Designing sustainable futures
Necessity of a multiscales approach

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Who am I?

1999 – PhD in Integrated Design, Grenoble, France

2000 – 2012 – Associate Professor at University of Technology of Compiègne, France
   « From mechanical design towards robust and collaborative design of mechatronics systems: an approach by combining technical performances of technical systems and knowledge management »

2012 - … - Professor at University of Technology of Troyes, France
   « From integrated design of technical systems towards responsible engineering »

Main interest in discussing and thinking on the future of industry but most of all of engineering
- Big challenges due to the current model of production and consumption

=> Description with a system modeling approach
Definition of production system

- **System**: set of elements in relation forming a whole which function as a unity.
- **Manufacturing**: relative to industry (set of economic activities which produce material goods and services by transforming raw materials)

How to design the production system for a sustainable future?
Strong link between manufacturing systems and industrial society

- Industrial society: set of human beings living in an organized group and where the industry is a structuring element of its organization

- Some elements of the industry structuring society:
  - Concepts of Branch and Value Chain
  - Concept of life cycle of products and services
  - Concept of design (supply creation process), production (supply chain)
  - More recently concept of end-of-life scenarios and associated strategies (reuse, remanufacturing, recycling, circular economy)
Which models, which limits?

- Organizational model of industrial societies:
  - Mass production
  - Globalization of markets and globalization of organizations
  - Strong integration within the sectors and branches

- 6 key elements changed in society [Cascio, 1995]:
  - Work
  - Employee selection
  - Training and development
  - Performance evaluation
  - Offsets (including incentives)
  - The development of organizations

- Access to resources (critical resources), waste, emissions, social responsibility
Early 90s [Allenby, 1992]:
Industrial ecology is defined as the means by which a state of sustainable development is approached and maintained

⇒ 3 degrees of maturation of the industrial society towards a sustainable industrial system

[Tibbs, 1993]: Industrial ecology: an environmental agenda for industry

⇒ 6 operational tracks of action


Since 2007 [ISIE 2007], integration of consumer as well as production issues
The major issues

- How to respond to the challenges of the development of society? What models of transitions?
- What role does technology play in these transitions?
- What role does engineering play in these transitions?

Transition =

- change of training and jobs
- change of economic models and structures
- change in lifestyle (and work)
Our approach

Institut Charles Delaunay: to design the technologies of tomorrow through an engineering approach to socio-technical systems

Human, Environment, Information Technology and Communication Department

Interdisciplinary Research Center on Sustainable Development (CREIDD)
Technology and sustainable development

Issues: Resource consumption
Waste management
Environmental impacts

What technology tomorrow?

Natural ecosystem
(living, mineral, water, air)

Society and technology
The team

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Towards an integrated product - territory approach

The territory
As an arrangement of material, human and symbolic resources able to structure the practical conditions of the existence of an individual or a collective social

Industrial and territorial ecology
- Flow of materials, water and energy
- Development Strategies
- Collective action and collaboration

Ecodesign
- Protection of the environment from design
- Life cycle impact
- Multi-step and multi-criteria approach

The product
As a result of a human activity in the form of a good, a service or a product-service system, associated with a use.

Foresight, governance, deployment strategies
Modeling, decision support, evaluation
Prospects and design of responsible innovations

What positioning of technology in society? What prospects and associated governance? What acceptability?

What link development territory / industrial? What restructuring of the sectors? What are the public / farmer / company / developer linkages?

How to eco-design production systems? What deployment methodologies? What tools for scripting, evaluation, decision support? Which company / territory integration? Which impact indicators?

Planetary scale

Environmental, economic and societal impact

Value networks (actors, sectors...)

Resource Management

Scale effects

Territory scale

Choix

Agréressources, valorisation de la plante entière

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Our scientific posture to work on transition

- **Sustainable development**
  - Response to the needs of the Company of the society
  - With a vision for the next 10-20 years, the long term Transition

- **Think about the change of state**
  - Understand and characterize the current state
  - Understand and characterize evolutions, trends of the current state
  - Characterize the trajectories initiated and identify hypothetical future states
  - Characterize a hypothetical future state and identify possible trajectories to reach it
Low sustainability and strong sustainability [Nemayer, 2003]

Maillefer 2010:

- If the decline in the quality of the environment is supposed to be offset by an increase in material goods, the design of sustainability is considered "low".
- If the possibilities of substitution between goods are supposed to be limited, let alone impossible, especially when nature is given an irreplaceable value, then the conception of sustainability is considered "strong".

