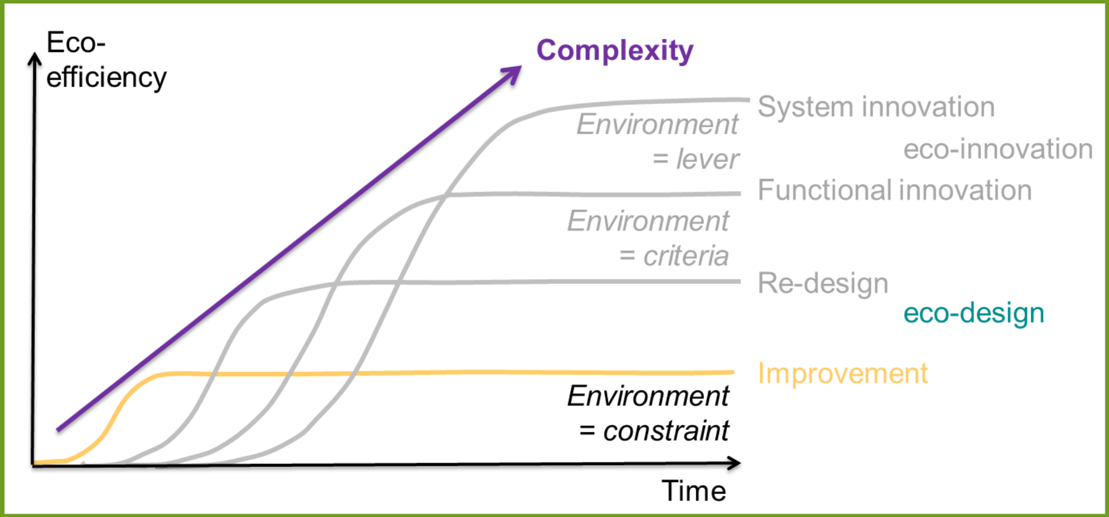
The impact of transformation stage has been lowered **BUT** total impact has been increased !!!

This is not environmental improvement…

From eco-improvement to eco-innovation

From Charter & Chick 1997, Brezet & van Hemel 1997





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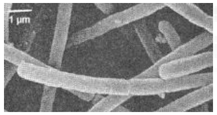
PROCESS IMROVEMENT

