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Summary of “Designing emerging technologies taking into account upscaling.”

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This summary presents the content of the paper entitled “**Designing emerging technologies taking into account upscaling**”, submitted to **Design Science** and still under review.

The content of this paper is summarized in the following abstract, extended with an overview of the results and the references cited in this research.

Abstract

Under the umbrella concepts of upscaling and emerging technology, are examined a wide variety of phenomena partly related to the environmental transition to achieve sustainability. The design literature does not provide an explicit common theoretical and practical framework to clarify the assessment method to handle « an » upscaling. In this nebulous context, designers are struggling to identify the characteristics to anticipate the consequences of emerging technology upscaling. This article therefore first proposes a structuring framework to analyze the literature in a wide range of industrial sectors (energy, chemistry, building, etc). This characterization brought out five prevalent archetypes clarifying the concepts of upscaling and emerging technology and their interactions. Then, a synthesis of invariants and methodological requirements for designers is proposed to deal with upscaling assessment according to each definition/archetype, based on a literature review of existing design methods. This literature review process showed a disparity in treatment for some archetypes, regarding the industrial sector. A discussion is consequently proposed in the conclusion to guide design practices.

Keywords: Keywords: Upscaling, Emerging technology, Integrated Design, Literature review, Absolute sustainability.

The upscaling archetypes

The upscaling of an emerging technology can be decomposed into facets depending on the declared goal, the studied object, and the stated scope (Riondet et al., 2022). Based on a literature review in design and engineering, these facets, also mentioned as “archetypes”. Table 1 presents the definition of each upscaling archetype, based on their usual goals, subjects and focuses. Then in column five, usual keywords have been identified as associated with one or several archetypes. Additionally, generic representations, illustrated in Figure 1, have been proposed to narrow the specificities of engineering fields. The spotlight of Figure 1 and Table 1 is on the common features (i.e. interdisciplinary invariants) shared by technology upscaling from different sectors such as energy and chemistry.

Upscaling archetype	Definition	Usual Goal	Usual subject	Focus	Associated keywords
Arch. 1 Scaling-up, up sizing	Design processes to generate a “prototype” at industrial/commercial scale.	Maximize maturity (often associated with productivity)	Technology/service upscaled	Technology upscaled	Technology Readiness Level (TRL), Maturity, Industrial scale, Scale-up, Pilot Prototype, Size, Gigafactory, Miniaturization, Early-stage technology, Scalability, Novel technology, Commercial scale, Scale up, Emerging technology, Upscaling
Arch. 2 Mass producing	Design processes to manage and anticipate the massive production of a technology. Productibility.	Maximize producibility	Technology/service upscaled	Technology upscaled in manufacture	Manufacturing Readiness Level (MRL1), Learning by doing, Mass-manufacturing, Commercialization, Design standardization, Massification, Industrialization process, Economy of scale, Scalability, Novel technology, Commercial scale, Scale up, Scaling, Emerging technology, Upscaling
Arch.3 Reaching a level, deploying	(Design) processes to translate transitions requirements into technology sector perspective.	Reaching a sufficient level of cumulated service	Technology upscaled / boundary of analysis	The cumulated service of the group of produced technology	Large-scale deployment, Market penetration, Technology diffusion, Market Readiness Level (MRL2), Planification, Terawatt level, Growth dynamic, Reaching ‘materiality’, Large-scale production, Raw material criticality, Transitioning Low-carbon transition, Energy transition, Levels, Niche technologies, Deployment, Technology adoption, Infrastructure, Scale up, Emerging technology, Scaling up, Upscaling
Arch.4 Up and down-zooming /integrating	Design processes to implement and/or manage a part or an entire complex system.	Maximize the efficiency of a complex system	Boundary of analysis	The technology interoperability to support its systemic integration	Grid integration, Interoperability, Acceptability, Network, Smart technology, Complex system, Urban metabolism, Socio-technical systems, Societal transformation, Multi-level, Transition pathways, Territory scale, Transitions, Levels, Niche technologies, Deployment, Technology adoption, Infrastructure, Scaling, Upscaling
Arch 5 Down-limiting	Methods to define an absolute (i.e. not relative) environmental limit for a system based on justice principles.	Assess the sustainability of a technology, service, human activity	Science-based limit of the domain (environmental limit)	The sustainability of a service provided by one product, or system	Planetary boundaries, Safe operating space (SoS), Downscaling, Carrying capacity, Share of SoS (SoSoS), Absolute Environmental Sustainability Assessment (AESA), Justice principle, Science based target (SBT), Planetary scale, Regional scale, Product scale, Allocation factor, Characterization factor, Normalization factor, Scaling