What models to deploy? = Which trajectories to build? In what perspective (weak / strong)?
Questions that remain

- Does the establishment of synergies on the management of energy and material flows and ecodesign enable sustainable development?
  - Long temporality (shared vision construction, difficulty of deployment)
  - Many technical and human factors
  - Trend towards the implementation of low sustainability solutions

- What methodologies for deployment of strong and weak sustainability?
  - What knowledge is necessary and to develop?
  - What perimeters to consider?
  - Which temporalities to consider?
What are the fundamental issues to be addressed?

- What perimeters of analysis and action? [Ceschin et al., 2016]
- What time scales of projection and action?

Articulate temporality of the action and temporality of the effects of the action.
## Proposal for a scenario design and analysis framework

<table>
<thead>
<tr>
<th>Time scales</th>
<th>Analysis</th>
<th>Level of uncertainties</th>
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<tbody>
<tr>
<td>Past</td>
<td></td>
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<tr>
<td>Present</td>
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<td>Short future (product's lifetime)</td>
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<td>Low to High</td>
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<td>Next future (consumer's lifetime)</td>
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<td>High to Low</td>
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<tr>
<td>Far future (next generations)</td>
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<td>Low to High</td>
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### Systems perimeters
- Product
- Industrial system
- Value network
- Territory anchoring

### Systems perimeters
- Low level of uncertainties
- High level of uncertainties
What we try to do

- Identification of the relationships between the different levels of perimeter? => systemic modeling
- Characterization of these relationships? => heuristic approach, coupling of qualitative approach (grids of analyzes) and quantitative (LCA, MFA, Criticality of Materials ...)
- Characterization of decision support indicators? => ISO 9000 to ISO 14000 to ISO 26000
- Taking into account local specificities? => a generic analytical and methodological framework to adapt in its deployment to local specificities
- Consideration of epistemic uncertainties? => coming soon?
What we’ve learnt after 15 years

- **Industrial ecology: identification and deployment of industrial symbiosis**
  - From recoupling biosphere and technospere principle to decoupling deployment (example of circular economy) => sometimes less waste, more economic gains, but also more emissions, more resources consumptions

- **Ecodesign: methods and tools, and deployment of ecodesign**
  - From eco-innovation wish to incremental proposal => sometimes less pollution but deployed only if economic gains in established companies

- **Global policies assesment**
  - From sustainable development objectives to current economy reinforcement => weak appropriation and understanding, local implementation without global assessment

- **Sustainability assesment**
  - Weak indicators => when existing, difficult to understand and to validate

=> low sustainability
Evolutions required

- develop a more holistic analysis and modeling approach
- develop design approaches and indicators which are more integrative of the sustainable development principles rather than separate social, environmental and economic aspects
- link stronger manufacturing evolution to consumption and social evolution
- develop social knowledge transmission on sustainability development to make awareness evolve faster

$=>$ strong sustainability: is it still possible?

Faster evolution  Prepare to crisis
Design another way: Deal with technology evolution and social evolution => More ability to define their need and design their technology.

Find wastes as resources, avoid non-renewable energy...

Transmit knowledge on new ways to design: develop design ability.

Tangible and intangible assets

Illustration
What are the challenges for industrial systems?

- Return to technology as a response to a societal need (not businesses)

- Need for interdisciplinary projects mobilizing multidisciplinary skills to
  - develop a holistic vision
  - understand the issues of resource management, waste and emissions ... and human need

- Consider both technical and human determinants in a sociotechnical systems analysis approach

- Propose new paradigms of modeling and evaluation for the design of new industrial systems rooted in their territory and open to the world
What issues for teaching and research?

- Develop multiple and "risky" visions => make strong assumptions

- Develop awareness and culture massively

- Train to deploy as a major transition factor
  - sensitize
  - Model and define methodologies that are out of order
  - To evolve the disciplinary methodologies taking into account the current transitions
Thank you for your attention