Unit operation level

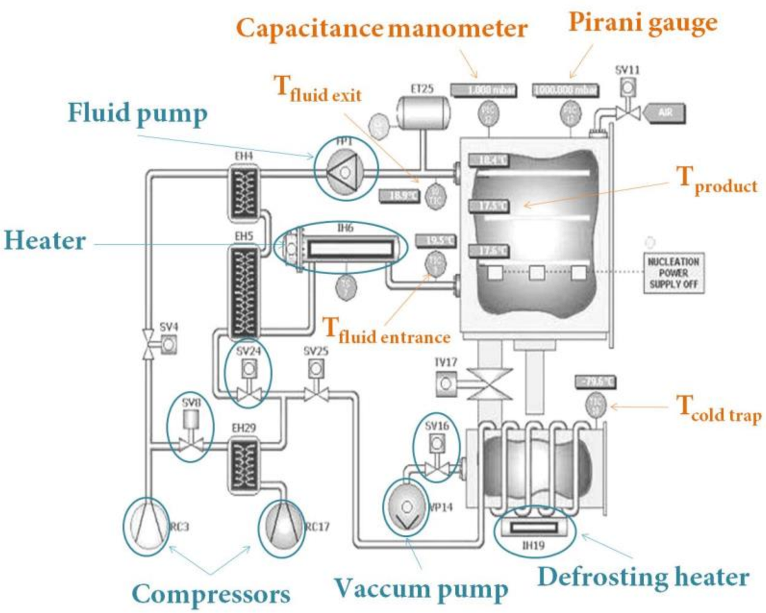
Optimization

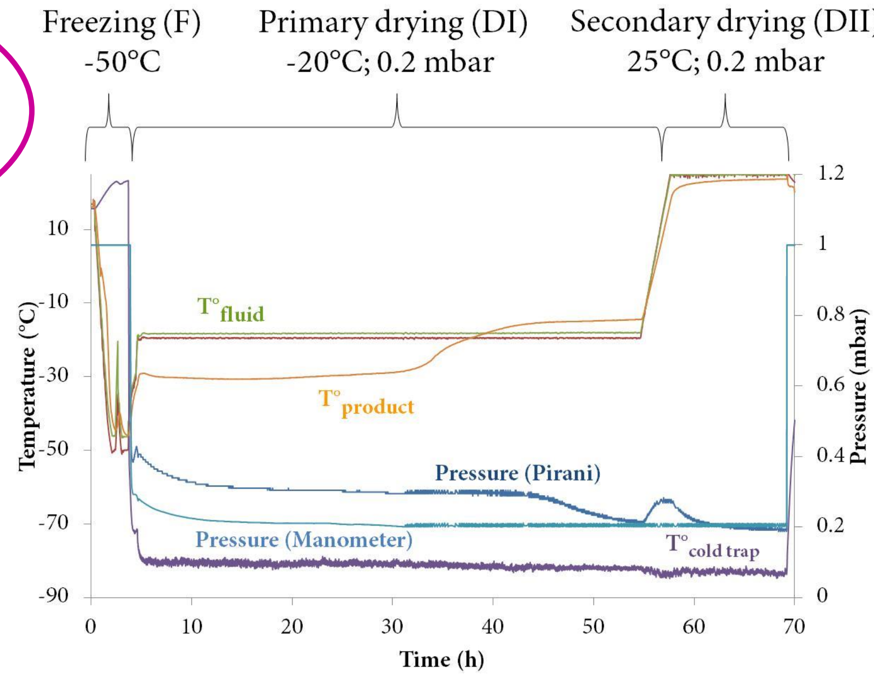
Freeze-drying of lactic acid bacteria



LyoBeta special
(Telstar, Terrassa, Spain)

Product parameters
Viability
Acidifying activity
Structure





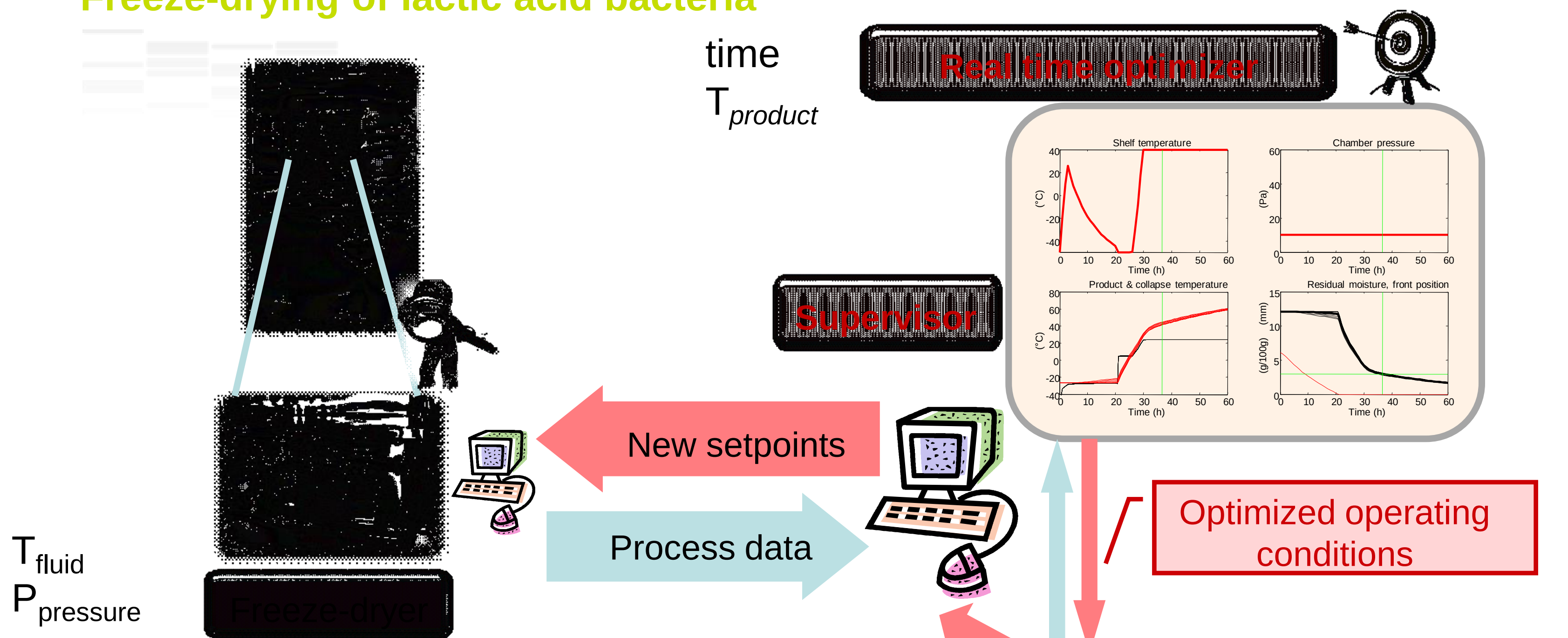
Process operating conditions
T_{fluid}, $T_{product}$ and $T_{cold\ trap}$
Pressure
Time

