UNIVERSITY OF TURKU

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PRECURSORS TO A ‘GOOD’ BIOECONOMY IN 2125:
MAKING SENSE OF BIOECONOMY & JUSTICE HORIZONS

First Foresight Report of the BioEcoJust Project

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EXECUTIVE SUMMARY

Introduction

The BioEconomy and Justice (BioEcoJust) is funded by the Academy of Finland BioFuture 2025 programme and aims to develop a future-oriented ethical and justice framework useful in assessing long-term bioeconomy developments. The project's foresight team at Finland Futures Research Centre (Turku School of Economics, University of Turku) is comprised of Markku Wilenius, Sofi Kurki, Amos Taylor and Nick Balcom Raleigh, with periodic contributions from Marianna Birmoser Ferreira-Aulu. The philosophy and ethics research group of the consortium is led by Matti Häyry at Aalto University. The project began in January 2017 and goes through December 2020.

The foresight team's task is to explore possible futures of the bioeconomy and produce new insights regarding what future contexts pose a challenge to contemporary frameworks for ethics and justice. The scope of this foresight work looks out to the year 2125 with a dual focus on the national concerns of Finland as well as the broader context of global challenges.

Methods

The foresight research is being conducted using a multi-method approach which includes an explorative literature search, horizon scanning process, a questionnaire-based Delphi study, draft scenarios, Futures Clinique participatory workshops, and action scenarios (see Figure 1). This method mix can be conceptualized as both a research pathway of interfacing inputs and outputs and as a system of interacting elements in which the resulting knowledge production is greater than what could be produced by any one method alone. Completed steps so far include the literature search and horizon scanning which feed into the next phases starting in 2019. To keep the final resulting foresight salient, horizon scanning continues throughout the project, feeding and being guided by the other methods.

The foresight team has also developed sensemaking tools and scenario seeds through the literature search and horizon scanning processes. These findings are presented in this report (see Part II) as well as a sensemaking framework comprised of two key sensemaking tools: Three Socio-Technology Domains – settings of technological development, and Five BioWorlds – groups of actors categorized by ethical stances in relation to bioeconomy development.

At the time of this report, which could be called the halfway point, preparations are being made to execute the Delphi study. Building on the sensemaking framework and related outputs, the next stages of research will invite experts from around the world to expand, challenge, and investigate ethical implications for the long-range future of the bioeconomy.

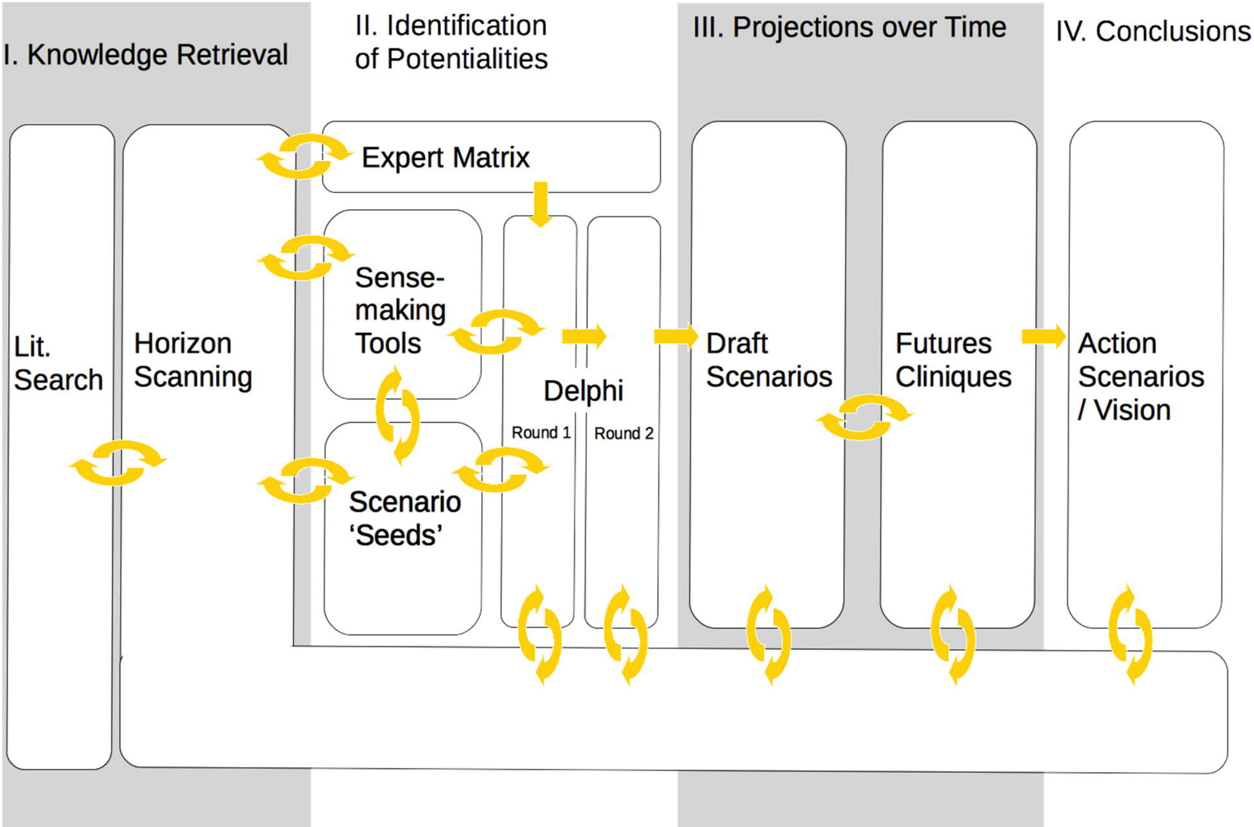

Figure 1. BioEcoJust Foresight Methods as a Dynamic System in context of the simplified generic model of foresight proposed by Lauster & Hansen-Casteel (2018).

The goal of the Delphi study is to collect and analyse data to produce draft scenarios. These draft scenarios will be used as background material in the futures workshops. Originally developed for situations where trend forecasts and mathematical modelling were inefficient in providing useful information about the future, the Delphi method has become one of the most popular methods in foresight and futures studies. It has been adopted for use in many disciplines to assess future developments by expert panels. The method applies iterative rounds of inquiry. In the second round, answers given in the previous round are used to generate new questions which support knowledge exchange among the panel experts and anonymous argumentation to avoid groupthink effects.

A Futures Clinique approach will be utilised in a series of workshops. The Futures Clinique method emphasizes the development of surprising ideas about the future – ideas that diverge radically from present notions on what is possible and probable. Because of this emphasis, the Futures Clinique approach is especially well suited for long timespans. The Futures Clinique workshops in this project will be used for surfacing the assumptions found in the draft scenarios; opening unexplored aspects of the scenarios; elaborating the scenarios towards action scenarios; and creating visions for bioeconomy for years 2025, 2075, and 2125. These workshops will focus especially on how new bioeconomy technologies could affect social systems and what kinds of decisions impact their development. The Future Clinique structure allows for the co-existence of competing views as different possibilities for the future. After the workshops, the final output of the entire method mix will be Action Scenarios, active frameworks for dynamically assessing the long-range ethical impacts of potential decisions taken in the present.

Initial findings

The first phase of research has produced several tools to help make sense and provide first insights regarding the bioeconomy in the year 2125:

- **Future Generations**, a thought experiment that concludes that the rising generation (age 20–30) in the year 2125 will be the great grandchildren of today's three-year-old children.
- **Nine Big Influences on 2125**, a set of well-grounded high-impact, low-uncertainty drivers which depict the complex challenges and overall conditions of the year 2125.
- **Human-Technology-Nature triangle**, a relational engine for defining goodness in the Bioeconomy, through which competing conceptions of how humans, technology, and nature should relate.
- **Five BioWorlds**, categories of actors defined by their implied characterization of what would be ethically good relationships among humans, technology and nature.
- **Three Socio-Technological Domains** which are fundamentally different but in places overlapping.

In the next phase of research, all of the sensemaking tools will be used to explore potential future directions for the bioeconomy. For example, at an operational level, they are being applied to select the expert panel and developing the questionnaire for the Delphi study. For the purposes of this executive summary, the five BioWorlds and Three Socio-Technological Domains are described in more detail while the others are elaborated in the full report (see Part II). However, in order to fully describe the BioWorlds, the Humanity-Nature-Technology Triangle (see Figure 2) needs to be mentioned because these two sensemaking tools are deeply interlinked.

The Humanity–Nature–Technology Triangle conceptualizes a set of relationships that are as old as antiquity and possibly all of human history. It is therefore a suitable 'sorting tool' for looking far into the future. The characteristics of the relationships among these three active nodes dynamically change over time with different types of actors applying new meanings and entailments to these relationships as their capacities, awareness, and affordances change.

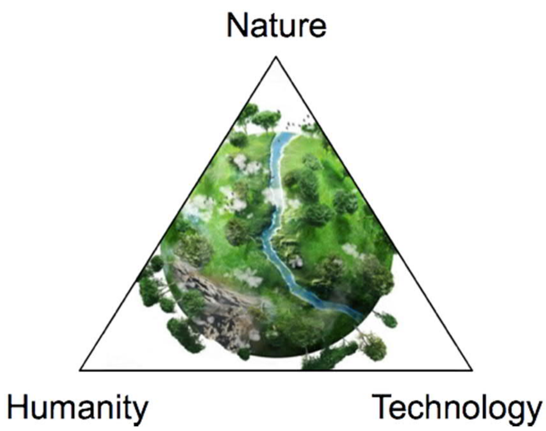

Figure 2. Triangle of relationships among Humanity, Nature & Technology.

The BioWorlds were developed from the Human-Nature-Technology triangle by asking: "What do various actors believe are the ethically good forms of these relationships?" Therefore, the relationships among humans, nature and technology have differing characteristics for each BioWorld. These variations can be briefly summarized as follows:

- **BioUtility** – Nature is a valuable source of biomass to gather for new products and services using increasingly efficient technologies.
- **BioMimicry** – Nature has produced many perfect examples of how to accomplish complicated tasks from which people can learn to create better, more sustainable technologies.
- **BioUpgrade** – Living organisms are generally flawed and can be improved through human interventions using sophisticated technologies.
- **BioRecovery** – Radical technologies should be applied to degraded lands and de-wilded places to rapidly recover ecosystems and re-establish their biodiversity.
- **BioEquality** – Humans must believe ourselves as equal to, not above, all other life on Earth; our technology should serve the purpose of protecting all 'survivors' of climate change.

These five BioWorlds clearly exist today and are argued by this project to have a high probability of existing in some form in the year 2125. There may be other nascent BioWorlds existing today that were missed in this study. New BioWorlds will also likely emerge over time as new configurations of the Human-Nature-Technology relationship triangle become possible due to changes in human capacities, affordances, and awareness. Either these missed nascent BioWorlds of today or the BioWorlds emerging in the future could develop to have high impact on the happenings of year 2125.

Three key technology areas have been selected from the horizon scanning for further analysis: **Soil, Forest,** and **Algae**. In qualitative analysis these labels became higher level organisers of items found in the project's literature search and horizon scanning. Each area functions as a vector of technological development and knowledge production, while having its own differentiating characteristics. Combined they are able to cover a wide scope containing multiple themes, sectors and practices which are illustrative of potentials of the whole bioeconomy. **Soil** represents novel initiatives in agriculture, which is becoming a focus of bioeconomy not only for traditional reasons, but also for its significance in addressing climate change. Healthy soil has the capacity to bind carbon from the air, and both old approaches like adding nutrient-rich compost to soil or encouraging rotation of crops, as well as novel ideas like enhancing the soil's capacity to bind carbon by adding biochar, a biologically active side product of energy production by bio-gasification, are gaining a foothold. **Forest** draws from the former paper and pulp industries transformation to utilise woody biomass and forest management knowledge in new ways to offer alternative materials that are more sustainable and climate friendly. Plastic made from wood or large building construction from timber offer interesting avenues. Bioreactors and refineries are definitive of the industry that greatly diversify the output of high value chemical streams as well as biofuel and pure energy. **Algae's** greatest potential is in its ability to generate high value chemicals and materials in controlled compact reactors at scale. These could produce great quantities of specific chemical combinations, even biofuels, while also being able to process and absorb C02 and other toxic waste materials. In nature, algae are often a visible negative effect of pollution in seas and lakes, however; when harnessed with human technology algae can be utilised in positive ways.

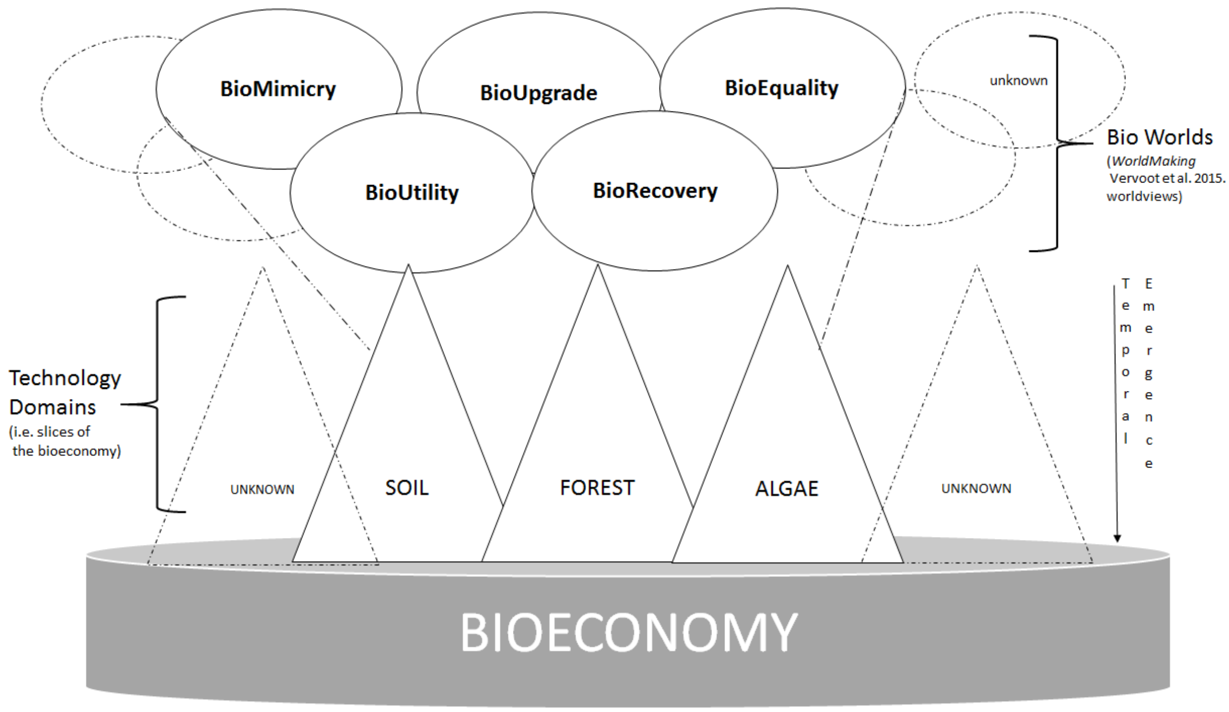

Figure 3. BioEcoJust Sensemaking Framework combining BioWorlds and Socio-Technological Domains

Combining the BioWorlds and Socio-Technological Domains produces a viable Sensemaking Framework for use throughout the remainder of this project (Figure C). In the centre of the figure are the three Socio-Technology Domains of Soil, Forest and Algae which thematically encapsulate different types of approaches, technologies, motivations, business models, and practices in the bioeconomy. The cones in the figure suggest emergence over time, with each domain emerging at different rates, moving toward greater saturation of the bioeconomy and ultimately overlapping the others. The topmost area of the figure depicts the Five BioWorlds: Networks of actors with their own belief systems, rationales, visions of the future, practices, and conceptualizations of reality. A primary distinction among the worlds is what these constellations of actors perceive as ethically 'good' in terms of how humans, technology, and nature interrelate.

The key way this sensemaking framework can be applied is to develop an understanding of a dynamic engine of change operating beneath the surface of bioeconomy developments while surfacing ethical and justice-oriented trouble spots. In the background of this framework is the potential for multiple green economies and phases of the global economy which can introduce new forms of growth, values and systems that better engage humanity, nature, and the planet (i.e. 'natural capital', Costanza et al. 1997 or 'doughnut economics', Raworth 2017).

In the development of the expert matrix, for example, the BioWorlds are combined with multiple sectors and multiple scales to produce an expert matrix which should have high potential to reveal conflicts and synergies among a wider variety of actors and help identify new kinds of ethical trouble spots. Additionally, the sensemaking framework will help us ask the panel more provocative and higher impact questions.

Connections to Futures Studies

Futures Studies includes an ethical principle called ‘decolonizing the future’ which means leaving as much of the future to be formed by the people of those futures. This principle can be confused with a notion of avoiding planning – but such a conclusion is not what it entails. Planning and execution of plans today can be critical to leaving a future decolonized because in many cases a lack of planning can lead to very negative consequences for future generations (e.g. poor planning can lead to slums around cities, inadequately educated populations, or war). The longer history of what is now called the Bioeconomy includes actual historical colonization. For instance, various European nations actively colonized the Americas and severely altered what is possible for the descendants of those lands’ original people. As the Bioeconomy develops, it will be essential for existing powers and rising powers to avoid repeating similar ethical offences through their deals to access lands inhabited by others or new ways to extract or produce value from the biome. The call for ‘decolonizing the future’ can be extended beyond human needs for justice to other forms of life. This so-called post-human perspective is one of great interest to the BioEcoJust project as it is arising as a future signal in our horizon scanning process.

Another ethical stance found in Futures Studies is concern for whether futures are open, inclusive and participatory or closed only for a select few where the voices of those who will be impacted are not heard on key decisions about the future. Furthermore, in Futures Studies consideration of many alternative futures rather than one set path is emphasized. Humans can impact many aspects of the future and our choices and actions make a difference. An example of a closed future we have inherited is the dominant and incumbent fossil fuel industries. While many developments have come from this abundant source of energy, the climate change resulting from burning these fuels is actively removing future options for future people. These industries have also introduced great resistance factors such as infrastructure investment lock-in and distribution patterns of geopolitical power which hamper today’s people to make the changes necessary to address climate change. When considering the Bioeconomy in this light, it is essential to question whether its development is opening futures by introducing new possibilities or closing futures by reinforcing existing unjust industries and patterns.

Conclusions

The long-term promise of the bioeconomy seeks to fundamentally change how humanity uses natural resources and relates to Earth's ecosystems and our technology. The bioeconomy will necessarily include being much more intelligent in how material goods and services, energy, and ecosystem services are produced. Understanding more deeply how nature works and how we could apply this knowledge into our technologies, infrastructure and building, we can then develop our societies in a more sustainable way.

Today’s critical trends haunting our future such as climate change, land degradation, water scarcity, species extinction, and massive population growth are vexingly interlinked. How well the Bioeconomy will address these challenges depends greatly on how justly and ethically it develops. The next 10–20 years will be decisive for our future and it is increasingly urgent to act to limit damages from climate change. How do we stop burning oil, overusing natural resources and wastefully producing and consuming material goods? Part of the answer to this question is bound to come from new advances in Bioeconomy sectors. Above all, the Bioeconomy holds huge promise – as well as huge risks – that require careful and ethical development toward a fairer and more just global society than what we have at present.

PART I – ABOUT BIOECOJUST

Photo by Janus Clemmensen on Unsplash.

1. INTRODUCTION

Societies move forward and change based on the needs and intentions of their members. Intentions can be good, less good, or bad, but usually are motivated by a search for something that someone views as desirable. Needs can be individual, or they can arise from collective experiences. The BioEcoJust project aims to find new dimensions to what are today, and would be in the future, ethically good intentions, motivations, and ultimately, actions, in a fully functional and globally active bioeconomy. The key question asked in the BioEcoJust project is "What is an ethically good bioeconomy?" The potentials in the bioeconomy are great. A myriad of solutions based on utilising natural resources as basis of a new kind of socio-economic system, to solve the climate change problems generated predominantly by the 19th and 20th century industrial society? And what kinds of futures are possible, desirable or avoidable if this challenge is met? To explore potential answers, the foresight team of the BioEcoJust project is building theoretical frameworks for assessing futures-oriented issues in the bioeconomy and drawing development paths from the present towards the year 2125, exploring different scenarios about our Bio-Futures. The scenarios will address key issues that have to do with systemic change from our current industrial model to one that is able to function sustainably on renewable resources. A key outcome of the project will be in the form of tools for thinking and acting regarding futures that involve the use of biological resources in both novel and ethical ways. From this perspective it is possible to better express what would be just and ethical futures.

