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On the Potential of the Bioeconomy as an Economic Growth Sector

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Fresh economic data on industrial value chains suggest that the existing industrial structures of the Bioeconomy do not show promise of short-term growth. Pursuing public policies to promote the Bioeconomy will not be a quick fix to an urgent problem such as the lackluster Finnish economy. Building an entire industrial ecosystem with its complex web of value chains is viable only as a patient long-term strategy. Government policies indeed need to be better aligned with and designed by leveraging promising weak signals from the economy, to reasonably assure the viability of their outcome or impact. In comparison to the Bioeconomy, economic signals from ICT-driven ecosystems such as Smart Grid and Smart Mobility indicate the emergence of new industry structures.

The last few years have witnessed an exponential growth in both political and commercial momentum for the concept of the Bioeconomy. The commitment to designing and supporting policies for the implementation of the concept runs high; institutions including national governments, the EU and the OECD have laid out long-term strategies to harness the progress in biological resource technologies for sustainable economic growth and improvements in physical and socio-economic welfare (see Box 1).

Box 1
Bioeconomy – A sample of definitions

"The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy. It is an essential alternative to the dangers and limitations of our current fossil-based economy and can be considered as the next wave in our economic development. It provides major opportunities for innovation, jobs and growth and as such will help to reindustrialise Europe."

– European Commission, Research & Innovation

From a broad economic perspective, the bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes. […] The application of biotechnology to primary production, health and industry could result in an emerging "bioeconomy" where biotechnology contributes to a significant share of economic output. The bioeconomy in 2030 is likely to involve three elements: advanced knowledge of genes and complex cell processes, renewable biomass, and the integration of biotechnology applications across sectors.

– The Bioeconomy to 2030: designing a policy agenda. International Futures Programme, OECD.

Finnish economic developers have been at the forefront of strategy design and already have something to show for it. Only as recently as 2014 did Finland rank second in WWF's Global Cleantech Innovation Index[1]. Led by the Ministry for Employment and the Economy, Finland has crafted national Bioeconomy strategies which are to be implemented by national and regional development agencies via various technology programs, such as the new Bioeconomy Development and Growth Programme run by Tekes, the Finnish Funding Agency for Innovation. Efforts between agencies are effectively coordinated via the Team Finland[2] consortium that comprises central ministries and economic development agencies in the country.

Finnish government committed to promotion of Bioeconomy

The strongest of commitments, however, has been made by the Finnish government itself. In a push to turn around a lackluster economy, the government has declared the "Bioeconomy and clean solutions" one of its five strategic priorities (see Box 2)[3]. In the spirit of the various existing definitions of the Bioeconomy, the Finnish Government defines the concept very broadly, including economic sectors such as energy, forestry and paper, natural resource management, and food and feeds.

Figure 1 portrays the circular economy envisioned to constitute the industrial structure of the Bioeconomy. The strategy is broad and rests on the implicit assumption that the conventional industrial pillars of the Finnish industry will interconnect via new value chain segments and integrate innovations in biological materials to provide new economic value added in the form of sustainable products and process technologies.

The viability of the strategy, then, hinges on whether there is tangible evidence of new inter-industry value chains being formed. This evidence would suggest that industries and markets have picked up on the promises of the Bioeconomy and started to adapt to and build out bio-based processes. The question about in-

Box 2
Bioeconomy and clean solutions

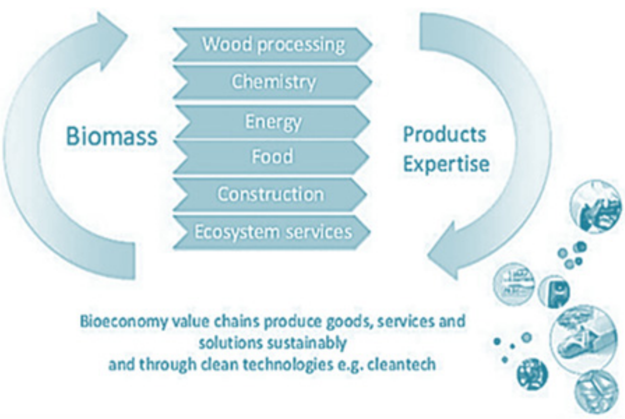
1. Towards carbon-free, clean and renewable energy cost-efficiently
2. Wood on the move and new products from forests
3. Breakthrough of a circular economy, getting waters into good condition
4. Finnish food production will be profitable, trade balance on the rise
5. Nature policy based on trust and fair means

Source: Finnish Government.