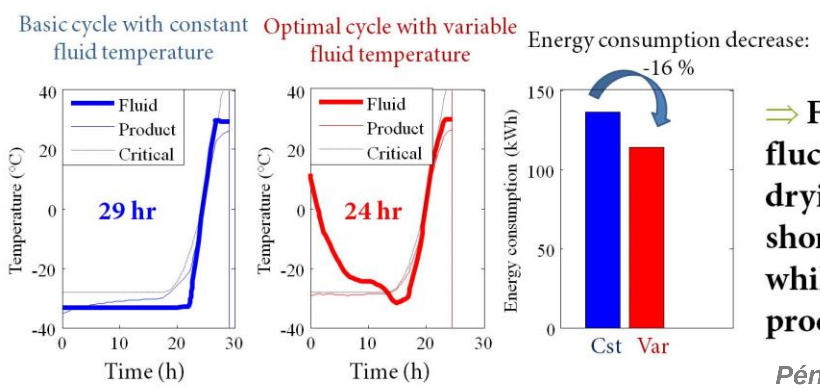
Mathematical model
Linear relationship

Process apparent energy consumptions
- Main components + Fans dedicated to compressors
- General supply

Optimization

Freeze-drying of lactic acid bacteria

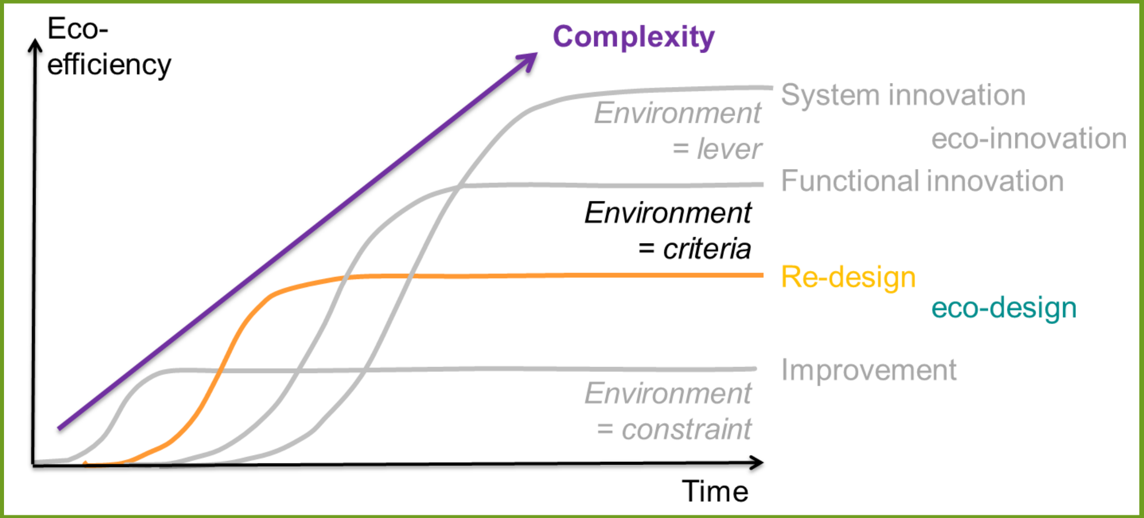




⇒ **Fluid temperature fluctuation in primary drying saves energy by shortening cycle duration, while maintaining the product quality**

Pénicaud et al. 2014

Trelea et al. 2009, Passot et al. 2011, Antelo et al. 2012



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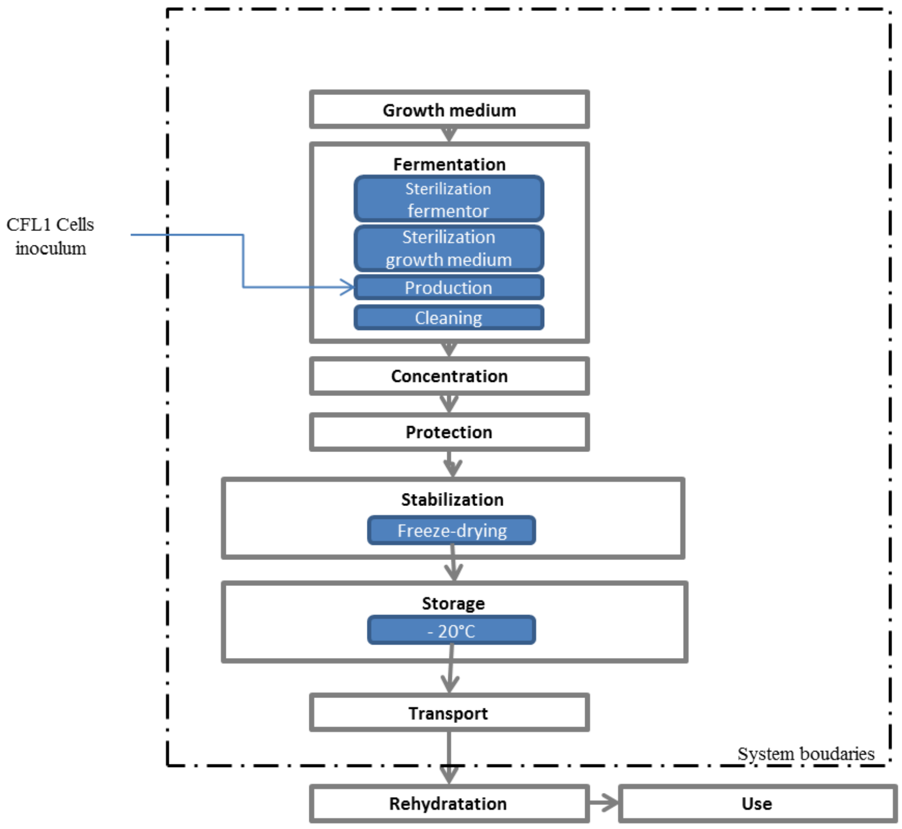
PROCESS ECO-DESIGN