In the first phase of the project, our focus has been on depicting and defining the landscape that can give rise to bioeconomy. There are great challenges in finding an all-encompassing definition for the term bioeconomy itself, able to capture all possible meanings this multifaceted phenomenon can refer to (see Chapter 1.1). Rather, the BioEcoJust project approaches the issue from a systemic perspective, where the interest is in bio-based solutions that offer a potential for large-scale societal transformation. An example of the kind of potentially transformative initiative would be for instance changing agricultural practices so that the ability of soil to bind significant amounts of carbon from the air to the soil is enhanced. This solution, as all of similar magnitude, will require political resoluteness. Here lies the second main interest of the BioEcoJust-project: illustrating the problematique surrounding the decision-making processes regarding potential solutions and their concrete implementation.

The futures are open, and as such in many ways dependent on the contingencies of political decision-making. A complex problem like climate change is apt to lead to decisions favouring success in the short-term, and thus these are adaptation-oriented strategies. However, complex and systemic problems typically require long-term solutions that address different facets of the issue. Such propositions coming from the policy-makers is much rarer for the simple reason that they are much more difficult, both technically, and especially politically. The kinds of decisions that change the system affect members of the society differently, leaving some better off than they were, but others less so. Understanding these societal decision-making situations, identifying the responsible decision-makers, the outcomes of decisions, and the dynamics of this inevitable outcome of producing winners and losers, are matters of ethical consideration. Analysis of these ethical aspects will be carried on in depth by the Aalto university team of the research consortium, headed by the consortium leader, Professor Matti Häyry.

In our report the futures team addresses ethical challenges by discussing what will open futures mean in this politically contested context, and by drawing attention to the ever-present topic of colonizing futures, meaning the tendency to occupy the future with far-reaching plans that are based on today's valuations and power interests. This, as well as the discussion of winners and losers in bioeconomy decisions, links with the distribution of power in making future-related decisions, always an important element when discussing societal negotiation processes. A concrete issue in societal negotiation, critical also in the context of the futures of bioeconomy is of course the question of who will pay for the costs incurred in the processes of preventing or mitigating climate change. One answer to this problematique is the forming of functional markets for carbon capture.

When estimating potential outcomes on a long, 100-year scale, their importance needs to be understood against a changing temporal context. Professor Oran Young from the University of Santa Barbara has studied the politics of environmental management. He points out that the value trade-offs, always present in any societal negotiation situation, and are significantly affected by the temporal dimension. This means that the character of values changes over time as a reflection of the changing societal mindset, in turn affected by the surrounding conditions. Therefore, we also assess different ethical valuations and mind-sets regarding our environment and its uses. The socio-cultural landscape of the next 100 years will evolve in the context of what can be anticipated to be coloured by increasing environmental stress, novel socio-economic logic, and technological change. The most challenging part of the anticipatory work is drafting possibilities for these collective mindset changes, assuming they will have the greatest effect on the decision-making situations over the next century.

In this report we present the results of the first phase of the study: potential key drivers of long-term change in bioeconomy in the technology, environment, social, and demographic spheres. This includes exploring emerging trends, projections, and weak signals in the field of new technologies, and new industries related to everyday life (food, energy, climate, urbanisation, construction, conservation, tourism etc.). The main aim until now has been to produce a detailed framework of sensemaking tools and scenario seeds to be utilised in the next phases: Delphi questionnaire, and Futures Clinique workshops.

The original research Foresight Questions for BioEcoJust are:

- FQ1: What kinds of possible future scenarios do experts produce for the bioeconomy in 2025, 2075, and 2125 based on estimates of technological possibilities and their societal feasibility?
- FQ2: What kinds of scenario paths extending from 2017 to 2125 can we form based on the results of the scenario work?
- FQ3: In these scenarios, what are the key issues that relate to social justice and social feasibility as identified by the experts?
- FQ4: What kinds of obstacles for adopting bioeconomy are identified?

These questions continue to guide the work while the research team remains open to modifying the questions or identifying new ones as needed.

1.1 What is Bioeconomy?

In a simple sense, bioeconomy means an economy that is fundamentally based on biological resources, services and activities. Humanity's ability to utilise nature for sustenance is nothing new, thinking about the key human developmental epochs from hunter-gatherer to herding livestock, to agriculture and to industrial, all have drawn their resources from nature in one way or another. Thus, the arrival of the concept of a 'bioeconomy' might be confusing as to its relevance when seeking what is new and in the future: after all the information age and the digital revolution that currently are understood as being representative of the future areas of growth, can seem as a clear move away from nature toward mechanistic, robotic, and virtual paradigms.

However, the bioeconomy is proposed as the next phase of economic development that offers potential new means for economic growth (e.g. Finland Ministry of Employment and the Economy 2014). In one perspective the term can be seen as just a strategy to revitalise waning industries such as forestry, pulp, and paper which have been hard hit by the digital revolution and need to be realigned toward new future markets, to offer jobs and growth in these sectors again. Another more recent perspective sees that a bioeconomy has a contributing role in fighting climate change, offering clean renewable alternatives to the problematic and depleting fossil-based fuels, materials and chemicals that dominate our consumer society (e.g. Priefer et al. 2017). The benefits of restoring and maintaining biodiversity in natural environments in a sustainable way suggest another focus that offers its own rethinking of 'growth'. Another perspective sees that the knowledge economy of the digital age is augmenting toward applying its thinking to biological sources, adept at finding new techniques in directly engaging it at its cellular or material level or transforming it to fit new as yet unconceived arenas. In considering a longer view of the future we might see these as the emergence of what could ultimately become a bio age or even a **Biosociety** (Mannermaa 2004) where the dominant growth is fundamentally understood to be drawn from a bioeconomy, where we might think of bio solutions in the same way we consider digital solutions of today. All of these perspectives represent the bioeconomy.

Attempting to produce a simple clear definition that covers all the previous perspectives, Mckormick & Kautto (2013) propose the following:

'A bioeconomy can be defined as an economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources'
(Mckormick & Kautto 2013).

This all-encompassing definition allows for a more general approach. However, it does not reveal within it the multiple varieties of wider interpretations that also exist, perhaps explaining why the term bioeconomy is slow to be understood in society. As a strategy, there are regional interpretations, biases and assumptions. Not all are automatically sustainable or circular or green (Hetemäki et al. 2017). A Finnish bioeconomy, European or American, Brazilian or African, for example have vastly different contexts, and to ultimately talk about a global understanding of the bioeconomy is not yet attainable. And yet we might consider that the bioeconomy for the first time is a set of global phenomena, engaging planetary issues with planetary effects, both positive and negative. This type of thinking requires new definitions that allow for the complexity to unfold.

Definitions of the bioeconomy are still open to interpretation. Bugge, Hansen & Klitkou (2016) ask 'What is bioeconomy?' They note that there is little consensus on what a bioeconomy is and in their literature review they categorise three general 'visions' of the bioeconomy that express different perspectives—

bio-technology, bio-resource and bio-ecology. Bio-technology vision's foundation is based on technology systems and solutions, bio-resource on those systems and solutions that maximise utilising resources, and bio-ecology vision' values those systems and solutions that support biodiversity and sustainable approaches to nature. These visions have similarities to the 'Five BioWorlds' sensemaking tool developed through this project's literature search and horizon scanning (see Chapter 4.5).

Another viewpoint suggests that the concept is still 'fuzzy' and therefore Golembiewskia et al. (2015) undertake an exploration (through a 'technology innovation management' perspective). They express that there is an interdisciplinary need for approaching bioeconomy research on novel technologies also from a societal standpoint. While it might be hard to articulate what a societal bioeconomy standpoint is and could be for the future, it is this perspective that offers a more interesting line of inquiry. A more holistic approach suggests the bioeconomy as:

"[…] the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors" (Hetemäki et al. 2017, 12, citing German Bioeconomy Council 2015).

This definition offers a more service-oriented perspective where eco-services as well as commercial services depict the complex systems and solutions at play. As our research demands a definition that serves a future oriented perspective to outline decisions and potential ethical issues, this holistic approach seems wise to adopt.

1.2 Kondratieff Wave Theory as a Meta-Framework for the Study

The Kondratieff wave (K-wave) theory is at its origin an economic theory explaining long-term fluctuations in commodity prices (Kondratieff 1928/1984). However, scholars interested in it, most notably Joseph Schumpeter (e.g. Schumpeter 1939/1984) and his intellectual followers, have built on the basic structure a more nuanced explanation of societal change. There, the changes in economic indicators like prices are only an easily perceivable reflection of a systemic structure. Different theories have been proposed for the generating mechanism of this phenomenon, but a consensus is still missing, to a point that the Kondratieff theory itself is often dismissed as a pseudo-theory by mainstream economists. However, the ideas continue to enjoy a steady following among scholars of varying backgrounds, from economists to historians to systems theorists and futures researchers, who find the explanatory power of the theory convincing in analysing societal data. In a nutshell, the K-wave theory brings attention to a wave-like fluctuating pattern in the economic history in capitalist economies. There, a pattern of a rising growth wave peaks to be followed by a descending trend, and after a crash the pattern begins anew. The waves bring with them repercussions that reach beyond the mere economic sphere, and it is these effects that scholars tend to be more interested. Linkages between the waves and widely different phenomena from infrastructure construction to occurrences of violence have been made in the literature. There are more specific interpretations of the phenomenon, for instance Carlota Perez' bimodal representation of a wave, distinguishing between "gilded" and "golden" ages of an upward cycle (Perez 2002). A typical explanation favoured by the Schumpeterian school of wave studies is that a novel technological driver builds a new market that feeds growth around it, at the same time changing societal practices to better suit the novel technological regime. This techno-centricity has also been criticised, with the argument that there is no one driver for the wave, but rather the issue involves a complex systemic pattern where all of the parts are affecting the outcomes (Ayres 1990a & 1990b).

For the purposes of this report we can represent the techno-economic history from the beginning of the 20th century as a succession of different technology-driven cycles (see Figure 4). What we can take from this illustration is a notion of history as a complex system, driven by a tendency to structure around a set of drivers, and form around 50-year wave-like patterns. This sort of a meta-framework is helpful as a methodological tool especially when aiming to anticipate long-term developments on a global scale.

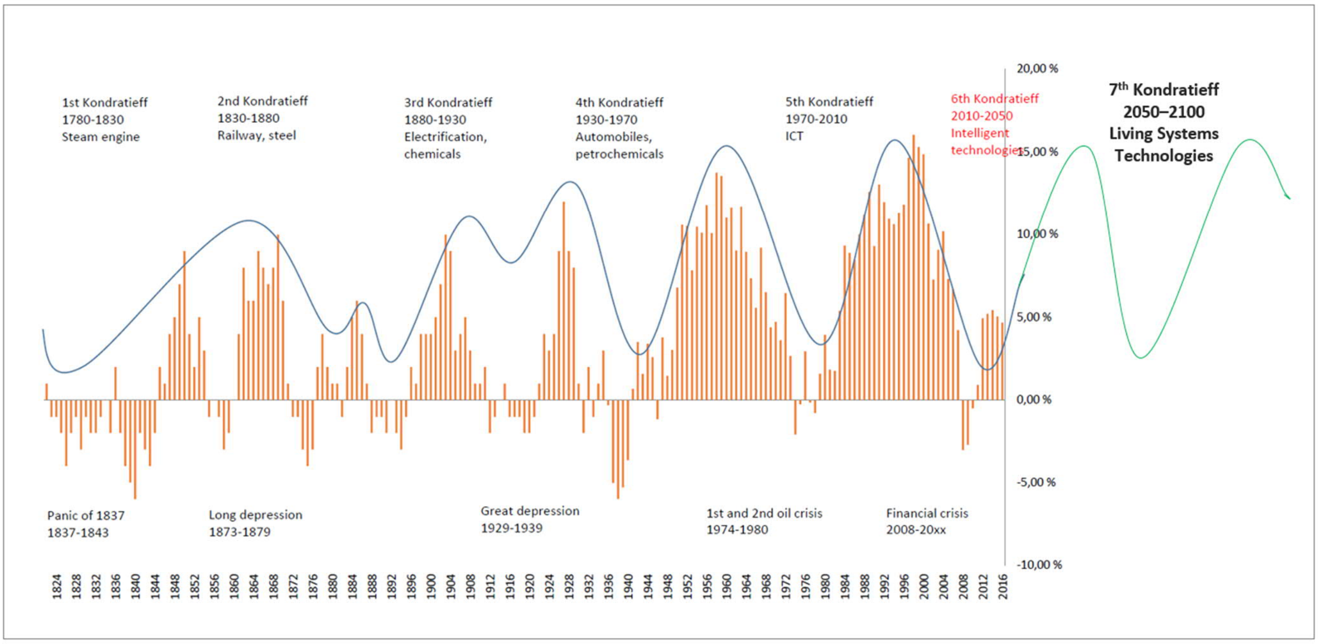

Figure 4. Rolling 10-year return on the S&P 500 from Jan. 1814 to Dec. 2016 in % per year (Source: Datastream, Bloomberg, Graph: Helsinki Capital Partners) with illustration of plausible 6th and 7th waves. Adapted from (Wilenius 2018).

K-Waves as a societal change theory posits that the technologies, modes of organising, and values that will define a wave are budding and already perceivable in the beginning of the previous wave. For illustration, we can take two examples from a recent technology history: the development of renewable energy technologies, and the development of digitalisation.

Table 1. Examples of technology development in the K-wave framework.

Weak signal phase, revolutionary ideas	Niche phenomenon	Mainstream	Becoming an issue of concern, building of the next platform
Tesla, early pioneers of energy technologies, early 1900s (3rd K-wave)	Wind-, solar-, bio- technology pilots, 1970s (5th K-wave)	Wind & Solar as mainstream technologies in the 6th wave.	7th wave?
Charles Babbage, Ada Lovelace, Difference Engine, 1820s (2nd K-wave)	The work of digital pioneers, Alan Turing's Universal Machine, 1930s (4th K-wave)	Digital technology as the technology driver of the 5th wave.	6th wave enabler of resource efficient solutions, growing concern over societal effects of evolving computational capacities.

Examples of niche phases of development include solar and wind energy technologies in the beginning of 1970s, or digital technologies in 1930s. Following this logic, we should now be able to find early predecessors of Seventh wave solutions that we hypothesize to be based on biological platforms, and with the weak signal phase ideas eventually forming the Eighth wave regime. The following thought experiment outlines how the next 100 years could go in terms of the K-wave framework and emphasizing the bio- and environmental perspectives as main drivers for events.

Sixth Wave (2010–2050): Starting in 2010, the Sixth wave will see the technology development emphasis on resource efficiency, building of a new energy system, and development of circular economy. Culturally, systems thinking, being the key idea in circular economy, will continue to develop post-material values, and a niche cultural phenomenon in societies is altruism. These Jeremy Rifkin claims in his book *Empathic Civilization* (2010) that major leaps in civilizations result from bursts in empathy. In the Sixth wave the speed of growth in both the economy, and resource use will come to a halt.

Around the year 2050 climate emissions will overshoot the accepted limits, as anticipated in the business-as-usual scenario of the IPCC special report on global warming of 1.5°c (IPPC 2018). Consequences of this will be increasingly dramatic weather phenomena, floods, fires and drought, experienced globally and in areas previously unaffected by such extreme conditions. Furthermore, various irreversible second order changes make the climate patterns increasingly unpredictable.

Seventh Wave (2050–2100): A changing world is moving from climate shock towards finally reaching a balance between use of resources, and their renewal. Biological systems have completely invaded industrial heritage systems, resulting in a transformation of industrial thinking to full-scale circular economy. Non-renewables are substituted by biologically manufactured materials, and new resource bases for commercial harvesting have been developed, for instance, in the oceans, an example being Kelp-forests that are now being employed for a variety of goods and services. Humans refine organic materials, and humanity's reach has turned the entire planet to a garden of careful nurturing and harvesting. The extreme utilitarianism that is characteristic to the 7th wave starts to be recognized as an increasing problem towards the end of the 7th wave. The scale of manipulation of the natural world threatens to make the whole concept of nature extinct. Also, culturally, the prevailing spirit of prioritising the well-being of the system before one's own individual aims is increasingly criticised.

Eighth Wave (2100–2150): The focus is on re-wilding the planet, and technologically produced biomimicry rather than large-scale exploitation of bio-based production. Harmonising the relationship between humans and nature is a value. Climate related natural catastrophes have reduced population numbers closer to the carrying capacity of the planetary boundaries. Small local communities are both a virtue and a necessity: organising in small tribe-like groups is considered to be more natural than living in the megacities of the previous waves. At the same time, the efforts to revive biodiversity benefit from sparse population densities.

The condensed images of the future presented above draw attention to the key dynamic of the waves: each growth phase is fed by a need arising from the previous wave but providing solutions to it in turn generates novel issues that start pressuring the system more as the wave is nearing its end. This type of a schematic approach is useful as a heuristic when taking on the challenge of anticipating very long-range futures. It is also a tool that helps in freeing oneself from the constraints and lock-ins that threaten to bind the thinking to the present reality.

1.3 Futures Studies Approach

Taking a futures studies perspective will help shed new light on potential new dynamics within our world's ever-changing complex systems. The value of anticipating these new dynamics is in how they will likely produce system characteristics very different from those we observe today.

The very concepts of bioeconomy and justice will profoundly change – as they have over the past 107 years—as we move toward the year 2125. To illustrate the change potential in the biosphere one only needs to bring to mind what agriculture was like just 50 years ago, before the full-scale introduction of fertilizers and machines. For instance, in Finland 1967 was the year when there were an equal number of tractors and horses in use on farms (Myyryläinen 1998). Techniques that widen the scope of what is seen as possible typically employ historical comparisons and analogies, but also find instances of futures within the present, a method referred to as horizon scanning. This project uses mixed methods as a way widen our perspectives, see beyond the given and prevailing concepts, and check our own biases and blind spots against outside views. We search for rich meanings, potentials, and interpretations that do not typically sit neatly in preassigned boxes.

In other words, the futures studies approach is necessarily receptive to surprising and challenging information and ready to produce surprising and challenging results. Famous quantum physicist Richard Feynman once called for the pursuit of 'interestingness'. The BioEcoJust project uniquely attempts to contribute foresight insights that go beyond those found in current day bioeconomy discussions.

1.4 Project Objectives and Scope

The expected results of this study will take the form of tools for anticipating, contemplating and discussing upcoming ethical challenges in the development of bioeconomy. Ideally, these tools will have high relevance and usefulness for decision-making at various levels in society – from corporate boards to political leaders to citizen-consumers. Rather than offering prescriptive instructions for how to act ethically in some deterministic vision of the future bioeconomy, our study seeks instead to develop rigorous sensemaking tools and action scenarios that can help decision makers and society at large to uncover hidden variables, generate new meanings, and see nuanced future potentials in our changing world.

We have identified three distinct key areas that we take as representative parts of the whole of the bioeconomy, these are general labels used to broadly organise clusters. These topical areas are **Soil**, **Forest** and **Algae** that can be briefly mentioned here. Soil is representative of the arenas of agriculture, especially new initiatives like regenerative agriculture and specifically highlighting the role that soil has in climate change through the sequestration of carbon dioxide; Forest represents the transformation of the forest industry to meet the societies challenges of climate change and the vital role in which managed forests retain biodiversity as well as forests as a carbon store; And finally Algae represents the relatively new field of innovative applications that produce alternative materials, biofuels, chemicals, foods and medicines, that potentially could offer new high value products through synthetic biology. Algae itself is being utilised in industrial process, but it is not exclusive to this field as microorganisms, mycelium, bacteria, fungi, sponges, have an equally important role. Thematically Algae for this stage of the clustering process offers a scope that connects this field's practice and knowledge. An argument could be made for microorganisms as a title, however the engagement of the subject has utilised algae as an entry point through the research action and discovery process, thus this term serves the researches early phase. Each of these above arenas have their own identity, systems and knowledge bases that often overlap and reveal the values and practices that they utilise. There are other areas that are weakly representative but surely would become stronger themes in the future, themes like Oceanic based bioeconomy – utilising the potential seas and oceans and water resources that are yet less dominant compared to the three other domains but may become more and more relevant.