Box 3
Definition: Inter-industrial value chains

Industrial evolution in the past two decades has mocked conventional industry boundaries as emerging industrial ecosystems such as telecommunication in the 1990s started to integrate technology from a large variety of industry sectors such as electrical equipment manufacturing, software development, and consumer electronics. Current growth sectors such as *Smart Grid* or *Smart Mobility* are even more agnostic of classical industry demarcations. For instance, to provide improved flexibility, reliability and efficiency in the generation and use of electricity, companies in the Smart Grid sector collaborate in an ecosystem that encompasses energy utilities, telecommunications operators, application and system software developers, data analytics service providers, energy storage developers, electrical component manufacturers, and communications equipment manufacturers. *Inter-industrial value chains*, as used to in this brief, refer to chains of *transactional supplier-client relationships across such industry boundaries*.

Fig. 1 Bioeconomy value chains (Source: TEM)



dustrial momentum is pivotal because creating an entire industry ecosystem from scratch – on political momentum and resources alone – is an extremely costly, inefficient and multi-generational undertaking.

Government policies indeed need to be designed by leveraging promising weak signals from the economy, to reasonably assure the viability of their outcome or impact. Given the long-lasting global excitement around concepts such as Cleantech and Finland's economic roots in natural resources and related expertise, it is easy to believe in a Finnish comparative advantage as grounds for industrial policy.

No transactional evidence of Bioeconomy on industry level

The evidence from economic data, however, is sobering. Company data[4] on inter-industry transactions reveal that the transactional connectivity, i.e. the existing value chain structure in the alleged Bioeconomy is weak at best (Fig. 2, *right* panel). There is no evidence of a (circular) value system structure that is envisioned in Figure 1. Compared with other inter-industrial cleantech ecosystems – such as the well-established Smart Grid sector (Fig. 2, *left* panel) – the focal industry sectors of the Bioeconomy seem to remain transactionally isolated in their conventional legacy value chains.[5]

What could be the problem? Maybe the all-encompassing bird's eye view on the *entire* Bioeconomy is too cursory an approach to reveal in-depth economic structures? One could ask whether evidence from economic actors in Bioeconomy *sub-sectors* provides more detail of their specific value chain relationships.

For instance, a look at Green Chemistry, an emerging industrial trend that seeks to substitute hazardous and fossil-based raw materials for sustainable and renewable resources such as biomass, provides for more promising results (Fig. 3). Robust transactional connectivity between a number of different industry sectors is clearly evident.[6]

An abstraction of the same map (Fig. 4, *right* panel) reveals a multi-industry structure that encompasses sectors such as chemicals, integrated oil and gas, paper, household products, industrial machinery and electric utilities. Surely this should be strong enough empirical evidence of a circular economy? Unfortunately, this is a premature conclusion. Comparing the structures of the Green Chemistry ecosystem to those of the familiar benchmark, Smart Grid (Fig. 4, *left* panel), reveals decisive structural weaknesses in the Green Chemistry ecosystem.

Fig. 3 Green chemistry value chains (D. Assanis)

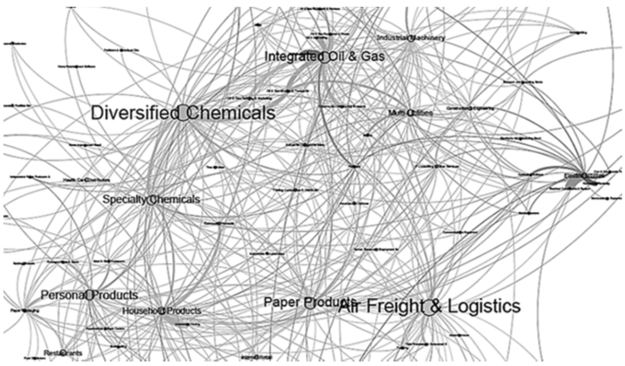


Fig. 2 The robustness of value chain structures in comparison: Smart Grid vs. Bioeconomy (D. Assanis)