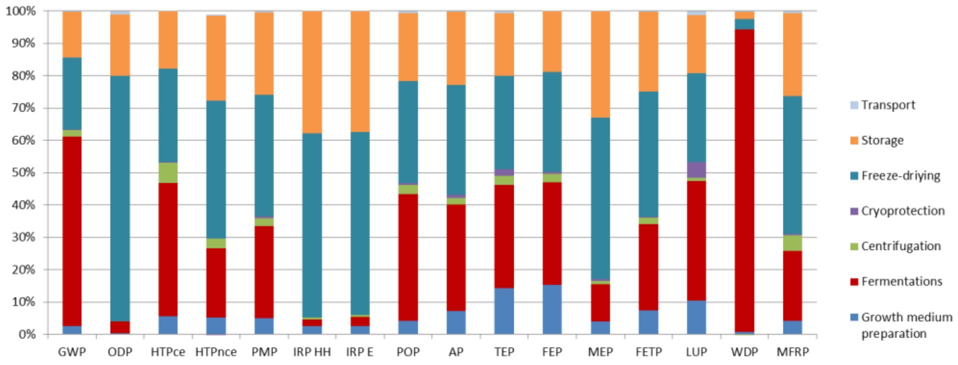
System level (plant, production process chain)

Life Cycle Assessment

Freeze-drying of lactic acid bacteria

- UF : Production, protection, stabilisation et stockage de 3 kg de bactéries lactiques
- Échelle d'étude : Pilote
- ILCD 2011 method





1 year storage -20°C

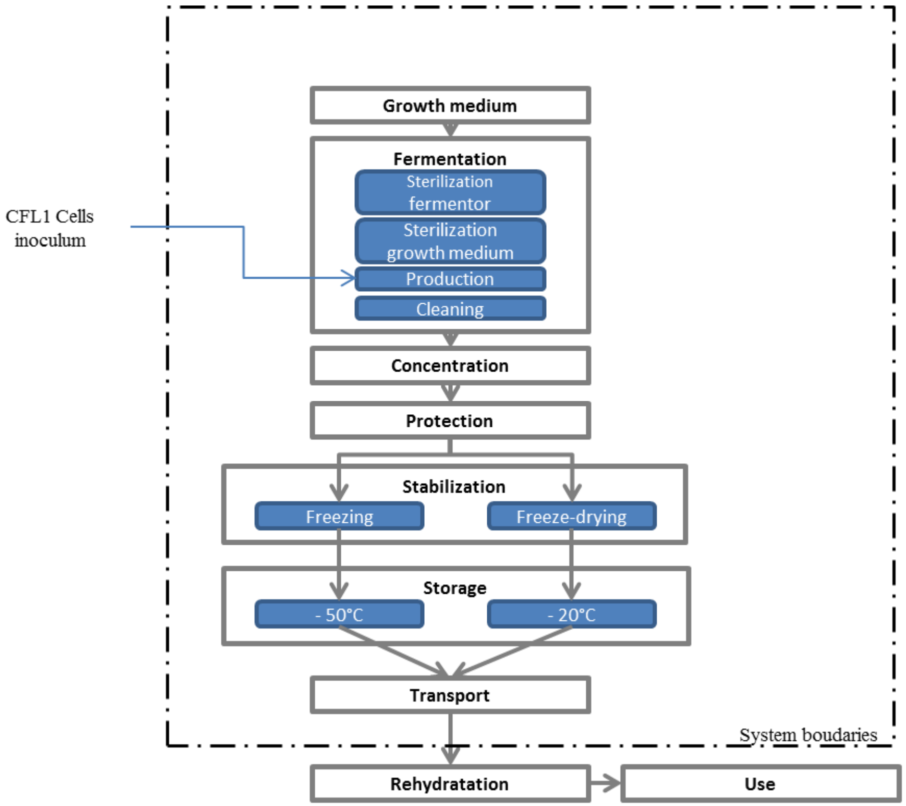
- **Toutes les étapes sont contributrices sur au moins un indicateur**
- **Principaux contributeurs :**
  - **Fermentation (de 3 à 94%),**
  - **Stockage (18 à 38%),**
  - **Lyophilisation (22 à 57 %)**

