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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6.1 Bioeconomy Systems

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/](https://hal.inrae.fr/hal-02866076; https://colloque.inrae.fr/bioeconomy2019/))
- **But the question remains ‘when are bioeconomies sustainable or unsustainable?’**
6.1 Bioeconomy Systems

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.

Today: exponential curves.  
Source: Intergovernmental Panel on Climate Change.  
Tomorrow: a need for balancing curves.
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

**Solar energy, N, C, H...**

**Rules**: regulations and incentives

**GHG, waste**

**Moves in a circular economy**

**Players**: stakeholders

**Wins/looses**: sustainable / unsustainable outcomes

**Production (agro/aqua)**

**Recycling & Re-use**

**Processing & Packaging**

**Transport & Distribution**

**Usage & Digestion & Consumption & Cooking**
(II): sustainable bioeconomy systems are balancing in the melting zone between order and chaos.
(III): sustainable bioeconomy systems are revealing sinusoidal patterns which are jointly resulting in helices, very stable but dynamic configurations.

The helix is the sum of sinusoidal curves of the behavior of players and utilization of pieces/products.

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

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.

Ref. [https://noaw2020.eu/](https://noaw2020.eu/) and Donner et al. (2020) [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.
Thank you very much for your attention

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