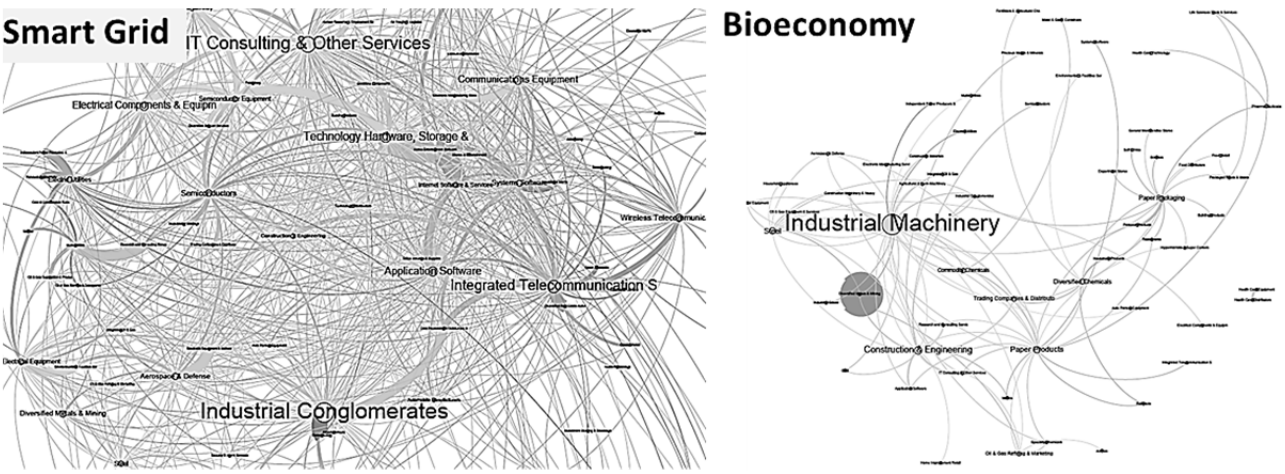
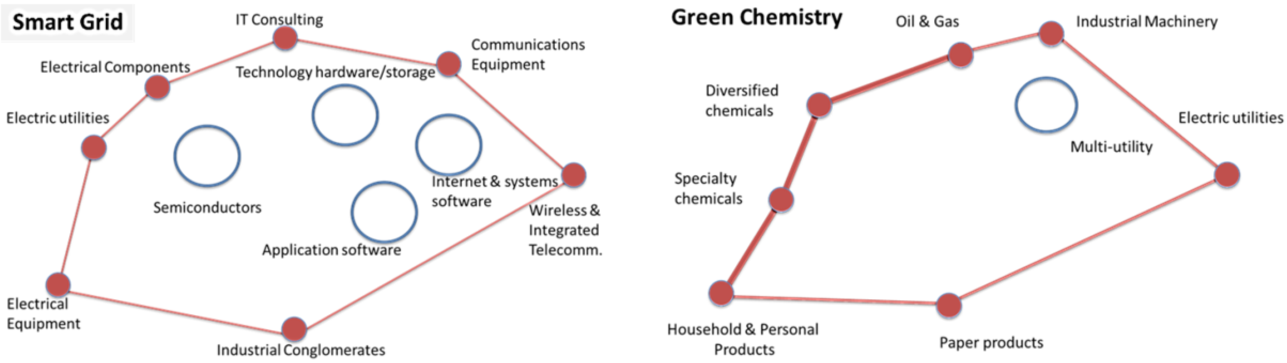


Fig. 4 Abstractions of value chain structures in comparison: Smart Grid vs. Green Chemistry



To explain them, however, one must first understand the roles single industry sectors play in emerging, cross-industrial ecosystems.

Catalyst sectors bridge conventional industry boundaries to form new ecosystems

The roles of industry sectors are differentiated based on their *network centrality* – the relative connectivity to all the other sectors in the ecosystem. Sectors of high centrality – encircled in blue in Fig. 4 – are designated *catalysts*. They are built on top of the infrastructure of *anchor sectors* that stake the *perimeter* of the ecosystem – the red boundaries in Fig. 4.

Anchors are less well connected to the emerging ecosystem as they are still relatively contained in their incumbent industrial value chains. However, they serve an extremely important role as the providers of capital-intensive infrastructure and vital technological components. Good examples of essential Smart Grid infrastructure are *energy production facilities* and *transmission grids* maintained by utilities and grid companies, as well as the *telecommunication networks* maintained by both integrated and wireless telecommunication operators. *Technological components*, in turn, are provided by electrical component and equipment manufacturers, industrial conglomerates – such as Siemens and Bosch – and communications equipment producers.