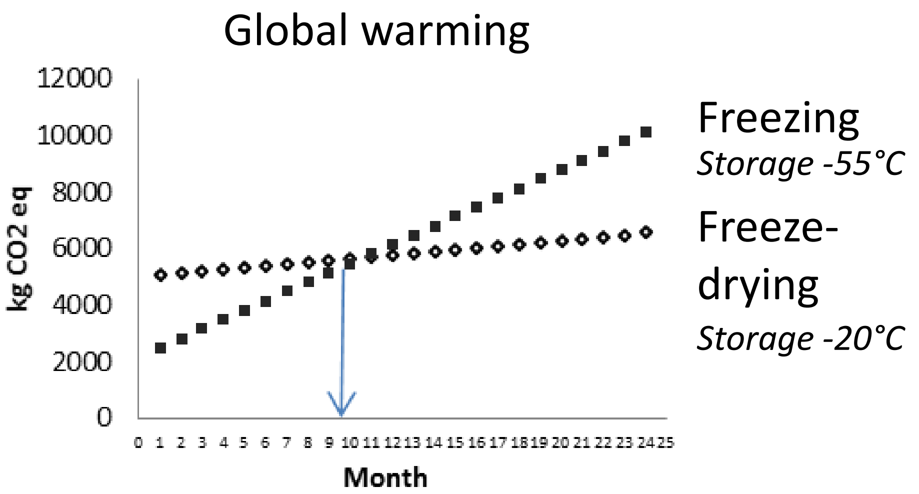
Monclus et al. 2015

Scenarios comparison

Freeze-drying vs freezing of lactic acid bacteria

- UF : Production, protection, stabilisation et stockage de 3 kg de bactéries lactiques
- Échelle d'étude : Pilote
- ILCD 2011 method





- **< 5 months storage : $I_{freezing} < I_{freeze\text{-}drying}$ on all the indicators**
- **9 months storage : $I_{freeze\text{-}drying} < I_{freezing}$ on half of the indicators**
- **> 28 months storage : $I_{freeze\text{-}drying} < I_{freezing}$ on all the indicators**

Monclus et al. 2015

Scenarios comparison

Freeze-drying vs freezing of lactic acid bacteria

Résultats

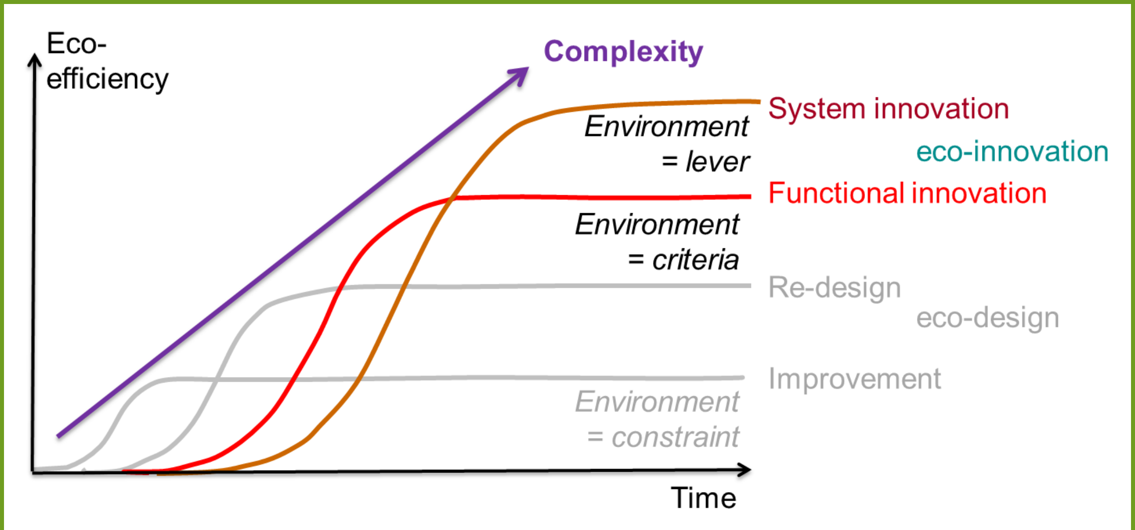
- Forte contribution du stockage et de la lyophilisation
- Pour un stockage > 9 mois une stabilisation par lyophilisation serait préférable