In qualitative analysis these labels became higher level organisers of contents. Each area functions as a technology and knowledge domain, and each have their own individual characteristics that are distinctly different from the others. Combined, they are able to cover a very wide scope that contains multiple themes, sectors and practices that are illustrative of the whole of bioeconomy. We will return to exploring these specific areas in more detail in Part II: Initial Findings, and Sensemaking Tools. Theme areas are used for structuring the research in the further phases of the project, namely the Delphi questionnaire and workshops.

The project by its nature is geared towards stirring discussion around the topics related to the bioeconomy. For this, it is important to maintain a steady stream of public presentations, seminars, and workshops (see Appendix 1). The project has been actively involved in arranging a discussion session as part of the Finnish Organic Society's symposium in collaboration with the Nessling Foundation on the topic of Carbon Underground. The seminar was arranged in conjunction with an invited research visit to explore carbon binding practices at the Qvidja farm in Parainen, Finland. The project has also presented its results several academic conferences: at European Commission Foresight Technology Assessment 2018 in Brussels; BioFuture 2025 Symposium hosted by Academy of Finland in Joensuu; and a symposium in Koli hosted by the BioFuture 2025 project Born Global, and the World Futures Conference in Tampere 2018. Professor Wilenius has delivered a number of speeches to various audiences on the topic of the BioEcoJust themes. Initial findings also served as the topical content of the Scenario Thinking course co-taught by Markku Wilenius, Amos Taylor, and Nick Balcom Raleigh for the master's degree program in futures studies at Turku School of Economics. The Scenario course functioned as a testing ground for scenario-making methodologies and allowed students to engage in early findings of the BioEcoJust project and build possible futures in relation to them. The project themes have also been explored by executive MBA students in the Corporate Foresight course at Turku School of Economics. Internationally, the project was presented at a Lima event for Peruvian business event. Taylor and Wilenius have also discussed BioEcoJust ideas in interviews with the media and in newspaper columns. Taylor and Balcom Raleigh have published blog posts openly analysing and sharing items horizon scanning items. Taylor also consulted with a local artist for a curated project Ilmastokanava (https://www.ilmastokanava.com/) that addresses climate change through pairing organisations with artists. As a result of the collaboration, a series of prints on the future challenge of economies and climate change were produced and exhibited at STOA Itäkeskus gallery space in Helsinki.

2. METHODS

The futures research is being conducted using a multi-method approach. This method mix can be conceptualized as both a research pathway of interfacing inputs and outputs and as a system of interacting elements in which the resulting knowledge production is bigger than what could be produced by any one of the methods alone (see Figure 5.)

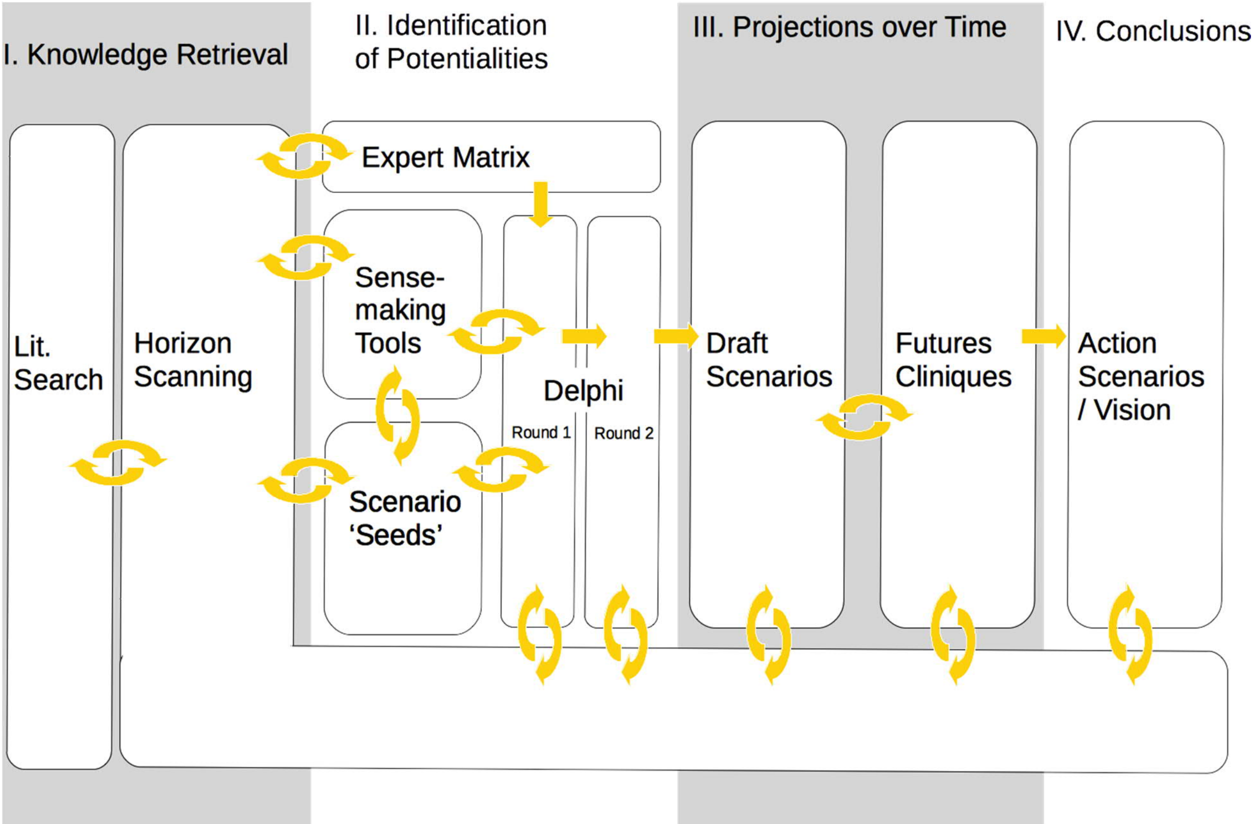

Figure 5. BioEcoJust Foresight Methods as a Dynamic System in context of the simplified generic model of foresight proposed by Lauster & Hansen-Casteel (2018).

The methods selected for the study fit in the four-phase generic model of a foresight process (Lauster & Hansen-Casteel 2018): Knowledge Retrieval, Identification of Potentialities, Projections over Time, and Conclusions. The literature review and horizon scan comprise the first phase of Knowledge Retrieval, while a reduced form of the horizon scanning method is expected to continue throughout the following phases. In the Identification of Potentialities phase Sensemaking Tools and Scenario Seeds are developed and experts are identified for the Delphi panel. For the third phase, Projections over Time, the findings from the previous two stages are transformed into Draft Scenarios. In the final phase, the work of the project will be synthesized into Action Scenarios key decision makers can use to ethically guide actions toward the future.

As of this report, the objective of the first phase – to bring relevant and up-to-date information into the process—has been completed via the **Literature Search** and **Horizon Scanning** (see Chapter 2.1 and 2.2). The Literature Search familiarized the foresight team with Bioeconomy scholarship as well as positioned the team's work in relation to various relevant academic fields. The sometimes overlapping Horizon

Scanning process opened the retrieval process to a wider range of sources including websites, news and magazine articles, interviews, conferences, conference abstracts, events, online videos, ads, and more. During this first phase of work, Horizon Scanning received a greater amount of time and attention and also exposed the research team to some of the most provocative and high-impact information. After the first phase, this Horizon Scanning process continues, but in a more limited way, as a way to keep our understanding of the research domain, 'future potentials of bioeconomy', fresh and inspire how the methods are applied in the following three phases.

During the last quarter of 2018, the focus of research moved into the second phase, 'Identification of Potentialities'. In this phase, the foresight team has produced **Sensemaking Tools** and **Scenario Seeds** by analysing and interpreting items and texts found via the Literature Search and Horizon Scanning process. Additionally, preparations for the Delphi, the major undertaking in phase 2, starting in 2019, have begun in terms of identifying potential expert panel members.

Draft Scenarios will be formed based on the outcomes of the Delphi study. It is important to note that these Draft Scenarios are intentionally going to be unfinished outputs so that the participants of the Futures Clinique (in phase 4) will feel more empowered to modify them by adding detail which is a way to entangle creativity and criticality to produce high-quality workshop outcomes (Balcom Raleigh & Heinonen 2018).

The final output of the project will be Action Scenarios, useable by decision makers in the public and private sector as well as interested members of the public to assess the ethicalness of actions toward future which impact the development of the bioeconomy. The desired outcome of the foresight part of BioEcoJust is to provoke meaningful, future-oriented, and ethically sophisticated discussions about how the bioeconomy can be developed.

2.1 Literature Search

The aim of the literature review is to become familiar with the history and current state of the research topic, the future of the bioeconomy. Another goal is to position the BioEcoJust project in relation to other relevant academic fields and identify gaps this research initiative is especially well-suited to fill.

The literature review was conducted in two bursts. In the first round of the literature review, a first goal was to locate other established literature reviews about the bioeconomy, in order to identify up-to-date definitions of the term, scope of the field, research initiatives, and researchers. This process began within the context of the Finnish perspective emphasizing the Forest-based bioeconomy, widening to a European perspective toward a more general understanding of the term, with regional and global perspectives. Searched bibliographic databases revealed existing literature reviews about the bioeconomy. Key papers were selected primarily by topic fit, other criteria demanded the articles were highly cited, well-written, broad in their scope, and thorough in explaining terminology (e.g. "bioethical maturity"). Additional articles were selected from the references used in those papers. A separate search was conducted for strategy reports and grey literature attempting to find ones that engaged societal perspectives and contrasting debates. While the search began systematically, over the process, leaps could be taken to new material based on what had been found up until that point. The process concluded with identification and selection of materials with the highest providence and credibility. These materials were read more carefully than the others. This work served as the basis for a priori tags and search terms for the Horizon Scanning process that emerged from literature review.

The second round of literature search was conducted "in the blind" of work already completed by the BioEcoJust project as of January 2018. The scope of this one-month search started from a global and general view of bioeconomy and generally stayed at this level, while gradually turning more attention to Europe. Some attention was also paid toward alternative uses of forests as mentioned in literature. The initial guiding questions for the search were “what is bioeconomy?” and “what credibly can be said about its future in the year 2125?” Along these lines the literature search aimed to identify already existing scenarios and future images for the bioeconomy and located the BioEcoJust project in relation to existing research efforts in Bioeconomy, technological development, and ecological stewardship.

Literature became key for defining the current understanding of the concept of Bioeconomy and its limitations. In respect to futures thinking works were found that specifically related to scenarios, visions, strategies and roadmaps. The literature reviews identified prevailing normative goals in the Bioeconomy and the state of the art, which positions the work of exploring alternative pathways toward the year 2125.

2.2 Horizon Scanning

Horizon Scanning is generally understood as the process of detecting emerging trends, threats and opportunities. It is the systematic scanning process that can be useful to gain knowledge of the relevant trends in the external environment that are likely to have a significant impact on the future with implications of those trends affecting the overall direction. These Horizon Scanning items can act to confirm or challenge current assumptions, identify actors, clarify regional and cultural differences, signal a new happening, elaborate on a previously existing phenomena, and indicate actor motivations. Many of the trends are drawn from qualitative data and are heuristic in nature, requiring interpretation and further analysis. As a form of future signals, trends are usually already widespread and active in society. On the other end of the spectrum are weak signals, a form of early information about emerging trends which may increase or decrease in influence or relevance over time (Ansoff 1984). Weak signals act as sources of evidence of future problems or possibilities and require interpretation to be fully utilized (Hiltunen 2010). In many cases, the weakest of weak signals can provide foresight practitioners with surprising and provocative ideas about the future.

Horizon Scanning can be seen as a systemized practice of seeing future potentials in present day phenomena. In BioEcoJust this method is operationalized as building in time for keeping tuned to local and global happenings in the bioeconomy. Rowe et al. (2015) warns of the possible limitations of horizon scanning, such as the risk of seeing too many patterns or for the distilled signals and frames as potentially blinding an organization's view of potentially important developments. Being aware of these risks, the BioEcoJust project continually challenges its own assumptions and seeks other ways of seeing the issues we uncover.

2.3 Methods to be Completed in 2019

The primary research method for collecting data for the scenarios will be a Delphi study. This part of the project is heavily informed by the findings from horizon scanning and literature review. The Delphi method is one of the most popular ones in foresight and Futures Studies, and it has been adopted also across different disciplines for assessing future developments by expert panels. The method includes two or more rounds of inquiry, in which answers from earlier rounds are synthesised into the questions for the next round, allowing participants to respond to the views of the other experts on the panel. The method supports anonymous argumentation which helps to avoid unproductive ego-driven conflicts and groupthink effects.

In this study a combination of thematic expert interviews and a two-round Delphi survey will be used for data gathering. This modified hybrid Delphi approach has been found to increase expert commitment over the research process and contribute to richer argumentation around the topic of interest. (cf. Landeta et al. 2011). Key informants are selected to the panel by using an expertise matrix (Kuusi et al. 2006). Expert views are clustered into scenarios by combining quantitative and qualitative data with the Q_2 scenario method (Varho & Tapio 2013).

In the beginning of 2019, the first-round Delphi questionnaire will be formulated and sent to a selected panel of experts. This formulation and selection process will be informed by the sensemaking framework resulting from the literature search and horizon scanning (chapters 2.1 & 2.2). Panellists are selected by using an expert matrix which will assist in ensuring a balanced mix of representatives from important areas, focussing on experts with both a technological and social interest in bioeconomy (Appendix 5).

Throughout the study, we are particularly interested in:

- Large-scale technology trends that can have century-wide impacts
- Potential social impacts of such technologies
- Outcomes, technological developments, and obstacles to of adopting bioeconomy
- Ethical trouble spots that may emerge as human capacities, nature, and technology change.

The expert scenarios are taken as background material for the futures workshops. A Futures Clinique approach will be utilised in the workshops (Heinonen & Ruotsalainen 2013). The Futures Clinique method emphasises participant variety with regard to occupations, generations, tastes, occupational sectors, etc. The method encourages development of ideas that diverge radically from present notions on what is possible and probable. The Futures Clinique approach is especially well suited for very long timespans. The Futures Clinique workshops in this project are used for discussing the acceptability of the expert scenarios; elaborating expert scenarios towards action scenarios; and creating a vision for bioeconomy for years 2025, 2075, and 2125.

The Futures Clinique workshops will focus especially on the societal effects of technology. Participants are encouraged to think about effects that biotechnology may have on social systems, and what kinds of decisions the adoption of different solutions will entail. The method allows for a presentation of competing views as different possibilities for the future.

PART II – INITIAL FINDINGS

Photo by Markus Spiske on Unsplash.

3. LITERATURE THEMES & SIGNIFICANT TEXTS

3.1 Key Themes Found in the Literature

Thematically the research discovered provocative areas of inquiry that give useful insights and where clear critical and conflicting issues reside. Some of these areas might be very familiar in the context of the bioeconomy (**bio-energy**), while others like **aviation biofuels, sustainable textiles, radical geoengineering, synthetic biology, conservation** and **rewilding initiatives** for example, rewrite the boundaries of the field. Thematically it has been important to engage surrounding fields to identify critical voices of the bioeconomy as well as those that promote core strategies, values and visions. As the bioeconomy can be said to be fractured and multisector (Birch 2017) that continuously engages new sectors, for this research engaging contrasting themes has been a fruitful way in which to gain an understanding of the potential dynamics of the whole.

3.2 Most Significant Literature Found in the Search

The most influential literature stems from our need not to merely document the industries current status quo and strategies but those works that reframe the discourse, critically challenge assumptions and reveal new societal implications. Those texts that deal with foresight naturally draw our attention like the Bioeconomy Flagship global Delphi study (German Bioeconomy Council 2015b). It gave us a clear foundation for assessing future potentials of BioEcoJust. In the study, foresight was used to examine the potential for the bioeconomy of key flagship projects being funded in Germany. Also, the academic critical dissections offered by Keen Birch (2017) as well as Jenny Andersson and Erik Westholm (2018) outline the fundamental problematics in the bioeconomy and in researching it. Andersson and Westholm identify industry influence and bias in bioeconomy research in Sweden and Birch wrote about the problematic political goals. There are many texts in line with Bugge, Hansen & Klitkou (2016) that aim to create an overall understanding of the literature and strategies of the bioeconomy, engaging and categorising its visions, shortcomings and potential. Literature related to the forest bioeconomy perspective is well established and speaks of the larger bioeconomy, utilising foresight to explore forest biomass growth and industries (Hurmakoski & Hetemäki 2013) that are often related to research by EFI European Forest Institute. Energy, technology and innovation are already substantially covered in the literature on research and development for example by VTT, even with some futures orientation (e.g. as roadmaps). This kind of technology-oriented research is typical in bioeconomy literature, however, it offers lesser examination on the societal implications and ethical issues in surrounding decision making that Vainio et al. (2018) and Mustalahti (2017) have suggested. Mustalahti engages the weak role of citizens in decision making for the bioeconomy, Vainio et al. (ibid.) identifies the limitations of the current bioeconomy to engage society and the environmental dangers that policy strategies almost ignore. Literature on biodiversity also offers critical perspectives. A report by Cerulogy prepared for Rainforest Foundation Norway indicates how deforestation impacts biodiversity (Malins 2017), where the biofuel demand from palm oil industry for example is examined globally to reveal its devastation to vulnerable ecosystems. The wide-ranging literature discovered reveals the complexity interwoven challenges of the subject.

4. REGIONAL REPORTS

As part of the desk study phase of the project, we conducted an international review of key areas of interest for our project's themes.

4.1 Germany

In the summer of 2017 Sofi Kurki visited the research group of Professor Andre Habisch, professor of social ethics and social policy at the Katholische Universität Eichstätt-Ingolstadt in Bavaria, Germany. Professor Habisch was a member of an ethical commission consulted for Germany's famous Energiewende process.[1] This practice of subjecting the decision about the future of Germany's energy policy to a consideration by a group of social scientists was the main initial interest for the research trip, and possibilities for replication in a bioeconomy context was one of the themes we wanted to explore further. The German approaches to bioeconomy were also of interest from the perspective of understanding global directions for the future bioeconomies, and during the trip the significance of this interest grew.[2] From the Energiewende consultation process we learned that a careful planning and ensuring a broad variety of viewpoints are crucial to a successful outcome, but that the conditions surrounding the decision were quite unique, and thus replication of the process in any trivial manner may be unobtainable.

For the bioeconomy, it was thought provoking to learn that measured by the market size and the number of companies, the size of industrial biotechnology is still very marginal, and every value chain is below 5-10% of the market. Although within the sphere of bioeconomy there is a tendency to view it as the future of economy, currently it must be recognized as still in a niche phase. In Germany (as elsewhere) part of the phenomenon of bioeconomy has to do with relabelling of already existing parts of the economy. This is one reflection of the fact that in Germany (as in Finland) a common understanding of what bioeconomy is, or what it should be, is still in formation.

In Germany, roughly, the bioeconomy field is divided into industrial biotechnology and the agriculture. Forestry is not a large part of the field. There is a rather stark divide between the agricultural and the biotechnological approaches to bioeconomy. This is reflected in the general attitudes of the actors. For instance, it is claimed that there is a tendency in agricultural bio-economy to label everything, even the very traditional agriculture, under bioeconomy. On the other hand, the biotechnology side focuses much more on innovation and industrial production, but the origins of the biomass are not of any concern. The difference between actors from different backgrounds is manifested also in the understanding of what bioeconomy means. Agriculturalists more naturally view it through substitution: "I will replace fossil fuels by biomass, which comes from forestry or agriculture." In other words, something exists, and I will do the same thing but with a different feedstock. But a background in biotechnology, industrial biotechnology, or synthetic biology are attracted to the mechanisms and organisms, and on how ecosystems function. The

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[1] For more information about Energiewende, see http://www.energiewende-global.com/en/ (Accessed 21.12.2018.)