Table 1 - Synthesis of archetypes definitions with associated keywords

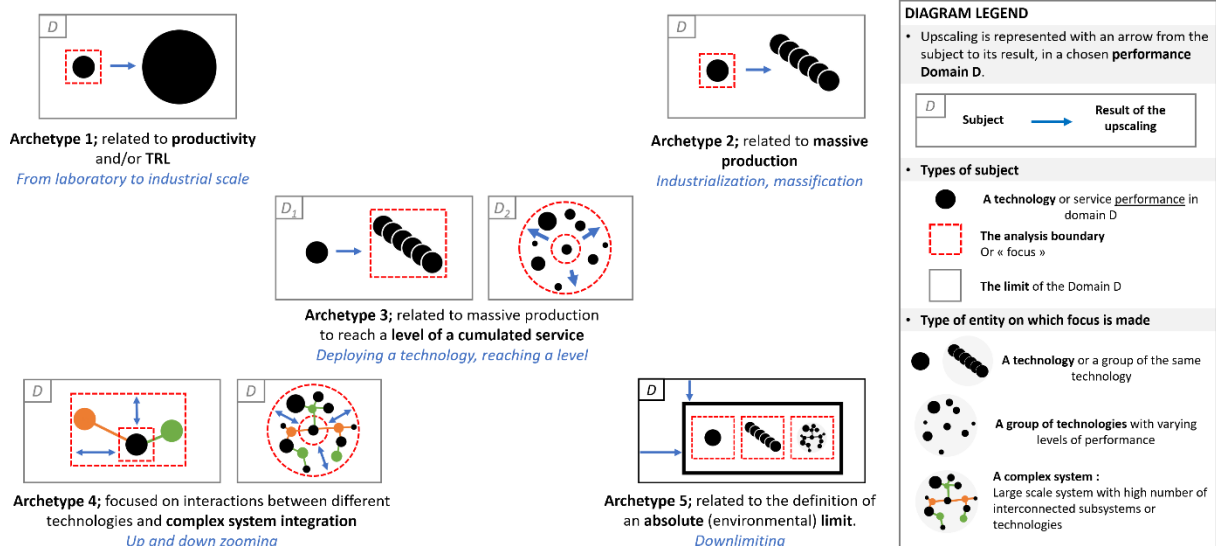


Figure 1- Visual summary of the five identified upscaling archetypes in the design and engineering literature.

Conversely, the matrix archetypes in regard to engineering fields presented in Figure 2 pinpoints the disparity of treatments of upscaling archetypes for nine industrial sectors (chemistry, waste treatment, energy, food, building, electronics, transport, production engineering, bioengineering, and nanoengineering).

