From growth to sustainable bioeconomy: a new cylindrical conceptual framework
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6. The transition to a sustainable bioeconomy

6.1 Bioeconomy Systems

From growth to sustainable bioeconomy: 
*a new cylindrical conceptual framework*

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Introduction: key considerations for sustainable bioeconomy systems:

- Sustainability defined by Brundtland in 1987
- Concept of bioeconomy introduced in 2002 with focus on biotechnology, then on resources bioeconomy and now on ecological bioeconomy
- Notion of boundaries by the Stockholm resilience centre: radar with planetary boundaries (Rockstrom et al, 2009)
- Notion of social lower limits: doughnut (Raworth 2017)
- EC sustainable and circular bioeconomy 2018
- In France, INRAE strategy focusing on complex, territorial bioeconomy systems (https://hal.inrae.fr/hal-02866076; https://colloque.inrae.fr/bioeconomy2019/)
- But the question remains ‘when are bioeconomies sustainable or unsustainable?’
Methodology: fundamentals of sustainable bioeconomy systems

- (Sustainable) bioeconomy systems can be integrally represented by the seven building blocks of game theory (I)
- Bioeconomy systems are sustainable if they are continuously evolving between order and chaos (II)
- The evolution is then following sinusoidal like patterns, and not continuous (linear, exponential,…) growth or decline ones;

>> Combined sinusoidal patterns form helices, the most stable but dynamic configurations in nature (III)

- (I) + (II) + (III) result in a conceptual framework, of a multiple cylinder configuration with an inner rigid zone, a sustainable safe operating zone and outer chaos zone.
6.1 Bioeconomy Systems

(I): the 7 ‘building blocks’ of ‘systems’ or ‘game theory’ are integrally describing (sustainable) bioeconomy systems

**Playing fields:**
- Food environments

**Pieces:**
- Resources, food and bio-based products

**Time (Δt):** duration

**Rules:** regulations and incentives

**Moves in a circular economy**

**Wins/looses:** sustainable / unsustainable outcomes
(II): sustainable bioeconomy systems are balancing in the melting zone between order and chaos.

Interactions 'K' between agents / actors / species / products / particles /..

Number of different agents/actors 'N' / species / products / particles /..

- Chaotic network of actors
- Self-organized dynamic network of actors
- Static (linear) network of actors
(III): sustainable bioeconomy systems are revealing sinusoidal patterns which are jointly resulting in helices, very stable but dynamic configurations.

Source: Modified image of https://www.radar.tutorial.eu/06.antenناس/pic/zirkulum.gif is included
(II)+(III) provide the following scheme:

**Behavior of players:** *sinusoidal in y-z plane* (actors in bio-economy)

**Utilization of pieces:** *sinusoidal in x-z plane* (biomass & bio-based products)

Source: Modified image of https://www.radartutorial.eu/06.antenras/ pic/zirkulanim.gif is included
(I)+(II)+(III) provide a new conceptual framework

Graphic representation of system building blocks & helical pathways evolving in between boundaries

6.1 Bioeconomy Systems

Verification of the appropriateness of the conceptual framework via case studies

**Case study:** valorization of agricultural waste and by-products > towards biogas and beyond:

- **Moves:** From farm to modern biogas company and now beyond: Recycling, bioenergy conversion, bio-fertilizer manufacturing
- **Pieces:** Biogas, dried fertilizer, other products in consideration; resources ‘manure’, by-products from vegetables, fruit and energy crops
- **Players:** Network of entrepreneur, local farmers, eco-villagers (heat), Town Hall, logistic suppliers and distributors (for targeted fertilizers), e-car holders (sharing electricity)
- **Playing field:** territorial scale, relatively well defined, since ~2000
- **Rules & constraints:** National legislation & subventions, limitation for feed-in tariffs, odors, local appreciation,
- **Outcomes:** technological, business & social innovations; valorization of organic waste, new products & markets for local producers, jobs created.

[https://hal.inrae.fr/hal-02624927/document](https://hal.inrae.fr/hal-02624927/document)
Is ‘the case’ sustainably evolving?

Our observations are:

- The case integrally considers all 7 ‘building blocks’ of game theory.
- The business activities are between (order-chaos) limits, impacted by rules (e.g. no landfill, subventions,..); and tend to show helical patterns.
- The outputs seem to be sustainable in all three pillars (PPP), thanks to combined business, social & technological innovations.
- The case (‘a bioeconomy system’) seeks to sustainably evolve by continuously adapting and innovating all building blocks coherently.
Conclusions

✓ The conceptual framework seems to cover all ‘building blocks’ of sustainable bioeconomy (sub-)systems and allows following their evolution pathway.

✓ In particular it dynamically connects system ‘building blocks’, taking into account regulations and geographical dimensions.

✓ An extensive analysis has been possible for 8 cases

✓ It permits to draw policy options for (territorialized) sustainable bioeconomy systems.
6.1 Bioeconomy Systems

Thank you very much for your attention

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