[2] The plural in the term reflects our conviction that it is wiser to think about plural forms of the Bioeconomy, rather than approach it as one monolith. This same notion is present in all futures thinking, where of course the term future is also mostly used in its plural form, futures.

focus then falls on the transfer of the mechanisms into new ways of production, and new ways of organizing the industry. Then the bioeconomy ends up being a contribution to circular economy. Different understandings of bioeconomy means in practice that a lot of effort goes into trying to find a new narrative, and a new definition from the perspective of integration of the different backgrounds.

Uniting these two approaches into one discussion is very challenging, and the challenge is echoed on a political level, where it becomes more concrete in defining which research projects fall under Ministry for research and education, and which under the Ministry of agriculture, the two key interested parties for shaping bioeconomy in Germany. However, there is a consensus in understanding that the bioeconomy can only be a success if the interested parties work close together.

The bioeconomy policy priority was described as rather new, replacing the focus on biotechnology. The transition to mission oriented bioeconomy and finding solutions to climate change focus was made only in 2010. An interesting feature in the national research strategy of bioeconomy in Germany is that it has a focus on societal issues. An open question (and one under study by the Fraunhofer ISI) is whether the mindset of bioeconomy actors and the innovation system around it is prepared to orient the activities towards the societal goals, like combating climate change, or is the mindset still closer to the traditional view emphasising economic competitiveness in the international market.

4.2 California

In November 2018 a research visit was made to California by Sofi Kurki and Markku Wilenius. Experts were interviewed to understand more about the Bioeconomy prospects at University of California's Santa Barbara and Berkeley campuses, and from the Singularity University. In addition, we talked with start-up entrepreneurs at All Power Labs involved with developing biochar for carbon sequestration, representatives of the Carbon Underground initiative engaging in promoting the health of soil to capture carbon from the air, AG Innovations, a consultancy specializing in facilitating discussions to engage communities in food systems and natural resource management, as well as with Jean-Michel Cousteau's Ocean Futures Society, an organisation dedicated to exploration of the oceans and education on their conservation.

The first thing to note about California in relation to bioeconomy is its universities that produce high quality basic research related to relevant topics. However, in many climate change related areas of bioeconomy, potential solutions coming from the academia lack functional markets, and market-based funding opportunities. Therefore, the jump from research to market is problematic, and is the reason why many bio-based initiatives tend to generate very little activity at the start-up level. This said, there are specific areas, like new materials, food, water, and waste management related issues, where the market approach is working. For instance, novel foods can be even said to be a hot topic for attracting venture capital. Mostly high tech still links with bio via more traditional forms of computing, like satellite-based monitoring of crops.

A few of the interviewees agreed that currently fighting climate change is less about technology and more about behaviour and socio-cultural attitudes. The Californian culture, even with all its appreciation of the natural world, can still be described as adaptive and reactive, a mode where it even excels and produces many workable solutions to current problems. However, on the other side of the coin is a certain lack in ability to seek out the root causes of issues, and a tendency to start regarding worsening conditions as “the new normal”, meaning adaptation and acceptance.

California’s reputation as a high-tech driven business hub often shadows its importance as an agriculturally significant area, producing the majority of agricultural products sold in the US market. Especially UC Davis is a hub for agricultural studies. Considering bioeconomy futures, it is interesting to note that patents based on agricultural research and development work have recently passed pharmaceuticals in the UC system's patent revenues. Farmers have recently turned to exploring bioeconomy especially for utilising the biomass that results as a side-product from their activities. This development is hindered by the generally cheap energy prices, making bio-based energy uncompetitive in the market. Agriculture is however becoming a focus of bioeconomy for its significance in affecting the climate change. Healthy soil has the capacity to bind carbon from the air, and both old approaches like adding carefully designed compost to soil, and encouraging rotation of crops, as well as novel ideas like enhancing the soil's capacity to bind carbon by adding biochar, a biologically active side product of energy production by bio-gasification, are gaining foothold. While interviewing a biomass gasifier generator producing company it become obvious that this direction is seen to be more lucrative than mere bioenergy production.

California has recently banned the use of plastic straws and bags. This was often brought up in discussions, but not so much as a sign of progress but rather as an example of the kinds of decisions that in the current political climate are possible, in contrast with more effective but politically more demanding decisions. Even if plastic may be for many reasons problematic, substituting plastic straws with paper ones hardly represents a game changer in the fight against environmental degradation and climate change. Bigger decisions are clearly needed but siloed decision-making structures, vested interests, and a general lack of leadership are among the reasons mentioned that are preventing more efficient governing of environmental matters. Effective tools like taxing harmful substances often run into powerful business interests and result in lock-ins in the governance structure.

In California, in addition to better known renewables like the solar energy, efforts are being made to develop alternative sources of energy from biomaterials. Kelp is a species of large algae seaweed that grows in forest like formations off the coast of California. It is extremely fast growing and has been harvested for many uses ranging from animal feed to ingredients for the cosmetics industry. Recently there has been a renewed interest in using kelp for fuel (the idea initially surfaced during the oil crisis of the 1970s), and a number of high-risk and potential high impact research projects have been funded by the government to explore the idea. Any significant fuel production scheme would require plantations of kelp forests, and such projects require both careful ecological consideration as well as working markets for the end product. As jumping directly to the fuel market would be economically doomed due to high production costs, attention is now focused on founding bridging markets to eventually enable fuel production.

Based on our California findings we mapped out some of the initial insights against our research question framework (see Chapter 1):

FQ1: What kinds of possible future scenarios (here pointed out as key solutions) do experts produce for bioeconomy in 2025, 2075, and 2125 based on estimates of technological possibilities and their societal feasibility?

- Transformation of diets to strictly plant based
- Development of agricultural practices to enable (significant) binding of coal from the air (carbon underground -initiative, biochar)
- Use of traditional biomass for new materials (e.g. nanocellulose)
- Moving large-scale biomass cultivation from land to sea (e.g. from corn fields to kelp forests), bypassing the food vs. energy debate.

FQ2: What kinds of scenario paths / drivers in scenarios extending from 2017 to 2125 can we form based on the results of the scenario work?

- End of subsidies for harmful agricultural products, taxing unhealthy products

- Building of markets for bioeconomy, e.g. bridge markets to bioenergy
- Agriculture looking for novel uses for its side products, biomass.

FQ3: In these scenarios, what are the key issues that relate to social justice and social feasibility as identified by the experts?

- Reformist ideas taken up by elites (organic food, growing of one's own food), unfeasible for lower classes
- Increasing financial disparity leaves more people vulnerable to effects of climate change, and lower quality foods.

FQ4: What kinds of obstacles for adopting bioeconomy are identified?

- Lack of markets for solutions that address climate change
- Lack of (political) leadership promoting the idea
- Challenges in governance

4.3 Australia

Many of the topical issues in California were also reflected in the context of Australia, where Markku Wilenius visited in January 2018. The main topic there regarding the future of bioeconomy seems to be represented by the multiple opportunities related to algae production. In the University of Technology, there is a lot of interest on this area. The university runs the Deep Green Biotech Hub, where have formed a multidisciplinary team, consisting of natural scientists and economists, who are exploring new ways of growing sustainable and profitable products from algae mass.

The exciting thing about algae is that you can develop potentially a very wide array of different products using algae as raw material. You can make biofuels, animal feeds, and different pharmaceutical and health products, use its oil to make for instance plastics and so forth. In fact, algae are like little "bio-factories" that can be widely applied for different human needs. The products on the current markets are usually done using about 10 different algae species, where in reality there is known to be at least 70,000 species.

The government of Australia seems to acknowledge a lot of opportunities here since they have started to fund these types of research. The next 10-20 years will probably see a huge rise of interest in these products as they can potentially replace a massive amount of non-renewable raw materials, such as oil. Global markets of algae could grow as high as US$ 44.7 Billion by 2023 according to an estimate made in March 2018 (Credence Research 2018).

4.4 Brazil

Brazil has one of the oldest traditions in bioeconomy, and it has also a very high potential in the new fields that are just opening up according to research by Finnish-Brazilian researcher Marianna Birmoser Ferreira-Aulu. Key lessons regarding how to ethically develop the bioeconomy can be found in Brazil's problematic colonial history, as well as the current discussions on regulatory framework in respect to agriculture, land, environment and human rights.

Large in area, Brazil has diverse biomes and ecosystems. Brazil is host to the largest biodiversity in the world (MMA 2018) and, as many areas are largely unexplored, the region has a great potential for new discoveries. As new species are being discovered and studied, there is a growing interest in exploring wild species and their genetic resources.

Brazil has always invested in biotechnology, especially in the area of agri-business. Since the Portuguese colonization period in the 16th century, Brazil has invested in large-scale monocultures for export. The long tradition in agriculture and livestock production from the colonial period evolved and later boosted with a prosperous production of biofuel. First-generation ethanol has been produced in Brazil since the 1930s. The global oil crisis encouraged Brazil to invest in production of biofuels, and by 1980s, most cars sold ran on alcohol. From 2003, with the introduction of flex fuel vehicles (FFV) consumers have had the option to fuel their cars with both ethanol/gasoline blend (dos Santos et al. 2016:42–43).

Brazil has abundant resources, and a long tradition in the agri-business, however, this is not enough to become a leader in Bioeconomy. To become a leader in this sector, Brazil must also master technical and organisational innovation. Although Brazil has a strong scientific base, the country is still walking on baby-steps in regard to innovation. Brazil has a long tradition of importing technology and specialized workforce from abroad, it is ranked 69 in the Global Innovation Index (2017: xviii), but if the State aims at being a leader in bioeconomy, this vicious cycle of importing know-how must be broken.

The main actors in bioeconomy today are the agribusiness and pharmaceutical industry. These actors are also important lobbyist and have powerful influence in local and State-level decision-making. With the support of the national government, proponents of bioeconomy are able to have economic policies, and even legislation in support of their interests.

Governance issues related to Bioeconomy are multi-fold and complex. Due to the power of agribusiness and pharmaceutical industry lobbyist in the current national government, policy making in the country is up to be reformulated. Three recently approved laws are especially interesting for the context of futures of bioeconomy and justice:

> ***The Biosafety Law (Law Nº 11.105/2005)*** *determines the standards of safety and mechanisms for genetically modified organisms (GMOs) and their derivatives, which are analysed by the governing body CTNBio, the National Technical Commission on Biosafety (CNI 2013:13).*

> ***Legislation (lei 7.735/2014)*** *allows access to public access to genetic resources and traditional knowledge associated to them. The law benefits the biotechnology industry, enabling them to explore the potential economic benefits of different products, but at the same time is contested by human rights activists, as a large proportion of these resources come from indigenous peoples' land. Although the legislation includes a clause that says the owners of traditional knowledge shall be justly compensated for their knowledge transfer, the law does not qualify traditional knowledge as an intellectual property right. By allowing public access to genetic resources and traditional knowledge, in effect this law goes against the* ***International Labour Organization Convention 169 (ILO C169)*** *which gives indigenous peoples the right to Free, Prior and Informed Consent (FPIC).*

According to ILO C169, indigenous peoples have the right to make choices about the development of their land and resources, including saying "no" for some instances. Indigenous populations were not involved in the formulation of the legislation that concern their intellectual property right. (ISA 2015) Ferreira-Aulu thoroughly presented FPIC in the Brazilian context in her master's thesis (2017: 64), and she argues that indigenous peoples have historically been denied of their right for FPIC in Brazil. This denial is present in many instances and different contexts, indigenous rights are treated as a costly nuisance to economic growth, giving reasons to believe that their rights are seen by the Brazilian hegemony only as obstacles to the development of the countries' economy.

So, why are these laws important for the future of bioeconomy and justice? As presented, the region is host to the largest biodiversity in the world. Once genetic resources and traditional knowledge associated to them become public access, underexploited areas, in particular Amazonia and the Cerrado become interesting for the agribusiness and the pharmaceutical industry. While strong businesses have intellectual property rights for their genetically modified goods, the traditional peoples who originally obtained knowledge about the benefits of different products gain very little recognition. How to balance economic growth with socio-environmental rights is yet a lesson to be learned.

According to research done by Marianna Birmoser Ferreira-Aulu, actors in bioeconomy have not (yet) published a lot of material with clear vision statements for the future of bioeconomy for the country. Perhaps this may be because the term 'bioeconomy' (or 'bioeconomia') is not a widely used in the region, thus, making the search for these vision statements more complicated.

CNI's vision for the Brazilian Bioeconomy

The Brazilian National Confederation of Industry (CNI) recently published their "Strategic Map of the Industry 2018-2022". In this publication, CNI presents an assemblage of issues they would like to see developed for the benefit of the industrial sector of the Brazilian society (CNI 2018 :42–161). The organization points out that the main barriers that Brazil needs to overcome to become a competitive nation are the lack of highly educated professionals, a general poor infrastructure, and an overwhelming complex taxation system (CNI 2018:26). The key drivers of change are changes in the legal system, development of industrial policies that promotes innovation and international business, improvement of state efficiency, de-bureaucratization, and investment on education (CNI 2018:31–32).

In CNI's vision, in 2022 Brazil uses the natural resources in an innovative, efficient and sustainable way. According to CNI, this is only possible with a simplification of the environmental licensing procedure. Efficiency in the use of natural resources is seen as beneficial not only for economic reasons, but also due to the understanding that there is a demand from consumers' side to lower the negative environmental impacts of production processes. In CNI's vision, when companies spend less time dealing various procedures to comply with legal requirements imposed by the State, they are more productive and less corrupt. (CNI 2018:42–161)

CNI promotes that the private sector should strengthen their network in order to raise awareness of the government and the civil society on the necessary changes needed for the development of the industry sector (CNI 2018:20). The industry sector, according to them, is more aware of technological innovations and trends in the international market than the State, and therefore, this sector has the duty to educate the State and the people; not only to be successful in their businesses, but also to advance as a society.

It is possible to interpret CNI's vision statement in a way that the private sector sells themselves as socially responsible as a means to obtain acceptance (good-washing). When reading CNI's report with this 'good-washing' interpretation in mind, it is possible to catch in-text nuances in favor for strengthening the private sector in the exclusive benefit of the private sector. In that interpretation, strengthening the industry sector's networks, as suggested, ensures more power in the decision-making process (for example through lobbying). Moreover, when CNI reasons the need to de-bureaucratize the Brazilian State, they claim excessive bureaucracy causes low productivity. In their argument, the private sector waste too much time and resources obtaining licenses, authorizations, and dealing with all kinds of procedures to comply with legal requirements imposed by the State, when they could be concentrating their efforts in innovation and development; and it is precisely this overwhelming number of requirements that stimulate corruption and informal work. (CNI 2018:70) CNI promotes the simplification of environmental licensing procedures in a way to make the process agile and clear. (2018:105)

Birmoser Ferreira-Aulu (2017) calls attention to the dangers of simplifying environmental licencing in Brazil. Brazil has recently suffered two significant socio-environmental disasters due the rupture of dams in the city of Mariana in November 2015 and the city of Brumadinho in January 2019. Simplification of environmental licensing may prove to be risky for the environment and the society, leaving the region more susceptible to other disasters. Instead of simplifying the licencing procedure, it should be an even more rigorous process than it is today. Moreover, she discusses that environmental licencing should be strengthened by improving social participation, reinforcing the conditions and resources of the environmental institutions, and improving the quality of the environmental impact assessments (ibid. 2017, 121).

Innovation in Brazilian science

Rampelotto (2016:6) describes Brazilian industry as “globally competitive in sectors that either derive from its abundant natural resources (oil and gas, agriculture), or were developed to preserve and protect them (aircraft and remote sensing). However, innovation in other sectors remains largely absent.” Rampelotto argues that the lack of innovation may be explained from the fact that Brazil invests very little of its GDP in R&D, and that federal investments are not mission-oriented. Moreover, there is very little interaction and collaboration between industry and universities. Scientist and doctors are concentrated in universities and research institutions, and there is a lack of highly educated professionals in the private sector. (ibid.) When looking at Brazil’s historical context (see Appendix A2.), it can be noticed how importing technology is a long-term trend in Brazil. Since colonization times in the 1500s, the country has always been dependent on technological import. Today, Brazil lacks PhDs and postdoctoral researchers in both its research institutions and in the private sector, and generally technical know-how is imported from abroad. This structural arrangement of its innovation processes is an obstacle to its development as a bioeconomy.

Toward Global Perspectives

These above regional investigations of Germany, Australia, California and Brazil are just snapshots from some of the really interesting countries that are currently dealing with the Bioeconomy. They have offered contrasting perspectives that reveal distinct geographical differences that are shown through their approaches to innovation and technology, as well as their culture and histories.

In the future, more investigations will be made into additional regions for consideration, particularly those in Asia that have seriously adopted policies and strategies to stimulate their economies and work toward tackling climate change. In this manner we are able to step closer to an understanding of what could constitute a global bioeconomy and its highly complex forms.

5. SENSEMAKING TOOLS

The sensemaking tools developed by the foresight research team as of this report are Four Forest Giants (Chapter 5.1), generational thinking (Chapter 5.2), nine high-impact influences on 2125 (subchapter 5.3), human-technology-nature relational triangle (Chapter 5.4), five bioworlds (subchapter 5.5), and three socio-technological knowledge domains (Chapter 5.6).

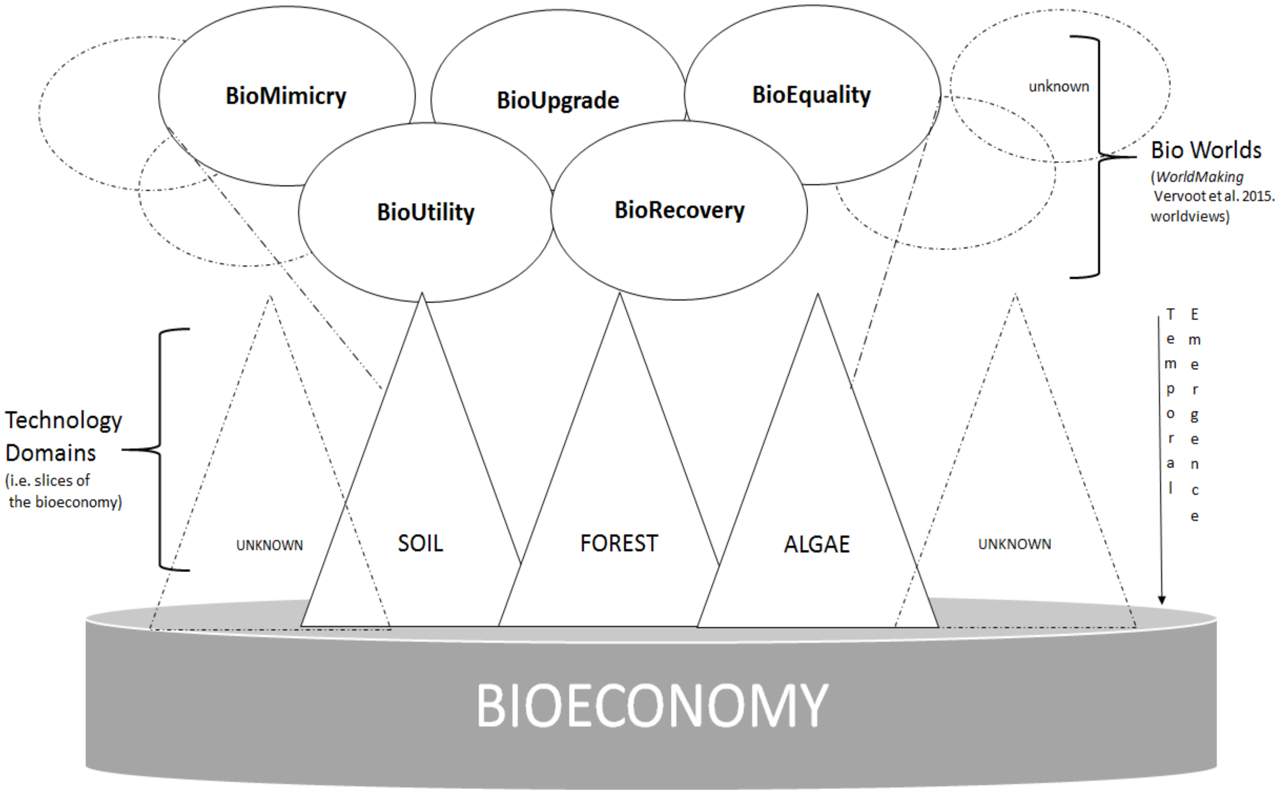


Figure 6. Sensemaking Framework for BioEcoJust

Of these, the three socio-technical domains and the five BioWorlds are combined to produce a Sensemaking Framework (Figure 6). In the centre of the figure are three socio-technological domains of Soil, Forest and Algae. These domains were selected because they thematically encapsulate different types of approaches, technologies, motivations, business models, and practices in the bioeconomy. These represent a slice of the overall bioeconomy, which indicate the broad contours of the emerging bioeconomy as a whole. Through these socio-technological domains, the foresight work can build from manageable foothold clusters. Although there are many other socio-technological domains existing today, these three are taken into focus for their differentiation in Bioeconomy activity as well as their similarity and complementary. The cones in the figure also suggest the emergence of these domains over time, each emerging at different rates, moving toward increasingly dominant position in the bioeconomy, ultimately overlapping others. This has proved useful in order to take a broad view of the bioeconomy, to test assumptions and seek alternative futures, and furthermore to identify conflicting positions and differences. From a Finnish perspective a forest-based bioeconomy is often assumed to be the most important one, however the potential impacts in innovative regenerative agriculture and bio-based production through algae offer alternative outlooks. The three socio-technical domains are explained more fully in Chapter 4.6.