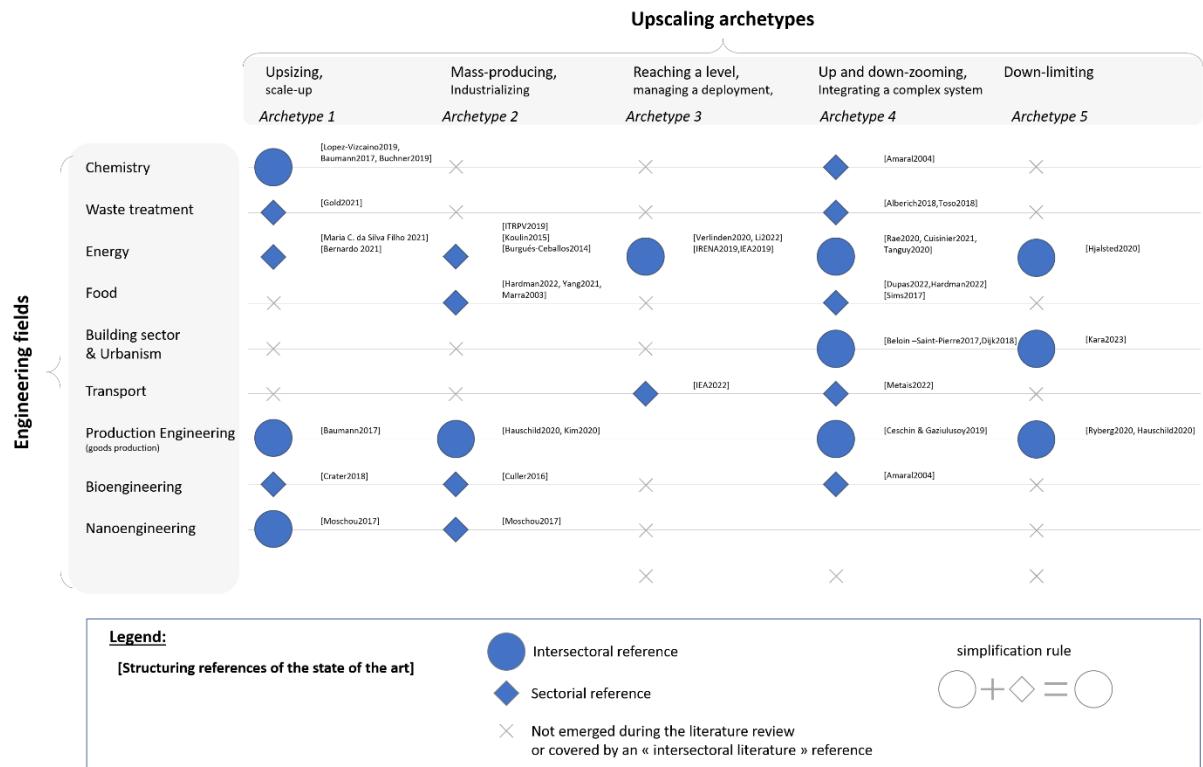


Figure 2- Visual summary of the disparity in treatment in the scientific literature for upscaling archetypes regarding the related engineering fields.

Figure 2 matrix is built on an extended literature review of techno-economic assessments per archetype of upscaling conducted from March 2021 to January 2024. The matrix displays the main references founded that best characterize one or more engineering field(s) archetype assessment. The engineering fields cited on the first column may be extended or detailed in the future. The intersectoral references have the potential to cover several fields. Those references may therefore support designers from different sectors in assessing the archetype of upscaling they are dealing with.

Archetype 1 main references: *Baumann and Lopatnikov, 2017; Buchner et al., 2019; López-Vizcaíno et al., 2019; Moschou and Tserepi, 2017*

Archetype 2 main references: *Hauschild et al., 2020; Kim et al., 2020*

Archetype 3 main references: *IEA, 2020; IRENA, 2019; Verlinden, 2020*

Archetype 4 main references: *Beloin-Saint-Pierre et al., 2017; Ceschin and Gaziulusoy, 2019; Cuisinier et al., 2021; Rae et al., 2020; Tanguy et al., 2020*

Archetype 5 main references: *Hjalsted et al., 2021; Kara et al., 2023; Ryberg et al., 2020*

This matrix is not exhaustive and is intended to be completed over time and additional research work.

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