Empirical evidence from economic transactional data shows that *catalyst* industry sectors, in turn, help to *integrate the anchor industries*; they *catalyze change* by way of building new value chains between previously disconnected industries. The effect is the generation of the capability to produce entirely new types of economic value add in the form of novel products and services that transform incumbent industries. In the case of Smart Grid, the impact manifests in increased efficiency, reliability and security through real-time, data-driven optimization technologies and services. One could conclude that in the case of the Smart Grid ecosystem it is the catalyst sectors that make the system intelligent. Catalyst sectors include many software-based industries such as *systems software*, *application software* and *data processing*. *Semiconductors* as well as *technology hardware and storage* further corroborate the centrality of IT-related solutions in tying together the intricate web of industrial activity in the smart grid ecosystem.

Evidence shows weak signals of incipient Green Chemistry value chains

So, what then is the major concern regarding Green Chemistry? Unlike the Smart Grid ecosystem, the Green Chemistry ecosystem *lacks meaningful catalyst industry sectors*. There are *only few* existing value chain structures between sectors that provide "green resources" – such as the biomass generating paper industry – and industries that would use them as sustainable inputs. On the contrary, the structure displayed in Fig. 4 (*right* panel) – abstracted from transactional data – represents the classical value chain structure of the chemical industry, consisting of its supplier relationships in the fossil raw materials industry, on the one hand, and its client relationships in the household product industry on the other. What we see in the picture is the industry's structure as it has existed for the past few decades. In short, there is no indication of encouraging trends towards a new, biomass-based circular economy.

That being said, a detailed examination of the map displayed in Fig. 3 reveals that there are weak first signals of incipient connections between the paper and chemicals sectors. The three sectors are bridged by a potential catalyst, the *commodity chemicals* sector (Fig. 5, green edges). According to the data at hand, this link is still very weak but could be early indication of an alternative, sustainable, biomass-based resource sourcing strategy of the chemicals sector. Evidence that this signal is at work in the real stocks and flows of the economy is based on investment by major chemical giants such as BASF and the Dow Chemical Company in entrepreneurial startups that have developed processes to generate new cellulose-based building blocks as input raw materials for chemical production.

Promotion of bioeconomy only viable as long-term, patient strategy with marginal short-term economic impact

What is to be made of the results? Clearly, the existing industrial structures do not promise short-term growth. The necessary circular value chain structures need to be developed first before the ecosystem can be expected to contribute to economic growth on any relevant scale. From emerging industry pilots in the Green Chemistry space – such as the number of rising bio-energy plants in Finland – we know that opportunities to harness the country's natural resources are seriously being probed. What is not known, however, is whether they will catalyze the much sought after economic growth.

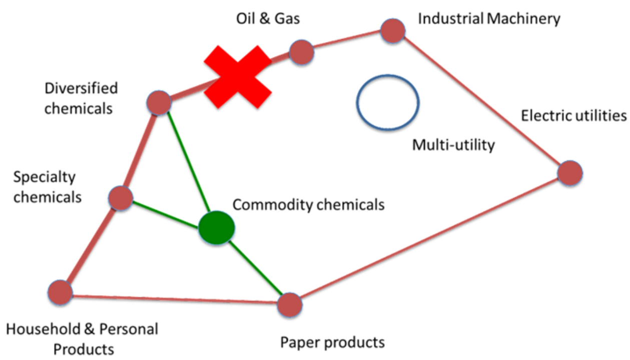
Here, the crucial question is whether renewables-based materials merely substitute for petrochemical raw materials in the economic plumbing system of the conventional industry structure, on the one hand, or whether they actually entail the emergence of entirely new economic activity, perhaps even the emergence of entirely new industry sectors, on the other. If the former scenario turns out to be the case, the best possible outcome from an economic point of view is an increase in competitiveness – fueled by a global drive towards industrial sustainability – of *the existing industry* at best. It could provide fading, incumbent industry sectors with enough ammunition to stay in the game. This, of course, is an admirable outcome in and by itself, especially if it helps to sustain existing jobs.

For real economic growth, i.e. new industrial activity and job creation, however, only true industrial renewal is sufficient. The incipient structures between biomass-producing sectors and the chemicals industry could be a seedling of such activity. New companies are being formed that refine biomass into a form exploitable by the chemicals industry. The biggest threat to the emergence of more robust links between biomass producing sectors and chemicals are the long-lived, vested interests between the fossil raw materials sector and the chemicals industry. However, evidence from Europe's largest chemical megacluster – the Antwerp-Ruhr-Rhein axis – is not encouraging. The strength and low cost supply of incumbent fossil fuel industries is at this time relegating bio-based materials to a niche substitute product, rather than displacing existing supply chains.