The topmost area of the Sensemaking Framework (Figure 6) depicts the BioWorlds. These are wide networks of actors which share common forms of worldmaking (see Goodman 1976) – positional viewpoints, with their own belief systems, rational, vision, practices, and conceptualizations of reality. The primary distinction among the BioWorlds is how these constellations of actors perceive 'what is good' in terms of how humans, technology, and nature interrelate. Because such a fundamental and longstanding set of relationships lies at the heart of these worlds, the foresight research team believes they have a high potential for continuing to exist through the year 2125. Each of the five BioWorlds is unique and adds another sensemaking layer in which to explore ethical the considerations for each socio-technological domain. While these five BioWorlds have been found in this project's literature search and horizon scanning process, there are likely additional nascent BioWorlds. However, the five selected BioWorlds provide a broad enough sample, as is with the socio-technological domains, to explore the present and long-term future of the bioeconomies. The significance of these combinations allows for a critical exploration of the whole, to understand contrasting the functioning systems at play.

The point of this sensemaking framework is not to declare the future will be one way or the other or to imagine one BioWorld dominating over the others, or one Socio-Technological domain being more significant than others. Rather, the main purpose of this sensemaking framework is to develop an understanding of a dynamical engine of change operating beneath the surface of bioeconomy developments and the ethical and justice-oriented practices related to them.

Examples of identified 'Future-oriented Problem Area Trends' from horizon scanning:

Climate Justice; radical carbon capture - geoengineering to BECCS (bio-energy-carbon-capture-storage); new technology equality; biodiversity; water and food security; land use and land change LULUCF; deforestation; bio-prospecting; citizen inclusion-participation; sustainability and impact on future generations; incumbent regime/closed futures; bioethical maturity; greenwashing; future need vs. current need; climate mitigation - resilience; energy sustainability etc.

5.1 Metaphor of Four Forest Giants

One of the first sensemaking tools produced from the horizon scanning process is the Forest Giant Metaphors which was published as a book chapter (Taylor 2017). The Forest Giants Metaphors are based on Taylor's findings with key actors in the Finnish forestry sector, attendance at industry and bioeconomy conferences, as well as first observations from Horizon Scanning. From a Finnish perspective and for other forested nations, a forest-based bioeconomy is the dominant future imaginary, while in other regional interpretations it holds a lesser position.

Concerning the forest-based bioeconomy certain metaphors seemed to be useful for describing attitudes and belief systems surrounding what the bioeconomy could provide, almost similar to pagan mythology. Taylor (2017) proposes four metaphors to describe the latent potentials of the Finnish forest sector for the bioeconomy (see Table 2).

Table 2. Four metaphors for the potentials of the bioeconomy

Sleeping Giant	Waking Giant	Waiting	Colossus
Potential resources and energy within biomass (forest), promise of novel feedstock, quantified potential biomass is prospected. Hope is placed on these alternatives. Unclear how they will be woken.	Scaled up biomass to meet new industry and society needs, replace former (fossil), wake new industries where nature equates growth. Growth runs close to global limits. Unpredictable outcomes but seen as worth the risk by those involved.	Biomass carbon sinks and biodiversity are allowed to prosper, cautiously waiting for the right solutions. Carbon sinks are quantified as giants to be worshiped for their other virtues.	Novel alternative giant, highly unexpected and highly impactful. This considers the future impacts and implications of artificial intelligence and synthetic biology for example.

The concept on the one hand suggests that the actual biomass of the forest can be called a 'Sleeping Giant' holding all the potential of energy and materials to be used and 'woken'. On the other hand, the forest has the essential value and role in maintaining carbon sinks and biodiversity of nature in this 'sleeping state'. The metaphors highlight the dichotomy and potentiality of differing forest uses, value, and roles within the larger ideas of growth and transformation.

5.2 Generational Thinking

For most of us, 2125 is beyond our own lifetimes. Therefore, it is helpful to position ourselves to this time horizon generational thinking. As the saying goes, "children are our future." Most people know some children – these may be neighbours, nieces or nephews, grandchildren, or sons or daughters. To locate yourself in relation to 2125, begin by imagining a 4-year-old child you personally know. With this person in mind, make the following three assumptions:

1. this 4-year-old child eventually chooses to (and can) have children;
2. this child and the child's descendants have children at the age of 30;
3. over the next 100 years the global average life expectancy increases from 70 to 90 years.

With these three assumptions, the number of future generations between now and 2125 can be charted to gain a sense of who will be alive in that year and at what life stages. The guiding questions are: How many generations are there between now and the year 2125? And, which generations will be alive during that year? Table 3 illustrates the answer:

Table 3. Generations between now and 2125

Year	**Generation 1** (Today's 4-year-old)	**Generation 2** (4 y.o.'s Child)	**Generation 3** (4 y.o.'s Grandchild)	**Generation 4** (4 y.o.'s Great Grandchild)
2015	[born] ↓ (0–10 y.o.)			
2025	↓ (10–20 y.o.)			
2035	↓ (20–30 y.o.)			
2045	↓ Child →	[born] ↓ (0–10 y.o.)		
2055	↓ (40–50 y.o.)	↓ (10–20 y.o.)		
2065	↓ (50–60 y.o.)	↓ (20–30 y.o.)		
2075	↓ (60–70 y.o.)	↓ (30–40 y.o.) Has Child →	[born] ↓ (0-10 y.o.)	
2085	↓ (70–80 y.o.) [dies]	↓ (40–50 y.o.)	↓ (10–20 y.o.)	
2095		↓ (50–60 y.o.)	↓ (20–30 y.o.)	
2105		↓ (60–70 y.o.)	↓ (30–40 y.o.) Has Child →	[born] ↓ (0–10 y.o.)
2115		↓ (70–80 y.o.)	↓ (40–50 y.o.)	↓
2125		↓ (80–90 y.o.) [dying]	↓ (50–60 y.o.)	↓ (20s)

This thought experiment shows that the majority of people who will be alive in 2125 will be the grandchildren and great children of today's three-year-olds. The grandchildren will be in their 50s and if today's life stage patterns hold, a portion of this generation will be at the 'top of their careers' and extensively considered to be 'in power' (e.g. running companies, government agencies, and holding key political offices). The great grandchildren will be 20-somethings in the year 2125, the rising generation gaining its foothold in life's grand adventure. Meanwhile, with the average life expectancy of 90 years, the three-year-old's children could very well be alive in 2125 but would be at the end of their lifespans seeing their children and grandchildren growing into adults.

Based on this thought experiment, the BioEcoJust project is exploring the futures that today's 3-year-old children grandchildren and great-grandchildren will inhabit. These are the future people whose world are under discussion. What actions taken today will give them the fullest range of options possible?

Futures studies scholars often highlight the responsibility present-day people have toward future generations. As an example, Tonn & Stiefel (2018, citing Tonn 2018) proposes there are 12 key areas of responsibility toward future generations:

1. Prevent risk of human extinction from exceeding ethical threshold;
2. Prevent risk of total extinction of life from exceeding ethical threshold;
3. Bequeath [*pass on*] sustainable societies;
4. Bequeath [*pass on*] sustainable systems of production;
5. Reduce risk of death from involuntary environmental risks;
6. Preserve the essence of nature;
7. Preserve the essence of the human species;
8. Maintain options for future generations;
9. Preserve knowledge for use by future generations;
10. Generate knowledge for survival of earth life;
11. Minimize humanity's regrets over unfinished business; and
12. Fully inform current generations about futures and obligations.

Furthermore, responsibility to future generations is a key part of the definition of sustainability. For example, the Brundtland Commission Report (1983) defines sustainability as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Responsibility toward future generations necessitates an ethical stance and a conceptualization of justice, themes which strongly resonate with BioEcoJust. As such, generational thinking is an important sense-making tool for our project.

5.3 Nine High-Impact Influences on 2125

Many high-impact influences already known today will define the contours of what living on Earth will be like in the year 2125. Of all of these driving influences, the following nine key influences are highlighted for the BioEcoJust project:

1. Climate Change & Necessary Carbon Capture
2. Population Growth & Consumption
3. Urbanization / Human Pressure
4. Oil Depletion
5. Land-use / Land Degradation / De-Wilding
6. Sea Level Rise / Melting Ice Caps
7. AI / Super AI / Confluence of Advanced Technologies
8. Biodiversity Loss & Caring for the Survivors
9. Continuously Changing Economic Practices

Of these, in this report we will delve deeper to four key themes: Climate Change and Carbon Capture, Population Growth & Consumption, Urbanization / Human Pressure, and Oil Depletion. However, all nine are equally important as they are even more impactful in relation to each other.

This sensemaking tool is not intended to predict the future, but rather to gather insights from well-established forecasting and futures work. Thinking in terms of scenario making, if these influences were placed on Ralston & Wilson's (2006) importance and uncertainty grid, they would be categorized as high-importance, low-uncertainty. These influences have been selected, based on the horizon scanning and literature reviews, because they will have a large role in shaping the actor motivations and environmental limitations in the formation and operation of the bioeconomy. It should be noted that between now and year 2125, new key influences could appear as well as surprising cross-impacts among all of them.

To say these key influences present challenges to future generations is an understatement. The year 2125 will be difficult for the great grandchildren of today's 4-year olds. Because hope plays an important role in human agency toward the future (see Heinäjärvi 2018) it is important to emphasize that our actions today can make a difference. While these influences are large-scale and complex, they are not deterministic forces. The future is still open, and the choices made by people today will affect how the future will ultimately be. As an illustration of how BioEcoJust is applying these big influences, the next four subchapters elaborate population growth and consumption; urbanization and human pressure; climate change and necessary carbon capture; and oil depletion.

5.3.1 Climate Change & Necessary Carbon Capture

When publishing the latest UN World Meteorological Organization report on global warming (WMO 2018), the WMO Secretary-General Petteri Taalas called for urgent action: “The science is clear. Without rapid cuts in CO2 and other greenhouse gases, climate change will have increasingly destructive and irreversible impacts on life on Earth. The window of opportunity for action is almost closed”. To stay below 1.5C increase, CO2 must be captured. This is called negative emissions. (Miles 2018; McGrath 2018.) Even while the Negative Emissions Technology is argued to be unproven, all simulations that successfully avoid a 2C increase in global temperature requires negative emissions at some point between now and 2100 (Obersteiner et al. 2018; IIASA 2018).

Addressing climate change a driving motivation to many key actors for promoting the growth of the bioeconomy. For any forward-looking study, climate change needs to be acknowledged as a key influence on Earth’s inhabitants, human and non-human, and their behaviours, patterns, and dynamics through the year 2125. At bare minimum, a plausible scenario for 2125 ought to incorporate a variable for how much global warming has occurred, what actions were taken to mitigate it, and what dynamics contributed to it.

The amount of increase in the global average temperature impacts the suitability of habitat for all of Earth’s species, including humans. From an economic perspective, global warming is expected to negatively impact economies of the Global South in terms of per capita outputs, and for instance economist Nicholas Stern described climate change as the “greatest and widest-ranging market failure ever seen” (Stern 2007). While it is still possible for actions taken between now and 2125 to avoid the worst cases of Global Warming, recent reports indicate that current commitments are too limited, progress toward them is too slow, and the trajectories of Greenhouse Gas Emissions look grim.

The Club of Rome has responded to the growing sense of climate crisis with their Climate Emergency Plan (Club of Rome Climate Emergency Plan) which proposes 10 steps to keep the forecast global average temperature increase less than 1.5 C:

1. *Halt fossil fuel expansion and fossil fuel subsidies by 2020: No new investments in coal, oil and gas exploration and development after 2020 and a phase-out of the existing fossil fuel industry by 2050. Phase-out of fossil fuel subsidies by 2020. Give priority to developing countries to avoid lock-in to the carbon economy.*
2. *Put a price on carbon to reflect the true cost of fossil fuel use and embedded carbon by 2020: Introduce carbon floor prices. Tax embedded carbon through targeted consumption taxes. Direct tax revenues to research, development and innovation for low-carbon solutions, cutting other taxes or supporting the welfare state.*
3. *Replace GDP growth as the main objective for societal progress and adopt new indicators that accurately measure welfare and wellbeing rather than production growth.*
4. *Improve refrigerant management by 2020. Adopt ambitious standards and policy to control leakages of refrigerants from existing appliances through better management practices and recovery, recycling, and destruction of refrigerants at the end of life.*
5. *Encourage exponential technology development by 2020: Create an International Task Force to explore alignment of exponential technologies and business models with the Paris Agreement to promote technology disruption in sectors where carbon emissions have been difficult to eliminate.*
6. *Ensure greater materials efficiency and circularity by 2025: Significantly reduce the impact of basic materials e.g. steel, cement, aluminium and plastics from almost 20% of global carbon emissions today by the early introduction of innovation, materials substitution, energy efficiency, renewable energy supply and circular material flows.*

7. *Accelerate regenerative land use policies and adaptation: Triple annual investments in large-scale REDD+ reforestation and estuarine marshland initiatives in developing countries. Compensate farmers for building carbon in the soils and promote forestry sequestration. Support efforts to restore degraded lands. Implement adaptive risk management procedures in every state, industry, city or community.*
8. *Ensure that population growth is kept under control by giving priority to education and health services for girls and women. Promote reproductive health and rights, including family planning programmes.*
9. *Provide for a just transition in all affected communities: Establish funding and re-training programmes for displaced workers and communities. Provide assistance in the diversification of higher carbon industries to lower carbon production. Call upon the top 10% earners of the world to cut their GHG emissions by half till 2030.*

Reinforcing this call for action, two recent scientific research projects show how it is possible to reach a development trajectory by 2050 that would keep global warming from exceeding 1.5 degrees C by 2100. Leonardo DiCaprio foundation partnered with University of Technology Sydney (UTS), two institutes at the German Aerospace Center (DLR), and the University of Melbourne's Climate & Energy College to propose a model for how such a transformation could be obtained. The main measures required would be a full transition to renewables coupled with global land restoration that would increase the resilience of natural ecosystems. The latter would be critical also in helping to ensure food security. Combined, these efforts would prevent increases in emissions, and also pull carbon out of atmosphere and store it in the forests and soil, creating approximately 400 GtCO2 of negative emissions. (Burkart 2019.)

Operating on the same time-scale of 2050, and with the same aim of producing emissions-free, affordable energy systems, the Neo Carbon Energy project envisions a future energy system, where solar and wind power and other renewables are linked with advanced storage technologies to meet global energy demands.[1] Their approach focuses on the energy transition, where distributed production, consumption and storage system is enabled by digitalization. The project named the resulting energy system model the *Internet of Energy*, IoE. A key innovation proposed and investigated by Neo Carbon Energy project, which differs from the One Earth Model, is using renewable energy to capture carbon from the atmosphere for use in synthesized hydrocarbon fuels. At scale, such a process could support neutral emissions.

The aforementioned are but examples of many similar kinds of efforts to map out possible systemic transformations that would make the ambitious seeming climate goals reachable. They are desirable also from other perspectives outside of the climate change focus, for instance the Neo Carbon Energy project stresses the democratizing effects of the distributed energy system, while the Leonardo DiCaprio Foundation's approach would have positive impacts for supporting biodiversity and healthy ecosystems. For the long-range scenarios of the Bioeconomy, these efforts constitute building blocks that enable envisioning an outlook on the futures where climate change can be addressed sustainably.

[1] The Neo Carbon Energy project website is http://www.neocarbonenergy.fi/, Accessed 21.12.2019.

5.3.2 Population Growth & Consumption

Today the global population is 7.6 billion. This number is expected to grow to 8.6 billion by 2030, 9.8 billion in 2050, and 11.2 billion in 2100. Even if current trends for decreasing fertility in many countries continue, the global population is forecast to grow (see Figure 7). (U.N. DESA 2017.) While it is still possible for the world population to be roughly the same as we have today if we can decrease the global average birth rate by .5 children, these projections indicate there could be more than 12 billion people living on Earth (or in a worse-case scenario, 20 billion) in the year 2125.

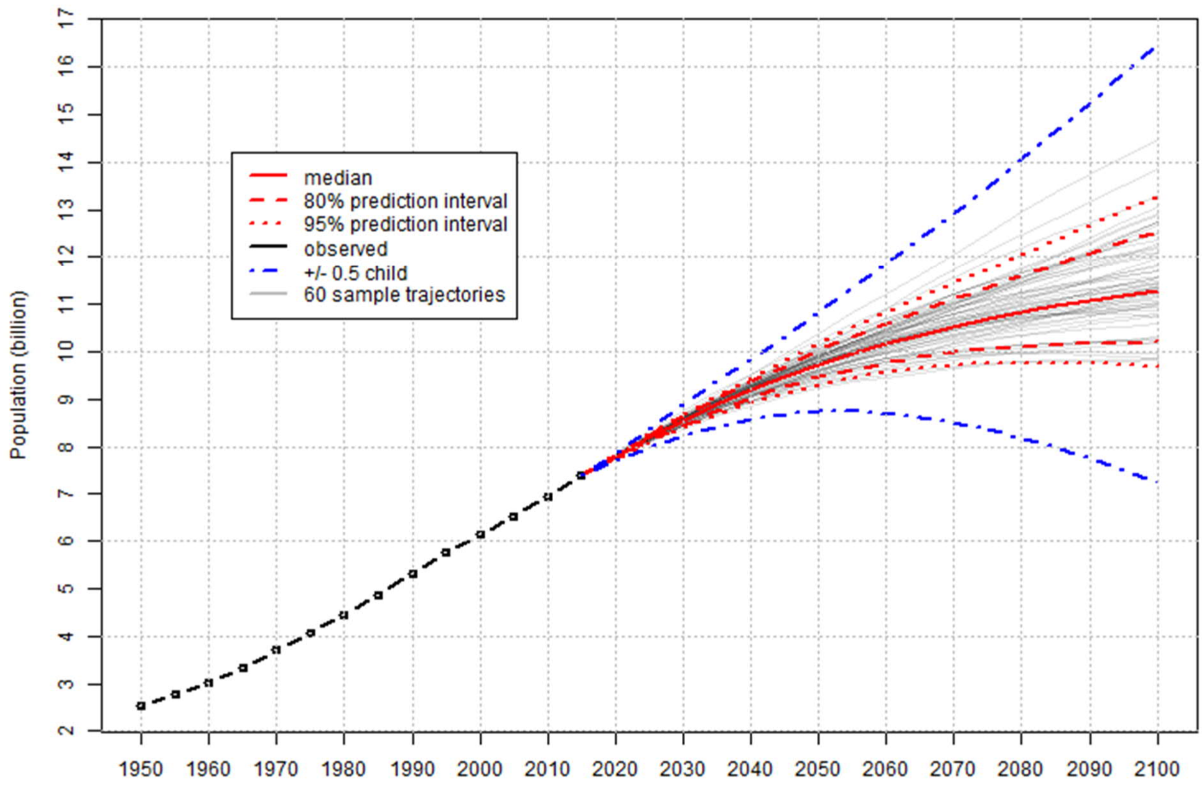


Figure 7. World Population Forecasts for 2100 (U.N. DESA 2017)

The consumption patterns from such a large global population will likely put tremendous pressure on Earth's natural systems and mined resources. In other words, future people – the grandchildren and great grandchildren of today's four-year-old children (see Chapter 4.2) – will face great challenges in growing enough food, accessing enough water, producing enough energy, and producing enough materials.