Pistes d'améliorations

- Améliorer les performances des appareils / reconcevoir
    - Fermenteur
    - Lyophilisateur
- Maintien de la qualité des ferments avec des températures de stockage plus élevées

- Prise en compte simultanée des dimensions produit / procédé / environnement
    - Intégration des connaissances

Monclus et al. 2015



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PROCESS ECO-INNOVATION

System level

Production de ferments lactiques

Ecole-chercheur Eco-conception INRA 2014

Comment éco-concevoir
/ re-concevoir
/ réinventer
ce système pour

produire des ferments
de qualité biologique souhaitée,
sûrs d'un point de vue sanitaire,
avec des impacts environnementaux minimums,
sans impact négatif sur la santé humaine,
et à moindre coût ?

Production de ferments lactiques

Ecole-chercheur Eco-conception INRA 2014

RE-QUESTIONNER LE SYSTÈME

- Reconsidérer choix historiques à la lumière des connaissances et technologies actuelles
  - Perte biodiversité et de typicité des produits
  - **Inclure <u>tous</u> les acteurs** pour prendre en compte les avis de chacun
    - Lobbys : producteurs de ferments et producteurs de lait

BESOIN D'UN BILAN

- Avoir une vision globale des impacts environnementaux (ACV)
- Analyse de pratiques pour adapter modes de production en fonction de l'utilisation
  - Enquête syndicats de producteurs de ferments

BESOIN DE RECHERCHES

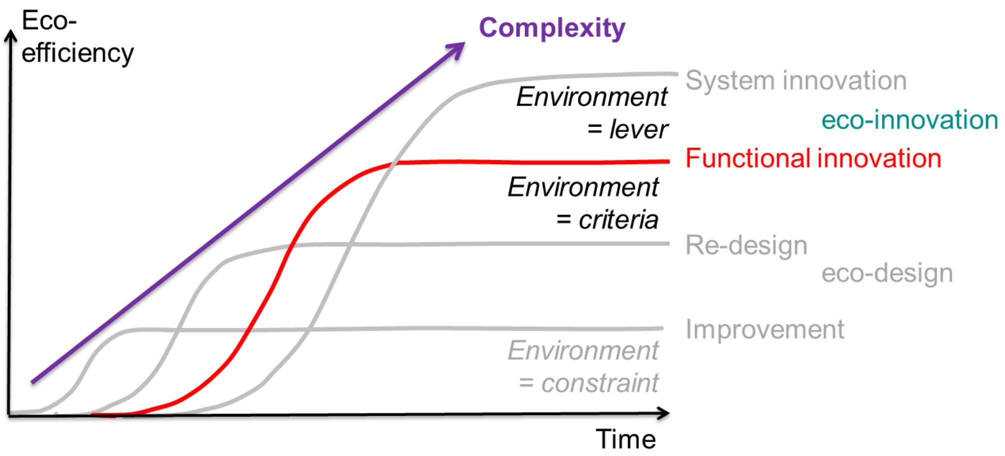
- Comprendre les **conditions de survie des ferments autrement que sous forme déshydratée**
- Comprendre le **risque sanitaire**
  - Interactions pathogènes – ferments
- Développer les **méthodes multicritères** pour comparer les stratégies

Production de ferments lactiques

Ecole-chercheur Eco-conception INRA 2014

RE-CONCEVOIR LE SYSTÈME : INNOVATION TECHNOLOGIQUE

- **Nouvelles méthodes de stabilisation / conservation** à imaginer
  - Atomisation ou autres pour souches thermo-tolérantes (40°C)
  - Bactéries immobilisées sur copeaux de bois
  - Bio-préservation (ajout d'une ou plusieurs bactéries dans le ferment pour limiter développement d'autres bactéries indésirables)