For an alternative, more sustainable structure to flourish and succeed, this strong link needs to be broken (see red cross in Fig. 5). This is a classic case for regulatory government intervention, justified by the environmentally negative externalities that entail the use of fossil raw materials.

In accordance with classical literature[7], one can argue that nurturing infant industries – such as Green Chemistry – is exactly what economic development policies are meant for. If such a strategy is chosen, however, the decision needs to be made with the awareness that, in case of the Bioeconomy in particular, it will not be a quick fix to an urgent problem such as the lackluster Finnish economy. Building an entire industrial ecosystem with its complex web of value chains is viable only as a patient long-term strategy that will far exceed the limits of any single term of office of any government. Beyond single pilots, there is currently limited

Fig. 5 Incipient value chains between paper and chemicals sectors



market validation for industrial momentum in the alleged Bioeconomy.

Roadmap to the design of a 'smart bioeconomy' program

The evidence and arguments presented here argue for a Smart Grid equivalent to the bioeconomy, and to uncover or promote an anchor-and-catalyst model to drive high value growth. The capital markets – where many of the industry value system data originate – argue for the understanding of signaling in the economy. One key signal that has been picked up from finance to industrial design, and is on the cusp of transitioning economies to a 'smart bio-economy', is biomimicry or bimimetics. Biomimicry, or smart bio-inspired design, engages sectors as diverse as finance, industrial design, the construction industry and energy. The PLNU Fermenian Economic Institute predicts that by 2030, bioinspiration will generate $425 billion of U.S. GDP and $1.6 trillion of global GDP.

Even though the hub of investment in biomimicry innovations is in the US, a recent thesis from Turku University of Applied Sciences highlighted the link between biomimicry and the green economy. Abstracted from Jenni Koho's thesis: "Biomimicry can be applied exactly on the same sectors of economy which have most export potential in the green economy: primary and secondary industries and in the energy sector."

Smart Grid encompassed value added services built on the existing infrastructure in the economy. Biomimicry takes the learning from bio-based processes and designs to rethink construction, energy, and finance. Given the strength of Finland in industrial design, the computational and software industries that encompass the platforms in new economies, and the heavy manufacturing and healthcare anchor industries that power the economy, biomimicry may well represent the 'smart bioeconomy' opportunity for the country.

Box 4
Key insights

- System-level evidence of industrial momentum in the larger Bioeconomy is weak.
- Economic policy promoting the Bioeconomy is not expected to generate short-term growth and must be patient.
- Moving to a bio-mass based economy might require policy intervention to break strong vested links between petro chemicals and industries using fossil raw materials in their processes.
- Other emerging ecosystems in the larger cleantech space, such as Smart Grid or Smart Mobility, already show clear industrial momentum.

Endnotes

1 http://awsassets.panda.org/downloads/wwf_report___global_cleantech_innovation_index_2014__final_.pdf

2 http://team.finland.fi/en/team-finland-in-brief (last visited 4.1.2016)

3 (last visited 4.1.2016)

4 The Bloomberg SPLC Database provides company-level data on supplier-client relationships and their bi-directional monetary exposures. The lines, called "edges", between the various sectors in Fig. 2 represent *existing transactional business relationships between companies in these sectors*. The thicker the edge is, the higher is the financial exposure between the sectors. Using the companies' industry classification codes, the data was aggregated onto the industry sector level. Data extracted in July 2015.

5 The network maps displayed in this brief have been built out based on a Finnish company population. However, no geographical limits have been imposed on the business partners of the companies in said population, respecting the fact that many – if not most – business relationships in the global economy are cross-border relationships. Therefore, the maps displayed here by no means represent exclusively domestic business ecosystems only.

6 The careful reader might wonder how a sub-sector (here Green Chemistry) of a larger ecosystem (here the Bioecon-omy) can display more robust connectivity than the ecosystem itself. The reason is that the map of the Bioeconomy in Fig. 2 only builds on the specific industrial sectors mentioned in the original government strategy briefs describing the Bioeconomy. In the case of Green Chemistry, we use a broader and more detailed set of industry sectors that are argued to contribute to the ecosystem. The differences in connectivity between the two approaches already shows that, to gain any feasible insights on the viability of an ecosystem, it is necessary to focus on clearly defined, thematic industry value systems.

7 Alexander Hamilton (1790): Report on the Subject of Manufactures.