The concept of Circular Economy (as it is called today), re-valuing, recirculating, deconstructing, and reassembling precious and difficult to produce resources may very well become common worldwide. Advocates of the Bioeconomy suggest the resource demands of this larger population could be met through new bio-based production systems, yet conventional ways of cultivating biomass typically come at the cost of land degradation and de-wilding.

5.3.3 Urbanization / Human Pressure

Urbanization and human pressure refer to the processes that convert land into city-like human habitat. While the concept of urbanization is widely familiar, the related concept of human pressure is less common in popular discussion. It is easiest to think of human pressure as the collective set of impacts from humans and human habitats on their surrounding environment. Examples include the production and flow of waste, the consumption and flow of water, the handling of sewage, streams of air pollution from industry and mobility systems, and the production and flow of energy. In addition to these are the reductions or fundamental transformations of land available to other species which produces pressure on non-human habitats.

Urbanization is often described as a megatrend and requires close attention by governing bodies around the world. In 2014, 29.7% of urban populations live in slums (U.N. Habitat 2016). Cross-cutting through developed and developing nations, human built environments continue to encroach into wild areas (Figure 8).

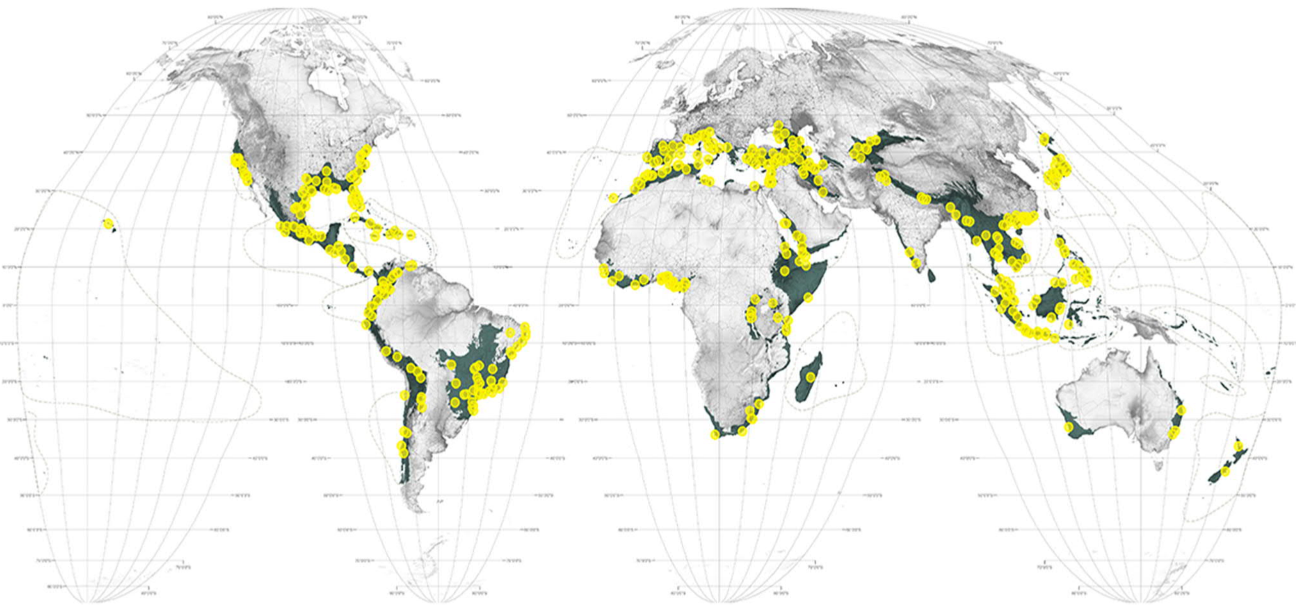


Figure 8. Hotspot Cities: cities of 300,000 or more people projected to sprawl into remnant habitat in the world's biological hotspots (Weller et al. 2017).

The implications for 2125 are that there could be many large urban areas with populations greater than 10 Million people (see Figure 9). Taking into account normal-sized cities and even small or medium sized cities, most of the world’s population will live in some form of urbanized settings. These urban habitats will provide the ‘affordance landscapes’ of these future people and urban nonhuman lifeforms. The encroachment humans make into their natural surroundings will invariably render unliveable the natural habitats of other species. These non-human species will need to move to another suitable natural habitat, adapt to their human-impacted landscapes, or face extinction.

Figure 9. 32 megacities with more than 10 million residents as of 2015 (European Commission 2016, 64).

5.3.4 Oil Depletion

According to OPEC Annual Statistical Bulletin 2017, the world is estimated to have 1.47 Trillion Barrels of Oil in Proven Reserves as of the end of 2016. World Oil Demand was 95.12 million barrels per day in 2016, a bit over a quarter of this is consumed as Gasoline, and other products include Kerosene, Distillates, Residuals, and Others.

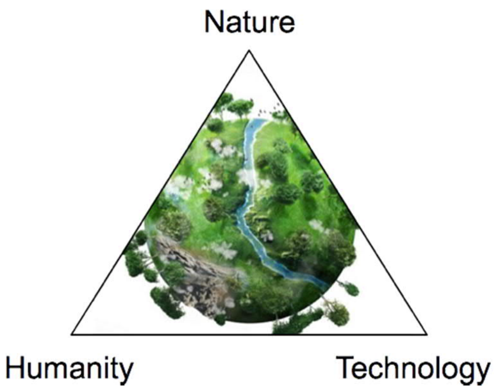
As mentioned in the Introduction, replacing petroleum as the source of the many materials and fuels is among the top motivations for developing the bioeconomy. It is included in this list of 9 big influences because of this. Some oil forecasts indicate it will either become completely used up or politically unavailable by 2125. The 'used up' arguments have been made since the 1970s and, as recently as 2003, time series projections have shown how all oil will be gone by 2125. However, measuring the amount of oil still available is a tricky process and the available reserves published by OPEC and others frequently change, often increasing as new discoveries and means of accessing hard to reach out are developed. Furthermore, recent advancements in AI tech for big data analysis are being applied by the petroleum industry to identify, access and more efficiently extract new reserves.

Meanwhile, awareness is rising of the need to stop Greenhouse Gas (GHG) emissions and rapidly scale up technologies that can capture GHG and produce negative emissions. It is probable that some legal, political and social pressures will be applied to stop the use of fossil fuels. In the ideal scenario for keeping global warming below a 1.5 C increase in average temperature, such a transition would occur as quickly as possible, at least by 2050. Under this line of thinking, it may not be that humanity runs out of oil, but that we choose not to use some last amount that remains.

The implication of this big influence for the year 2125 is that everything we now make from oil – from gasoline to plastic – will need to come from some other source. In a future well-established Bioeconomy, the sources for these products will likely be something derived from life forms. How this material replacement is accomplished, will either involve more land used for biomass forests and crops or lab-grown human-manipulated microorganisms. New production systems and techniques incorporating life-forms, carbon capture technology, Artificial Intelligence and high-performance computing, and new modes of economic exchange (e.g. circular economy) may play a large role in the puzzle.

5.4 Human-Nature-Technology Triangle

The Human-Nature-Technology Triangle is a key sensemaking tool for considering long-term futures. This set of relationships has probably been active throughout all of human history and prehistory. The existence of this three-part relationship and its evolving dynamics will likely continue into the deep future. The characteristics of the triangle of relationships are dynamic are continually changing over time. The relationships, while a human construct, are not necessarily human-focused. Humanity acts on (and through) technology and nature; technology acts on (and through) nature and humans; and nature acts on (and through) technology and humans (Figure 10).



Human ← **Nature** → Technology
(Technology ←) (→ Human)

Nature ← **Technology** → Human
(Human ←) (→ Nature)

Technology ← **Human** → Nature
(Nature ←) (→ Technology)

Figure 10. Triangular relationship of Nature-Technology-Humans and detail of relationship flows from one node to the others along its three edges (Balcom Raleigh et al. 2018).

5.5 Five BioWorlds

The sensemaking tool of BioWorlds is inspired by the ‘scenarios as worldmaking’ approach used by Vervoot et al. (2015). While similar, ‘worldmaking’ is not the same as an individual’s worldview. According to Vervoot et al. (ibid., 64, citing Goodman 1978), the concept of worldmaking indicates “reality is equivalent to multiple, coexisting worlds – a *pluriverse*” and “Each world carries its own particular characteristics, which may or may not be shared by other worlds.” Technically what we are calling BioWorlds are archetypes which could describe a set of individuals or organizational actors and their many worlds – complete with their interests, concerns, value systems, ways of knowing, ways of perceiving, and general assumptions about their environment, and general conceptualizations of ‘how things work.’ In other words, the five BioWorlds are a set of archetypes by which Bioeconomy actors and their proclamations, actions, motivations and aspirations can be clustered and interpreted. These five BioWorlds are selected to reflect differing perspectives found in the literature search and horizon scanning (see Chapters 2.2 & 2.3) regarding values and norms, as well as what is desirable and ethically good in present and future bioeconomy. As highly developed constellations of actors who will have varying power or capacity over time, the BioWorlds introduce factors of high-impact and high-uncertainty to our nine key influences. Furthermore, the BioWorlds have high potential to shed new light on old problems as their conflicts and synergies are mapped to reveal difficult ethical puzzles (Balcom Raleigh et al. 2018). The five BioWorlds are BioUtility, BioUpgrade, Bio-Mimicry, BioRecovery, and BioEquality.

Because the Human-Nature-Technology Triangle is as old as antiquity and possible all of human history, we find it to be a suitable framework for looking far into the future. The BioWorlds are developed from the Human-Nature-Technology triangle by asking “what do bioeconomy actors believe is the ethically good way for these relationships to be?” The relationships among humans, nature and technology have differing characteristics for each BioWorld. These variations can be briefly summarized as:

- **BioUtility** – Nature is a valuable source of biomass for us to grow and harvest for new products and services using increasingly efficient technologies.
- **BioMimicry** – Nature holds many perfect examples of how to accomplish complicated tasks which we can learn from to create better, more sustainable technologies.
- **BioUpgrade** – Living organisms are generally flawed, but can be improved through human interventions using sophisticated technologies.
- **BioRecovery** – Radical technologies should be applied to degraded lands and de-wilded places to rapidly recover ecosystems and re-establish their biodiversity.
- **BioEquality** – Humans must believe ourselves as equal to, not above, all other life on Earth; our technology should serve the purpose of protecting all ‘survivors’ of climate change.

These five BioWorlds clearly exist today and arguably have a high probability of existing in some form in the year 2125. Some nascent BioWorlds which may ultimately develop to have high impact on what is happening in the year 2125 may have been missed and new BioWorlds could also emerge over time. Surprising BioWorlds can appear as human capacities, affordances, and awareness change leading to new particular configurations of the Human–Nature–Technology relational triangle. The five BioWorlds are presented in more detail as they were presented in Balcom Raleigh et al. (2018, 4–5) in the following subchapters.

5.5.1 BioUtilisation

“In the Bio-utilisation world, non-human life forms produce materials, foods, and fuels for humanity. This world focuses on maximizing the growth of bio-mass and efficiently using harvested biomass. Humans develop and use technology to produce source materials from nature. People rely on natural systems to produce value and wealth. By focusing on efficient utilization of biomass, challenges to just relationships among nations and people continue to emerge from the continuation of the ‘plantationocene’ worldview in which land is for producing biomass and labour of people is to be exploited to produce the biomass (Haraway 2015, 162). Robotic farming technologies may mitigate some labour exploitation, but the practices of ‘taking land’ are continually underlying this process. Nature is frequently treated in an agrarian way, focusing on monocrops and mechanical systems for maximizing the harvest of those crops. In a knowledge-based bioeconomy, know-how related to planting, growing, harvesting, extracting, and production of products are key drivers for ongoing evolution. With deep links into humanity’s agrarian past, this world is in many ways business-as-usual, but with added emphasis on efficiency, knowledge, and innovation." (Balcom Raleigh et al. 2018, 4.)

5.5.2 BioUpgrade

"In the Bio-upgrade world, life forms are considered flawed and human intervention is believed to be an appropriate way of improving their effectiveness in expressing specific traits and helping people achieve their goals. In this world, technology is used to customize and enhance organisms to perform specific tasks or produce specific outcomes. Nature, from its genetic, chemical, physical, and ecosystem levels, is manipulated and governed at will. An engineering solutionist perspective is taken toward nature. For example, most plant species rely on the least efficient form of photosynthesis, using only a fraction of the carbon dioxide molecules an enzyme captures. These plants can be edited to use a less common photosynthesis process and achieve better growth with fewer inputs as well as better carbon capture (Mann 2018). In another example, the tradition of saving seeds from best performing individual plants may be replaced by advanced gene editing technologies. In Bio-upgrade, lifeforms with any type of useful biomass, bio-output or characteristics can and will be modified to express those traits chosen by humans or human technologies. Additionally, algae and other simple life forms are quickly modified to produce exact chemical outputs. For this world, know-how related to observing and explaining genetic processes, DNA coding, predictive modelling, and lifeform design are essential. Human-made innovations can improve nature." (Balcom Raleigh et al. 2018, 4)

5.5.3 BioMimicry

"The Bio-Mimicry world positions nature as an ultimate creative force and teacher. Solutions to human problems are sought by studying nature and natural systems. Unlike Bio-Upgrade, this worldview treats nature as the 'state of the art' produced by billions of years of evolution. In this world, nature is valued for its models and templates, which are frequently applied to human technologies as a means for achieving sustainability goals. In emulating natural systems, humans use technology to seek balance with Earth's ecosystems. Nature is regarded as the penultimate creative force and is adored for its ingenuity. Human invention is improved when inspired by solutions found in nature. Know-how related to systems thinking, observing and explaining biological phenomena, design, and applied creativity are key for this world." (Balcom Raleigh et al., 4.)

5.5.4 BioRecovery

"In the Bio-Recovery world, people are highly aware that human pressure in the form of urbanization, agriculture, and extraction of minerals and oil has degraded land and ecosystems around the world. Feeling accountable for causing this situation, radical human-made technology is applied to recover these ecosystems as rapidly as possible. A key motivation is the belief that once nature is restored, nature will be able to better provide resources for humanity and other species. Restored soil, marine, and forest ecosystems are seen as the most effective way to capture much of the carbon dioxide humans have released by burning fossil fuels. 'Active ecology' – rapidly developed insights derived from research conducted using big data and machine learning tools – informs ecological interventions (White et al. 2015). Start-ups emerge to apply robotics, space-based monitoring, big data, blockchain and artificial intelligence to restore ecosystems and manage them once they are recovered. The stated goal in this world is to restore and preserve 50% of earth's available land in as 'natural' a state as possible. Due to the massive deployments of technology to make this happen, the term 'natural' means something different than 'wild' as these preserved territories are carefully managed. An example of the Bio-Recovery perspective can be found in the work of World Resources Institute (Wu et al. 2018). This world relies on know-how related to assessing the health of an ecosystem, devising technological interventions to support restoration, and monitoring the recovery of ecosystems as well as their CO2 consumption." (Balcom Raleigh et al. 2018.)

5.5.5 BioEquality

"The Bio-equality world proclaims that all life holds equal value and rejects the idea that nature must do something for humans in order to be valued or respected. In this world, humans understand themselves to be among and in relation to many other Earthlings. All living species who have survived the ecological devastation wrought by climate change (+2C to +8C) are considered the 'kin' of humanity (Haraway 2015). People are not above nature and are not entitled to use its technology to manage or interfere with its processes. "Right now, the earth is full of refugees, human and not, without refuge" (ibid., 160). This world of actors promotes a trans-species framework for justice." (Balcom Raleigh et al. 2018.) The following is a quote that captures the essence of this world in the present: "Right now, the earth is full of refugees, human and not, without refuge" (Haraway ibid.).' This point is emphasized by Sassen (2016) who proposes the key driver for migration of people, which could be arguably extended to all animals and organisms, is the loss of habitat. In the Bio-Equality world all life is respected simply for being, because continued existence is in itself quite remarkable in light of the great (and increasing) struggle it requires.

5.5.6 How BioWorlds will be applied in BioEcoJust

As part of the Sensemaking Framework, these BioWorlds will be continually elaborated based on the new materials, actors, and developments we observe through our ongoing sensemaking process. They are also used as a selection factor and interpretational lens for new items selected in the horizon scanning process. The five BioWorlds have already served us in the role of helping the research team find, select, and interpret new items in our ongoing horizon scanning process (e.g. Balcom Raleigh & Taylor 2018a; 2018b). As mentioned earlier, this sensemaking tool is being used to help us select the expert panel for the Delphi and as a basis for many of our Delphi questions.

Ideally, the BioWorlds will help us add depth and ethical nuances to the exploratory scenarios. A first exploration of this potential was made in the paper Balcom Raleigh, Taylor, and Wilenius presented at Foresight Technology Assessment 2018 in Brussels (Balcom Raleigh et al. 2018). In that paper, the five worlds were systematically collided into each other and every possible pairing was assessed for its synergies and conflicts. Additionally, conflicts and synergies internal to the worlds were identified (Tables 4 & 5).

Table 4. Ten Inter-World Collision Points & Synergies (Balcom Raleigh et al. 2018).

	Conflicts	**Synergies**
BioUtilisation with BioUpgrade	Conservative stakeholders of established markets potentially destabilized by new innovations that could disrupt status quo. An 'upgraded lifeform' could have unexpected negative impacts on 'biomass crops'.	These two worlds have similarities in how they regard nature. Both see it as something to be made subservient to human needs. These two worlds ultimately focus on the material production potentials of nature. Both apply technology to obtain their objectives.
BioUtilisation with BioMimicry	History of established human made knowledge and practice over nature confronted with knowledge drawn from nature are fundamentally at odds. (e.g. Bio-Utilization would suggest humans is better at designing perfect systems.)	They are both using nature, but in different ways. One sees it as a source of materials, and the other sees it as a source of ideas.
BioUtilisation with BioRecovery	Taking and giving back carbon and biodiversity on this front wage two opposing perspectives. Carbon and biodiversity are valued differently. However, a respect for the careful management and abundance is held by both camps. In some cases, the forests have been restored because the forestry industry had economic motivation to restore them.	When sustainable practices are in use, Bio-utilization prioritizes keeping natural systems in a productive state over the long-term. Bio-recovery has a similar objective but is defining productive more broadly toward planetary objectives. Both worlds aim to utilize human survival.
BioUtilisation with BioEquality	These two worlds may be in greatest conflict. Bio-utilisation destroys habitat for non-human lifeforms while bio-equality ideals are seen as unrealistic in relation to meeting human needs.	Given the opportunity of growth and ability to engage with new abundance the assumption is that financially it is more profitable to follow the path in which new values are being established (i.e. matured sustainable development, ecology, circular etc.) If bio-equality is a mainstream value, the utilisation perspective will be compelled by market forces to meet it.
BioUpgrade with BioMimicry	For these worlds, the fundamental difference is their views of nature. Mimicry respects nature as perfectly ordered and creative. Upgrade sees nature as flawed and chancy. Upgrade puts technology into nature. Mimicry puts nature into technology.	Both worlds are, at some level, in awe of natural systems, even if bio-upgrade seeks to improve those systems. Both worlds draw from nature's potential, upgrade seeks to enhance nature via human intervention, the other sees to enhance human design via nature. There is a common emphasis on improving technology.