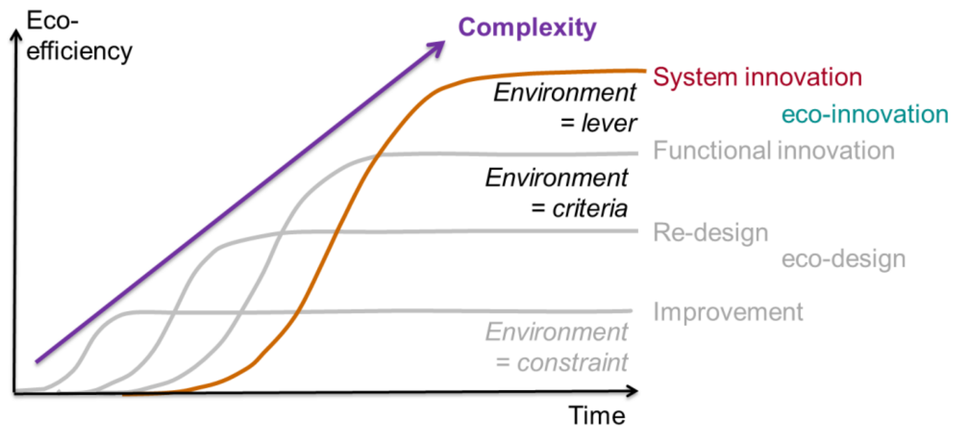


Production de ferments lactiques

Ecole-chercheur Eco-conception INRA 2014

RE-INVENTER LE SYSTÈME : INNOVATION ORGANISATIONNELLE

- **Internaliser** la production de ferments chez l'utilisateur
  - Repenser la **sécurité sanitaire** des ferments produits en interne
    - Détection rapide (en ligne ?) de pathogènes et de la qualité du ferment
  - Étudier comment se font les systèmes traditionnels pour comprendre pourquoi ça marche / ça ne marche pas et trouver des solutions pour **maintenir la qualité**



_05

WORKSHOP PROCESS ECO-DESIGN

4-5 February 2016, Paris

Eco-design of Agri-Bio-Industry Processes

Which outlooks and which research questions?

- Organizing committee
  - Caroline Pénicaud, PhD, Senior Scientist, INRA, coord.
  - Violaine Athès, PhD, Professor, AgroParisTech
  - Catherine Bonazzi, PhD, Research Director, INRA
  - Fernanda Fonseca, PhD, Research Director, INRA
  - Benoît Gabrielle, PhD, Professor, AgroParisTech
  - Geneviève Gésan-Guiziou, PhD, Research Director, INRA
  - Hedi Romdhana, PhD, Associate Professor, AgroParisTech
  - Gwenola Yannou-Le Bris, PhD, Associate Professor, AgroParisTech
- Sponsors
- About 60 participants coming from 16 countrys
  - Austria
  - Belgium
  - Canada
  - Denmark
  - Finland
  - France
  - Germany
  - Greece
  - Ireland
  - Italy
  - Luxembourg
  - Netherlands
  - Spain
  - Sweden
  - Switzerland
  - Turkey

Eco-design of Agri-Bio-Industry Processes

Conference (1 day)

- Session 1 – Environmental assessment for eco-design of agri-bio-industry processes
  - 1.1. Life Cycle Assessment, multicriteria assessment method as a reference
  - 1.2. Thermodynamic methods (MFA, SEA, Exergy, Eco-exergy)
  - 1.3. Round table: Potentials, limits and complementarities of these methods for the eco-assessment of processes

- Session 2 – Eco-design strategies applied to agri-bio-industry processes
  - 2.1. Environmental assessment tools coupled to process engineering tools to compare process scenarios
  - 2.2. Numerical strategies for process on-line monitoring and process redesign
  - 2.3. Decision support tools
  - 2.4. Round table: Potentials, limits and complementarities of these approaches for process eco-design and eco-innovation

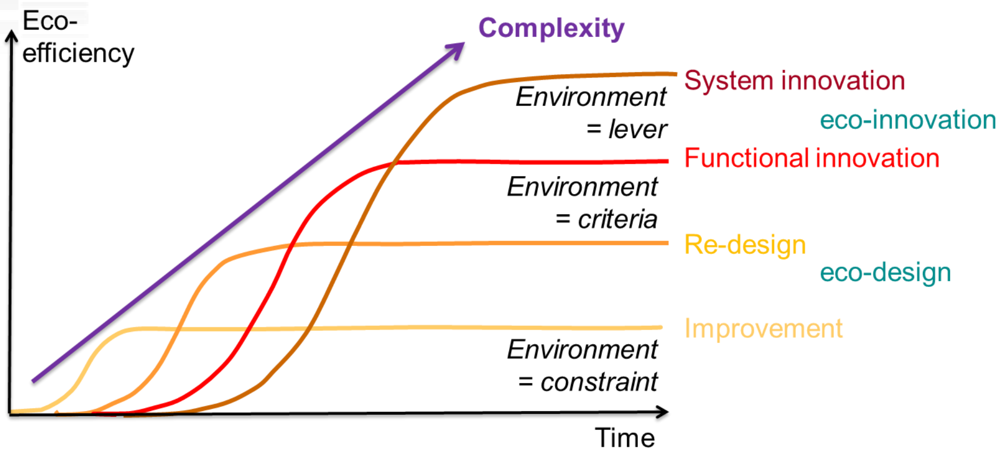
Workshop (1/2 day)

- Presentation of the COST FOODMC (Alberto Tonda) + General discussion
- Working groups
  - Sustainability assessment of agri-bio-industry processes
  - Integration of agri-bio-industry processes into a sustainable value chain
- General discussion

➜ COST about eco-design of agri-food processes to be submitted in September 2016

COST – Topics of interest

Design strategy

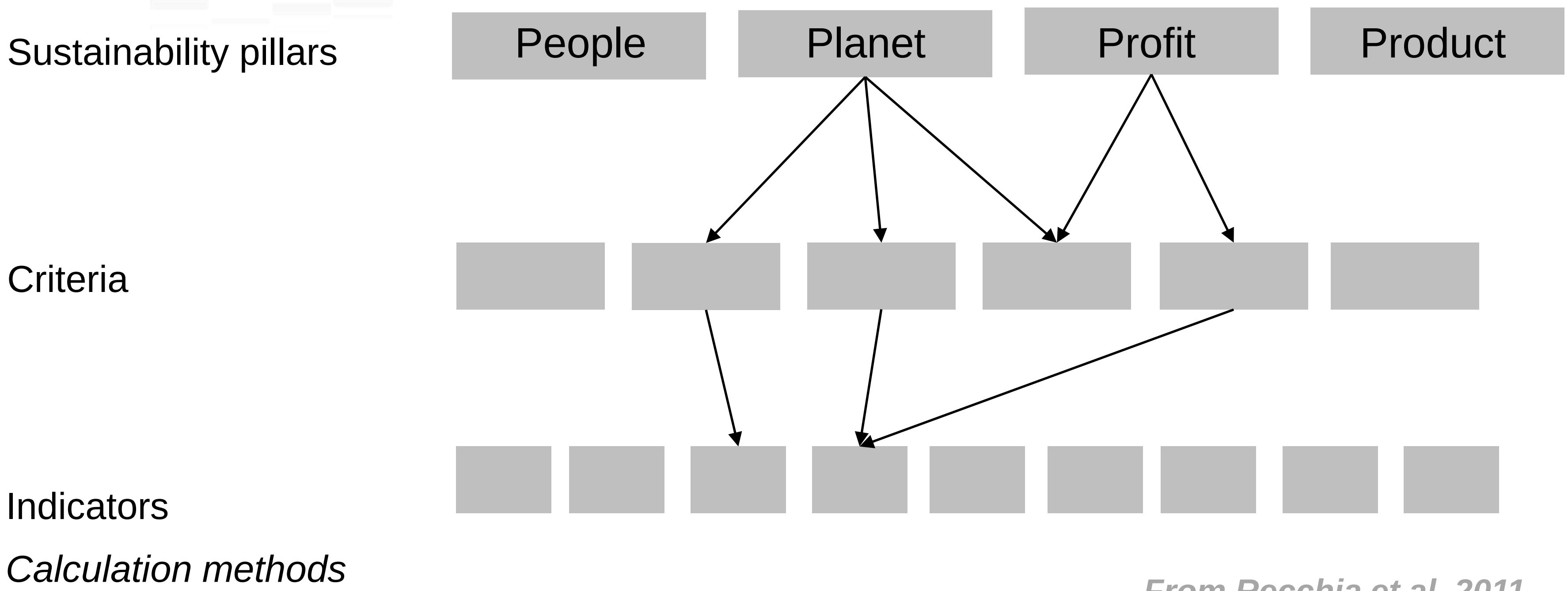


- Different **design strategies** as a function of the objective (optimization, re-think the whole system…)
  - **Tools**: (simplified) LCA, simulators that can be adapted to take into account environmental indicators...
  - **Innovation** (disruptive innovations or technologies as well as organizational innovation): still a bottleneck because of a lack of data at early stage of project development, a lack of resources and timing issues.

- **Formalization and sharing of sustainable design strategies => high levels of eco-efficiency**

COST – Topics of interest

Assessment



From Recchia et al. 2011

- Choice, calculation, harmonization, prioritization and selection procedures for **criteria** and **indicators**
  - **Calculation methods**
  - **Allocation rules**

COST – Topics of interest

Data

Indicators

Calculation methods

Data

- Data **collection and gathering strategies**
  - From lab to industry but also post-retail, including waste quantification
  - Ensure the transfer of R&D data to pilot-plant or industrial scales
  - Variability / uncertainty

- **Stakeholder's interactions**
  - From all stages of the agri-bio chain (production at farm and field levels; processing; retail; consumption)
  - Security of the data and know-how / contractualization
  - Development of adequate tools for promoting exchanges and sharing of data (participatory practices)

COST – link with FoodMC

- Scientific aspects
  - Modeling
  - Coupling between simulators and assessment tools
  - Optimization
  - Knowledge integration
  - Multicriteria analysis

- In practice
  - Case studies
  - Workshops, training schools

Thank you!