BioUpgrade with BioRecovery	A risk in BioUpgrade comes from unintended consequences, such as an upgraded organism coaxing the evolution other organisms such as viruses or parasites. Such a system could severely interfere with a bio-recovery intervention.	Both worlds are motivated by helping nature flourish. For bio-upgrade, this means modifying organisms to help them succeed. For bio-recovery it means assisting organisms in rebuilding their ecosystems and habitats.
BioUpgrade with BioEquality	These two worlds despise each other. BioUpgrade is too reckless with non-human lifeforms which Bio-equality sees as kin.	Helping other species succeed in a changed climate and environment is a shared goal between both worlds.
BioMimicry with BioRecovery	The radical technological interventions of Bio-recovery often overtake slower natural processes. The Bio-Mimicry world sees Bio-recovery world's urgent actions as violating the 'perfect solutions from nature'.	Biomimicry can be useful in developing bio-recovery technologies. For instance, a swarm of drone bees to help pollinate the plants could be inspired by understanding how insects pollinate plants in nature.
BioMimicry with BioEquality	BioEquality and BioMimicry do not agree about the essential value of nature. Bio-equality criticizes bio-mimicry for its insistence on utilizing nature for human ends. Bio-mimicry finds Bio-equality too idealistic. Meeting human needs by emulating nature is better than exploiting nature.	These worlds share a high regard for nonhuman living beings in nature. There are differences in how this reverence is paid, for bio-mimicry, other living beings in nature are a creative force while for bio-equality they are equal peers.
BioEquality with BioRecovery	At their most fundamental levels, these worlds see nature very differently while having overlapping assumptions. Recovery is driven by more immediate survival needs of resistance, where equality is more inclusive and more long-term symbiotic transformation.	Both worlds seek to help non-human living beings succeed in difficult circumstances. For bio-equality, there is a greater emphasis on the direct relationship between nature and humanity. Whereas in bio-recovery there is greater emphasis on applying technology to 'restore ecosystems'.

Table 5. Five Intra-World Conflicts and Synergies (Balcom Raleigh et al. 2018).

	Conflicts	Synergies
BioUtilisation	Land-use decisions require balancing human needs for material, food, energy and habitat. Human habitats place pressure on wildernesses and 'natural areas' because of their benefits to humans.	Shared assumptions regarding utilization as ultimately necessary allow for more cohesion in decisions and actions that produce biomass. Stewardship of natural areas so they can later be used by humans is valorous.
BioUpgrade	Disagreements regarding the ownership of genetic information and know-how are common among key players. There are different playing fields for individual DIY makers versus big science and companies.	Simply BioUpgrade can be seen as the pursuit of knowledge and applying it as a solution.
BioMimicry	Innovators see risk in sharing their discoveries about natural systems so that they can be first to profit from them.	The potential drawn from nature seems limitless, and similar patterns are shared enthusiastically but applied diversely across many sectors.
BioRecovery	There could be overlapping efforts or competing strategies for restoring a specific area of land. In such cases, one start-up or initiative may have very different ideas from another.	The common cause of recovering degraded lands unites communities and nations in action.
BioEquality	A world that gives high value to non-human lifeforms may have challenges in defining where the boundaries of this policy are. Is it better to reduce the number of fellow beings harmed by a human action or do qualitative aspects, such as relative sentience, matter more?	Expanded sense of 'kin' leads to a new set of mainstream values that simultaneously reify human rights while raising the rights of other living things.

When the BioWorlds are collided, new dimensions of future ethical issues are exposed, adding nuance, depth, and multiple perspectives to conventional Bioeconomy discussions. As the BioEcoJust project seeks to identify high-impact ethical contexts in which difficult decisions will need to be made in relation to the development of the bioeconomy, these BioWorlds become a valuable sensemaking tool. While there are likely even more BioWorlds existing today, and many that are yet to emerge in the future – these shed insight into the possible dynamics and systems of discord and harmony among various networks of actors. Because they are based on what various actors believe to be ethically 'good' relationships among humans, technology, and nature, the worlds also demand greater reflection upon how bioeconomy developments themselves could change those relationships.

For the above reasons, participatory elements for workshops inspired by the BioWorlds could provoke new thinking from Futures Clinique participants or could aid in the development of Action Scenarios, the final output of this phase of the BioEcoJust project.

5.6 Three Socio-Technological Domains

Many technology domains were found to be valorised and frequently emphasized in the literature and horizon scan items the research team found during Phase 1 of this foresight study. Of these many domains, the team selected three areas of bioeconomy development which hold high potential to produce bifurcations – or – points at which the overall system state is transformed into a new one. The three technology domains of Forests, Soil, and Algae. These represent potential large-scale impactful changes in social, technological, and ecological systems. From these seeds, evidence-based narratives are developed. From these 'stories about the future' some first insights into possible ethical challenges are developed. These domains emerged from research engagements with expert gatherings and events such as the 1st Nordic Algae Symposium 2018 (NAS18)[1], Carbon Underground (Ymparisto tiedonfoorumi)[2], World Circular Economy Forum 2017 Helsinki (WCEF).[3] These three themes were clearly represented generally in bioeconomy related events. While these are articulated below as important domains, they are presented here as brief snapshots to illustrate their diverse characteristics and explore different dynamics that contribute to a much expanded understanding of the bioeconomy and its trajectories.

5.6.1 Regenerative Agriculture

Soils' potential for the bioeconomy has been largely overlooked. The fight against climate change is dominated by actions directed toward transformation to low carbon renewable energy. But the future challenges should also engage other sources of carbon, for example agriculture has been seen as one of the greatest contributors to CO_2 (Zomer et al. 2017; UN FAO 2015), where soil works as a balance precariously emitting and sequesters carbon (Crowther et al. 2016), and soils ability to radically draw down carbon and mitigate greenhouse gasses has been generally overlooked (Paustin et al. 2016; Machmuller et al. 2015; Taylor 2017b). In light of this what is referred to as Regenerative Agriculture specifically presents the capabilities of new agricultural practice to adopt not only a climate mitigation approach but also proactively using carbon capture through the growth of plants natural ability that restores the capabilities of nature to function

[1] See http://www.nordaqua.fi/nas18

[2] See http://www.ymparistotiedonfoorumi.fi/carbon-underground/, Accessed 21.12.2018.

[3] https://www.sitra.fi/en/projects/world-circular-economy-forum-2017/#wcef2017, Accessed 21.12.2018.

more effectively. Food production in this light is strategically reinvented to identify its role to facilitate positive change, which thereby engages the multitude of sectors from production to consumption, while improving the dangerous situation of soil degradation.

The Carbon Underground initiative for example have undertaken the role of promoting regenerative agriculture, presenting these ideas with BioEcoJust at a symposium on how soil can help us tackle climate change.[1] Carbon Underground argues that a drawdown of 250 gigatons CO_2 is necessary to meet the 2015 Paris Climate agreement. Restoring soil to a healthy state on at least 25% of agricultural land would produce the negative emissions needed for the goal. Regenerative agriculture has the added benefit of boosting the productivity of agricultural lands. For regenerative agriculture to have its maximum impact, food production systems will need to be transformed.

Future Narrative – Regenerative Agriculture

Earth's human population is above 10 billion in 2125. Food systems must have maximum productivity. Agriculture systems are fundamentally changed – nearly all farmed land has an impactful 'regenerative' program for its soil. These programs are largely credited for the world achieving its carbon sequestration targets. However, some parts of how carbon capture in soil works continue to be unknown and accidental 'carbon releases' occasionally happen. An ingrained concern for carbon escaping the soil leads to vast anti-tilling crackdowns.

[1] See http://www.ymparistotiedonfoorumi.fi/carbon-underground/, accessed 21.12.2018.

5.6.2 Algae

Algae as an alternative source of biomass to produce alternative foods, materials and chemicals etc. represents a future potential that is not yet realised, it is still very much in the emerging phase, although its application and impact could be broad or strategically important. Algae factories of the future according to Raslavicius et al. (2018) could for example produce "liquid, solid and gaseous biofuels [that] may become commercially available in the years 2020-2025[…] as algae to fuel systems has not been accomplished yet", where most have failed in business or have moved on to other easier to produce and market high value products like cosmetics or animal feed. They conclude "that future climate change mitigation will rely on a synergistic combination of C02 capture and utilization technologies, with microalgal carbon capture and biomass production playing a significant role." (Raslavicius et al. 2018.)

Industry in the form of *photobioreactors* are illustrative of the novel practices, that are customisable and modular cultivation systems using for example open raceway ponds, tubular, and flat panel photobioreactors that allow for controlled environments that stimulate algae growth, that are often automated. Raceways (open ponds with circulation of waterways) are primitive but effective ways for producing pure algae biomass that also have a function of cleaning industrial waste flows. Often animal feed is obtained easily from algae biomass where sequestered CO2 and downstream industrial chemicals are collected and transformed also, revealing the intrinsic circular economy service qualities of this industry. Interestingly algae start-ups seem to be establishing themselves in brownfield former industrial areas, disused airport runways, or adjacent to C02 emitting power-plants. Algae is closely linked to biotechnology and information technology, offering a nature-based bio medium in which to create lab based smart systems at scale (i.e. potentially making any high value chemical, biofuel in a reactor). However, it is the transition from lab-to-industry-to-consumer that is the largest challenge. Algae from a biotechnology stance is representative and involved in the study of synthetic biology, that is the manipulation of genes and the promotion of strains to promote certain attributes, like high value chemical compounds or strains that can process toxic waste. This can be depicted as **Coding with Algae**, where combining knowledge from the IT sector with high-potential gene editing and gene-printing technologies marks a potential turning point and convergence of computational and bio systems.

Future Narrative – Coding with Algae

Nearly all chemicals, food additives, and cosmetics are produced via algae labs. Humanity no longer uses virgin petrochemicals. The innovative momentum leading to this point has now turned from replacing petrochemicals and related materials to discovering new exotic outputs. There have been synthetic lifeform spills along the way, a few of which have devastated key ecosystems. These are the new 'oil spills' of the time. Algae lab technology can be deployed in any country empowering local turn-key production.

5.6.3 Forest

The case of **Forest** draws from the pulp and paper industries' transformation to utilise woody biomass and forest management knowledge in new ways to offer alternative materials that are more sustainable and climate friendly. It is this such proposal that the Finnish Bioeconomy has suggested has a special role for the forest industry. Wood construction, forest-based textiles and bioplastics for example offer such emerging innovations in which plastic can be made from wood, textiles switch to wood based sources or large building construction from timber, all offer interesting avenues in which to transfer and circulate consumption to more sustainable paths (Hetemaki 2017: 32 - 38). Bioreactors and refineries are definitive of the industry that greatly diversify the output of high value chemical and pharmaceutical streams as well as biofuel and as an energy source. In contrast the forest as a carbon store and rich biodiverse ecosystem has also an equal role to play, where services that focus on the experience the forest has to offer and its maintenance offer other avenues of growth. It is the services that are connected through the forests multi-sector networks that further offer diverse outputs ranging from climate regulation, water and soil protection to tourism and cultural services, to name just a few (ibid 39). The forest as an effective carbon capture tool is often heavily featured, even for those industries who utilise the forest materials. Thus, the forest represents a fragile balance between an abundant and vital source of future alternative materials and services, and the essential maintenance and restoration of forests in which to protect the planet.

Future Narrative – Forests as Factories

In the year 2125, most of Earth's forests are managed for the most efficient production of biomass. Nearly every tree has a human use and is simulated, monitored carefully for its development, and tracked in the global ledger that evolved from blockchain. Human demands of the forest are held in tension with the goal of preserving biodiversity. Materials produced from trees are mainstream and no longer niche. Some tree-based materials are not easily discarded or reused and enter the waste stream.

PART III – CONNECTIONS TO THE BIGGER PICTURE

Photo by Photo by Shane Stagner on Unsplash.

6. ETHICS IN TERMS OF FUTURES STUDIES

6.1 Decolonising Futures

Since the 1970s, futures studies scholars have raised alarm about the field's propensity to colonize the future. The basic idea is that futures are too often treated as empty temporalities to which actors in the present feel entitled to fill with their own future endeavours. An example of a strongly colonized future is that produced by Karl Rove and his peers who launched the U.S. culture wars approximately 40 years ago which have arguably culminated in the Trump Administration. In other words, the young people of 2018 see the futures they desired and were working toward crushed by old-fashioned, nationalistic, and spiteful policies, values, and ways of acting.

Futures Studies includes an ethical call to 'decolonize the future' which means leaving as much of the future to be formed by the people who live in those futures (see Sardar 1993). This principle can be confused with a notion of avoiding planning, but such a conclusion is not what it entails. Planning and execution of plans today can be critical to leaving a future decolonized because in many cases a lack of planning can lead very negative consequences for future generations (e.g. poor planning can lead to slums around cities, inadequately educated populations, or war). The longer history of what is now called the Bioeconomy includes actual historical colonization. For instance, various European nations actively colonized the Americas and severely altered what is possible for the descendants of those lands' original people. As the Bioeconomy develops, it will be essential for existing powers and rising powers to avoid repeating similar ethical offences through their deals to access new lands or new ways to extract or produce value from the biome. We can extend the call for 'decolonizing the future' beyond human needs for justice to other forms of life. This so-called post-human perspective is one of great interest to the BioEcoJust project as it is arising as a future signal in the horizon scanning process and is a potential source for surprising futures.

In business and industry, actions intended to 'colonize the future' happen frequently. For example, dominating a market in the future is often championed as a key pathway to wealth and prosperity (e.g. see the 'blue ocean strategy' proposed by Kim & Mauborgne 2005). In practice, it would be difficult to conduct business without concretized future objectives setting out 5–10-year plans and objectives. Furthermore, technological developments and acquisitions can lead to new socio-technical lock-ins, stranded investments, or ways of doing business. We acknowledge there will always probably be some need for this type of thinking in business, but from a Futures Studies ethical perspective, we encourage business interests to balance such ambitions with a deep consideration of how today's choices could limit or 'expand the options for humanity' (Slaughter and Riedy 2009).

6.2 Open Bio-Futures

From a Futures Studies perspective on ethical thinking, perhaps one of the most obvious issues can be to ask, *Are the potential futures open, inclusive and participatory? Or are they closed, only specified for a select few, where the voices of individuals outside are not heard concerning key decisions about the future?* Furthermore, in Futures Studies we consider many alternative futures rather than one set path, where there are always choices, and some are preferable futures that reveal sets of values. The closed future we might understand for example as the incumbent fossil industries that many of us might agree considering climate change, do not have a future. From this thinking we must make efforts to end use of coal and oil and the products derived from them. From these industries we might see them as locked-in and invested-in a limited and finite paradigm. When considering the bioeconomy in this light, we must ask do we see it as open or closed? Certainly, the bioeconomy has great potential to be open, but as it is based on many existing industries with their own locked-in investments, policies and subsidies, it is pertinent to ask to what extent are they in danger of being in a closed future? This concept represents one of the key ways in which the BioEcoJust team are approaching the subject areas of justice, ethics and nature. The important task is to constantly explore **Open Bio-Futures**.

The current challenges we face due to climate change demand transitions and pathways to meet the Paris Agreement, as one pressing example, however the bioeconomy should be understood as much more than just a mechanism for a linear transition to replace the goods of the fossil industry, this would be in danger of limiting its potential to merely replicate our current consumer habits. Even if it can be acknowledged that this is one of the crucial contributions of the bioeconomy has to facilitate this transition and to affect change. However, thinking about a much longer time horizon beyond 100 years it becomes important to understand that there will still come new challenges, new values, and economies and global needs in the future. This line of thought was presented by Amos Taylor at the Koli BioFuture2025 Research Seminar (September 2018) under the title Operating in Open Bio-Futures.

7. DISCUSSION AND CONCLUSIONS

The Bioeconomy today is a field full of promise, brimming with potentially transformative solutions, and developments still only in their infancy. The aim of this report has been to convey the findings of the BioEcoJust foresight research to date, and especially to highlight the core critical thinking involved in approaching the future of the bioeconomy for the next 100 years. The key themes found in literature about Bioeconomy have identified it as a highly complex and important subject. At the same time, it is also somewhat fuzzy and fractured, with multiple sectors that often are in contrast to one another. Considering the ambitious scale of this investigation – the next 107 years – it is clear that a redefinition of the bioeconomy is needed in order to detach from the discussions which are too deeply bounded on the present. A key interest in interpreting the literature then became understanding the boundaries of the various definitions offered, and also understanding their inherent assumptions about the nature of the concept, with direct links with their potential futures implications.

The approach selected enables questioning the basic tenants of the current prevailing economic model and allows for alternative interpretations and paths for the future. It also reinforces how some of the paths forward appear more open than others. The definitions themselves have been important, as they reveal the expanding nature and level of maturity of the Bioeconomy, moving from technical niche categories toward more service-oriented and societal interpretations.

It is good to bear in mind that despite the seemingly undeveloped status of the field as a unified concept, there are many individual developments that are already fully under way, transforming our approach to the natural world, and turning the attention to novel, in some cases previously untapped resources in our environment. The significance of this transformation is vast, and its effects on our environment dependent on the attitudes and values we attach to nature, technology, and ourselves as a species. In other words, it is equally important with what kind of a mind-set and ethical value system this opportunity is seized. The following example illustrates this point.

Kelp, a large algae seaweed grows in forest-like formations in shallow oceans and has exceptional properties that make it a potential source of raw material for a number of goods, ranging from cosmetics to biofuels. With an industrial mindset, harvesting this unique plant could lead to environmental disasters, a foretaste of which was given when in 2018 a kelp harvesting company proposed to collect the biomass by dredging the coast of Scotland. Dredging would of course not only affect the kelp that is the main commercial interest but take along everything surrounding it. Kelp forests are host to a large number of animals, invertebrates, and other types of algae, making their biodiversity value extremely high. It is likely that this biodiversity also supports the kelp in its growth. Approaches like dredging go against other aims such as restoring entire ecosystems to serve as habitats for otherwise threatened species. Human purposes can in this approach be satisfied without causing harm to the system. To be able to attain this ideal requires profound, science-based understanding of what conditions maintain balance in the ecosystem. The same is true in efforts to rehabilitate coral reef communities to be able to fight the effects of warming sea water and salinity changes. Conservation and innovation are thus intimately interlinked in all bio-related endeavours. Basic science is a platform we need to use in order to make both preservation and innovation happen.

What hope then is there that a mindset change towards a more systemic understanding is underway? Here the concept of Kondratieff waves (K-waves) is helpful (Chapter 2). The main problems overshadowing our time have been caused by an exploitative, supply-side logic to produce advances in the standard of living. The problems related to this pattern are widely recognized. In the K-waves theory, advances in technological development are coupled with changes in worldview, and one cannot progress without the other. In this perspective, a general prerequisite for a future Bioeconomy as the all-encompassing systemic transformation it is envisioned, is also a shift in general attitudes towards how resources are used. The initiative in Scotland to dredge kelp was met with a loud outcry from local people, conservationists, and ecological experts (Amos 2018).

This case, and many like it, remind us that questions related to developing the Bioeconomy are always at their heart questions of how humans and technology should interact and utilize living ecosystems. Such questions, at their core are ethical ones that require deep and difficult reconsiderations of what are ethically good and just ways in which to work toward open Bioeconomy futures. Therefore, parallel to our explorations of the current state of the Bioeconomy technological and societal developments, we have built a meta-theoretical framework for producing insights into these issues. These “sensemaking tools”, enable operating on broader chronological horizons and focusing on key ethical dilemmas present in any decision about the long-range futures of the Bioeconomy. Thus, these tools hold potential to introduce new thinking into how the bioeconomies of the future could unfold. First of our sense making tools, the Five BioWorlds approach, suggest ways in which conflicting viewpoints and colliding rationalisations can reveal the core tensions within current and future bioeconomies from the perspective of the differing worldviews and value-based approaches to natural resource use and the economy. On the other hand, along with tensions, the BioWorlds analysis equally reveals the synergies between different approaches. Secondly, the three socio-technological domains of *forest, soil* and *algae* allow a broad thematic clustering of the materials collected from the horizon scanning process. This clustering does not of course remain only at the level of the materials from which the Bioeconomy is being built, but rather shows three different operational logics that can be These two sensemaking tools when combined allow for our research a more dynamic understanding of the field, which in turn aids in the goal of identifying the ethical dimensions, the decisions and the decision makers.

The report introduces also global perspectives, revealing different regional geographic flavours of the bioeconomy. In California unearthing the importance of ecology of the oceans as well as being technological rich were the focus of fieldwork; and in Brazil the history and importance is emblematic of colonisation and bioprospecting; in Australia an acute need for alternative approaches has led to pursuing experimental utilisation of algae. These divergent global perspectives reveal their own systemic individuality, while at the same time they are all under the umbrella of the bioeconomy.

The literature search, horizon scanning, and theoretical framework building done in this first phase of the BioEcoJust project are paving the way for the second phase, where with the help of an expert panel that will discuss our topic in a two-round Delphi process. We are preparing to formulate more concrete scenarios for the next 100 years of the Bioeconomy. These will be discussed in Futures Clinique workshops, also in the second part of our project. All these efforts are building a more thorough, holistic understanding of the opportunities and threats, decisions and key decision-making agents, and most importantly, possibilities for forming a common agenda for pursuing the futures of the Bioeconomy in the next century.

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Appendix 1. Social Impact of BioEcoJust

Presentations 2018, sorted by date

- Academy of Finland BioFuture 2025, Joensuu, May 15–16, 2018 (Markku, Amos, Nick)
- Ministry of Environment Annual Days: "How to build sustainable ecosystem in the cities," May 2018, Helsinki (Markku)
- Pulp & Paper Mass Exhibition: "Bioeconomy: Visiting tomorrow today," May 2018 (Markku)
- European Commission Foresight Technology Assessment, June 2018, Brussels (Nick, Amos, Markku)
- Futures Conference, June 2018, Tampere (Amos)
- Koli Born Global Research Seminar, Koli (Amos)
- Finnish chapter of Club of Rome, October 2018 (Markku)
- Bioeconomy Symbiosis of the Green Economy, Helsinki, October 2018 (Markku)
- Peruvian Foresight and Innovation Biofuture Lab, November 2018, Lima Peru (Marianna)

Teaching

- BioEcoJust themes in part of 'FUTU 2 Scenario Thinking' course at TSE (Markku, Amos, Nick)
- Project mentioned in lecture given to Minneapolis College and Art Design, Futures of Individuals and Society course, September 2018 (Nick)
- Project as case mentioned in Corporate Foresight eMBA at Turku School of Economics - University of Turku, October 2018 (Amos)

Hosted International Guests

- David Johnson and Larry Kophold of Carbon Underground visit and symposium, October 2017.
- Jerome Glenn of the Millennium Project visit, June 2018.

Media Appearances

- Markku Wilenius is quoted in Suomen Kuvalehti 8.10.2018: "IPCC:n ilmastoraportin tyly viesti: pelkät päästöleikkaukset eivät riitä – Peli ei silti ole vielä menetetty." (Translation: IPCC climate report tense message: only emission cuts are not enough – The game has not yet been lost) https://suomenkuvalehti.fi/jutut/tiede/ipccn-ilmastoraportin-tyly-viesti-pelkat-paastoleikkaukset-eivat-riita-peli-ei-silti-ole-viela-menetetty/ (Accessed 9.10.2018.).
- Amos T. Taylor is interviewed on Radio Helsinki *One Quart Radio* podcast on 22.2.2018 in the episode "Miltä näyttää maailman tulevaisuus?" http://www.radiohelsinki.fi/podcastit/milta-nayttaa-maailman-tulevaisuus/, Accessed 27.2.2018.
- Amos T. Taylor is interviewed by Jatkumo Ry project video 2.10.2018 https://youtu.be/fvwnKU3xXwM
- Markku Wilenius is quoted in article about the Soil Underground visit: Yli-Parkas, Hanne (2017) Maaperä unohdettu ilmastonmuutoksessa (Translation: Soil has been forgotten in climate change). 28.10.2017, *Turun Sanomat*.

Columns and Blog Posts

Sorted by date, past to present, and not by author.

- Taylor, Amos (2017) Alternative Futures of the Carbon Underground. 29.11.2017 Finland Futures Research Centre Blog. https://ffrc.wordpress.com/2017/11/29/carbon-underground/ (Accessed 24.10.2018)
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Appendix 2. History & Potentials of Brazilian Bioeconomy

By Marianna Birmoser Ferreira-Aulu

Brazil is known for its vast land area, abundant resources, and extraordinary biodiversity. Already in 1500’s, in the dawn of the Portuguese colonization, the agricultural sector had a strategic importance in Brazilian economy. The development of the Brazilian society is closely tied with the development of national agriculture. The history of agricultural development in Brazil may be one way to explain why the advancement of biotechnology is not yet the main agenda for the nation's economic development.

Historically, agriculture in Brazil was established using slave workforce. The Atlantic slave trade era brought millions of people from Africa to Brazil, and they were the driving force of Brazilian economy in the sectors of agriculture, natural resource exploitation, and the mining industry. Brazil was the last country in the Western world to abolished slavery in 1888. However, slavery-like conditions are still being reported today (Angelo 2017). In the 1600’s, during the colonial period, the main agricultural export was sugar.

In the 1800’s Brazil became an important exporter of coffee. The expansion of the coffee trade coincides with the political independence from Portugal, with stronger economic ties with England, with the abolishment of slavery, and also with a mass immigration of Italians in the Southeast Brazil. Colonies of immigrants from Italy provided cheap workforce in coffee plantations, enriching the Southeast, especially the State of São Paulo. The late 1800’s and early 1900’s was marked by the establishment of two oligarchies composed of landowners of coffee farms in São Paulo and cattle farms in Minas Gerais. This period of Brazilian history is referred to “política do café-com-leite”, the “coffee-with-milk politics”. The first presidents in Brazilian history alternated between the two states, and so for many years the country was ran by these landowners, who were mostly conservatives and extremely dependent on imported technology and products (Giacomazzi 2016, 21). The café-com-leite oligarchy dominated not only the economy, but also the politics of Brazil.

The years 1876-1945 are known as the Amazon Rubber Boom (Resor 1977: 341). At the time, rubber extraction was an economy founded on wild species harvest, and the techniques used were based on local indigenous knowledge. The demand of rubber rapidly grew in the international market due to the need of this resource in the industrial world, particularly on the production of automobiles, which was booming at the time. As the extraction of rubber was a high labour-intensive business, the industry lead to the creation of a new social class in Amazonia, the rubber tappers. Known as seringueiros, the rubber tappers were immigrant workers from other parts of Brazil who had very primitive living conditions, and were out of work during the Amazonian rainy season, which can be four to six-months long. (Resor 1977: 347).

By 1909 rubber was the second largest export crop, behind coffee. The success of the rubber industry at the time drove the development of the city of Manaus, the capital of the Amazonas state. (Resor 1977: 354–355) However, this production boom ended abruptly with the successful cultivation of the para rubber tree in Asia (The Economics 2012). It is said that the botanist and bio-pirate Sir Henry Wickham smuggled 70,000 seeds of the para rubber tree (Hevea brasiliensis Willd. ex Adr. de Juss.) to England (Resor 1977: 343, Rao et al. 2012:81). These seeds were taken to the Botanical Gardens in the UK and later sent to Asia and Africa for cultivation. Brazil soon lost the international market of rubber to these regions. Brazilian production was done in the forest, using wild species harvest in primitive conditions; meanwhile in Asia and Africa para rubber farms were well managed and trees were more productive as farmers used unidirectional selection for yield, a cyclical generation wise assortative mating pattern to improve the production of rubber (Rao et al. 2012:81).

The Brazilian Economy was strongly based on agricultural exports until the 1930s. The situation began to change dramatically after Getúlio Vargas' coup d'etat (1930-1954). Vargas' administration is characterized by a shift from agriculture-based economy to an industrialized one. (Pereira et al. 2012:3) His administration was authoritarian and interventionist, modeled on Mussolini's Italy. Steered by Getúlio Vargas' strategic investment on industries, on the decades to come, the Southeast Brazil developed its urban centers, particularly São Paulo and Rio de Janeiro where the capital of Brazil was located at the time. Descendants of landowners from São Paulo would travel to Europe for studies, and families of agrarian conservatives would pioneer the Brazilian industry. (Giacomazzi 2016:21)

"Opportunities for agribusiness exports were identified as a means to generate funds to finance imports of technology and capital assets for the emerging industrial sector" (Pereira et al. 2012:3)

Government-led industrialization continued after Vargas' suicide under President Jucelino Kubitschek's administration. Kubitschek lauched an ambitious target plan of advancement economy called "fifty years in five". However, development lost momentum in 1964 with another coup d'etat, this time, by the military. (Giacomazzi 2016:22).

The Brazilian military dictatorship (1964–1985) is characterized by political instability, social mobilization for reforms, and declining economic growth (Giacomazzi 2016:22). However, it is also a moment where Brazil invested in urbanization and in energy and transport infrastructure. Large hydroelectric power plants were built during this period, as well as federal and state highway systems, which were key to agricultural expansion. Although agriculture played a key role in Brazilian economy, until the 1960's, the country systematically received food aid from abroad. The industrialization policy during the military dictatorship was aimed at reducing imports based on exchange controls, and the food prices were kept artificially low, shifting the power from rural areas to cities. (Pereira et al. 2012:3)

It was during the military dictatorship time that Brazil began to invest in technology, research and development (R&D) in agriculture. The Brazilian Agricultural Research Corporation (EMBRAPA) was formed, and this institution is key in biotechnology still today.

One important achievement of R&D in agriculture in the 1970's was the improvement of productivity in the Brazilian Cerrado. The Brazilian Cerrado biome occupies about 25% of the country's land area. It is a dry, savannah-like area that greatly improved yield due to improvements on soil fertility, biological nitrogen fixation (BNF), new plant varieties and hybrids, as well as integrated crop and livestock systems. (Pereira et al. 2012:7)

In the global setting, the 1970's was a period of energy crisis triggered by petroleum shortages. It was in this context that Brazil launched the National Fuel Alcohol Program (Proalcool), promoting first-generation ethanol from sugarcane, as well as R&D to this industry. Ethanol was already being produced in Brazil since the 1930's, and was promoted by the Institute of Sugar and Alcohol, created during Vargas' administration to endorse the agro-industrial policy on sugar production and consumption in Brazil (Ecolex 2018). However, it was only in the 1970's with the support of the Proalcool Program that ethanol production really became competitive, and sugarcane productivity boosted in the country. By the end of the decade, the Brazilian Government required vehicle manufacturers to develop motor engines to use hydrated ethanol as fuel (E100). This fuel had a minimum content of 92.6% ethanol. By mid 1980's, over 90% of automobile sales went to neat ethanol powered cars. From 2003, with the introduction of flex fuel vehicles (FFV) consumers have had the option to fuel their cars with both ethanol/gasoline blend. (dos Santos et al. 2016:42-43) According to dos Santos et al. "the vast majority of ethanol distilleries integrate sugar mills that allow sugarcane to be processed into either sugar or ethanol" (2016: 43). This strategic feature of the distilleries allows producers to alternate the destination of sugarcane juice based on the attractiveness of ethanol and sugar markets.

R&D destined to improve the production of second-generation ethanol is ongoing. Researchers from Campinas (dos Santos et al. 2016) for example, are conducting experiments on different yeasts for second-generation ethanol production. As GMO yeast strains are tested, strict rules must be applied accounting to concerns regarding potential health and environment risks of these organisms. (dos Santos et al. 2016:52). Second-generation ethanol plants have been operational in Brazil since 2014. Brazilian plants use foreign biotechnology to process agricultural residues like sugarcane bagasse and lignin into biofuel. The first cellulosic ethanol facility in the Southern Hemisphere was the GranBio's plant, in Alagoas, Brazil. This plant enables Brazilian ethanol production to be increased by 50% per ha due to its use of agricultural residues. The technology used for producing second-generation ethanol is high in complexity and is a prime example of how biotechnology is being used in Brazil today. (dos Santos et al. 2016:53–54)

Several actors promote activities related to Bioeconomy in Brazil. The table below provides a list of actors that have been mentioned in the literature reviewed for this article. Actors vary from governmental organizations, to academic and research institutions, as well as the industry sector, and the civil society. This chapter will briefly profile some of these actors and their activities.

Table. Actors Promoting Bioeconomy in Brazil.

…	Acronym	Official Name	English Translation
Governmental Organizations	CNPEM	Centro Nacional de Pesquisa em Energia e Materiais	Brazilian Center for Research in Energy and Materials (under MCTI)
	CTBE	Laboratório Nacional de Ciência e Tecnologia do Bioetanol	Brazilian Bioethanol Science and Technology Lab. (under MCTI)
	LNNano	Laboratório Nacional de Nanotecnologia	Brazilian Nanotechnology National Laboratory (LNNano)
	MCTIC	Ministério da Ciência, Tecnologia, Inovações e Comunicações	Ministry of Science, Technology, Innovations and communications
Academic / Research Institutions	DWIH-SP		German House for Research and Innovation in São Paulo
	FAPESP	Fundação de Amparo à Pesquisa	São Paulo Research Foundation
	INT	Instituto Nacional de Biotecnologia	
	UFRJ	Universidade Federal do Rio de Janeiro	Federal University of Rio de Janeiro
	USP	Universidade de São Paulo	University of São Paulo
	UPF	Universidade Passo Fundo	University of Passo Fundo
			Ludwig Institute for Cancer Research
Industry Sector	ABBI	Associação Brasileira de Biotecnologia Industrial	Brazilian Industrial Biotechnological Association

	ABRAB		Association of Brazilian Biotechnology Businesses
	BIOBRASIL		
	CNI	Confederação Nacional da Indústria	
	FALAEB		Latin American Federation of Biotechnology Companies
	FIESP	Federação das Indústrias do Estado de São Paulo	
	MEI	Mobilização Empresarial pela Inovação	
	SEBRAE	Serviço Brasileiro de Apoio a micro e pequenas empresas	

FAPESP has written a bioenergy research plan in 2008

The Brazilian Industrial Biotechnological Association (ABBI) is a non-profit, non-governmental organization founded in 2014. The association represents institutions and companies of various sectors of the society acting in the area of bioeconomy, particularly within white (industrial) biotechnology. According to ABBI, bioeconomy is a sector of economy that use or develop bioproducts, that is, products that use living organisms (genetically modified or not) in activities that have economic interest. According to this association, the development of industrial biotechnology in Brazil is a key driver of economic and social development to the country, and it is their mission to promote favorable conditions for the development of the biotech industry taking sustainable development into account. (ABBI 2018A) Some prominent associates of ABBI are, for example, Abengoa, Amyris, BASF, Biochemtex, Braskem, DSM, Du Pont, GranBio, Novozymes, Raízen and Rhodia Solvay Group. (ABBI 2018B).

Appendix 3. Glossary of Terms

An output of the horizon scanning process is this 'living' glossary which the research team continually updates as it conducts its research. As terms and concepts new to the team are found, we note them and attempt to define them. The following is an incomplete list of such terms concerning the future of the bioeconomy found as December 2018.

Agroecosystem – A systems view the inputs and outputs plus ecological and environmental situation of agricultural production.

Agroforestry – "a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels" (International Council for Research into Agroforestry [http://www.cgiar.org/icraf]).' (See Collins and Qualset 1998, 132).

Arbuscular mycorrhiza – Underground fungi networks that have symbiotic relationships with higher-order plants (e.g. trees) and contribute to that plants capacities to thrive in an environment.

Artificial Photosynthesis – Technologies developed to mimic the process of life-based photosynthesis: energy production and storage via sunlight interacting with CO2.

Agroforestry – Integration of forests and agricultural production. For example, the USDA Agroforestry Center describes the following types of agroforestry. From https://farmingthewoods.com/2013/04/04/forest-farming-vs-forest-gardening-whats-the-difference-2/, Accessed 22.1.2018:

- Forest Farming (see its entry below).
- Silvopasture – grazing animals under a forest canopy of about 50% cover, so that grasses can persist
- Riparian Buffer – tree crop systems in waterways like streams, rivers, wetlands, etc.
- Windbreaks – tree crop systems to buffer effects of wind on soil conditions (they prevent wind erosion.)
- Alley Cropping – rows of trees in between conventional crops, like Black Walnuts in-between rows of corn or soybeans

Bioeconomy – "The part of the economy using biological resources or bioprocesses for the production of value-added products, such as food, feed, materials, fuels, chemicals, bio-based products and bioenergy." (BBIA Glossary of Terms, accessed 11.1.2018.) ''a world where biotechnology contributes to a significant share of economic output'' and as ''involv[ing] three elements: biotechnological knowledge, renewable biomass, and integration across applications'' (OECD 2009, 22). See interview with John Bell on the next rising wave of the bioeconomy. https://ilbioeconomista.com/2018/05/24/an-interview-with-john-bell-director-at-the-eu-commission-in-charge-of-bioeconomy-the-bioeconomy-promises-to-lead-the-next-rising-wave-of-global-economic-development/, Accessed 24.5.2018.

Blue Bioeconomy – Described as bioeconomy focused on Maritime (see Baltic Blue Biotechnology Alliance)

Bioenergy with Carbon Capture and Storage (BECCS): A suite of technologies for carbon dioxide removal. Fast-growing trees and grasses are planted, then burned to make renewable energy, then pumped underground as carbon capture.

Biomass – Working definition: Raw material produced by living systems. “Organic matter that can be used either as a source of energy or for its chemical components (FAO, n.d.)”

Biomaterials – Materials produced from Biomass.

Bio-principled City – Urban planning based on the principles of closed material and energy cycles, cascading uses of natural resources, multi-functional urban spaces combined with biotopes, green belts and spaces.

Bioprospecting – Described as exploring for biomaterial or bioinformation (at the scale of enzymes, biochemicals, or DNA sequences) that can be utilized for some biotechnology purpose. It is like prospecting for gold. An example would be seeking a cure for cancer in nature, and then finding it in some rare plant.

Bioreactor façade – A façade surface that uses lifeforms such as microalgae to produce energy. A demonstration building was built in Hamburg with a system developed by SSC Strategic Science Consult.

Black Liquor – ‘a by-product from chemical pulping process, is typically used for producing heat and electricity’ (Hänninen et al. 2018, 14).

Bright Green – An environmental perspective that points to an ecologically balanced future that is better than now due to advances in technology and ways of living. It is well described here: https://en.wikipedia.org/wiki/Bright_green_environmentalism

C4 Photosynthesis – A rare form of photosynthesis naturally present in few plants that increases the efficiency of carbon capture and utilization in the photosynthesis process. Researchers funded by the Bill and Melinda Gates Foundation are working to activate this form of photosynthesis in rice. (Mann 2018).

Cadastral System – “a method of recording the physical location of real properties and listing real property rights. It is the ‘where’ component of the property rights system, securing the legal status of real properties and providing the foundation for effective land tenure transactions.” Finland’s system is a variation of Germany’s and includes three parts maintained by National Land Survey of Finland (NLS): the cadastre (the real property register), land register (the title and mortgage register), and cadastral map. (Krigsholm et al. 2017.)

Cellular Agriculture — Growing food conventionally farmed in the lab from cells (YCombinator blog post).

Clean Meat – Meat-like ‘food that is scientifically indistinguishable from animal products like meat and dairy, using only cells and not harming any animals.’ (YCombinator blog post).

CO_2 Removal (CDR) – Technologies for removing CO_2. (Mentioned in EASAC Policy Report 35)

Contango – “The normal situation in which the spot or cash price of a commodity is lower than the forward price.” A term frequently used in the Oil Industry. (Google Dictionary, accessed 11.1.2018.)

Coppicing – “a reproduction method whereby a tree is cut back periodically to stimulate new growth through dormant buds on the ‘stool,’ or stump.” (McLeod 2015 [The Woodland Homestead])

Cyanobacteria – Micro- and Macroalgae -- the topic of the NordAqua symposium in Helsinki 31.1.2018.

Digital Agriculture – ‘The use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production’ (Digital Agriculture, UNCompact).

Direct Storage of Sunlight – A not yet available energy storage solution that is actively pursued research into artificial photosynthesis.

Ecological Networks – The main idea of an Ecological Network is to connect several key ecological sites together by corridors of land where migrating species can make their journeys between the sites without human interference. A longer description of the forms these take can be found here: http://www.sicirec.org/definitions/corridors

Evidence-based Narratives (EBN) – A foresight approach developed and recommended the EC project ReCREATE (RECREATE is an FP7 Coordinating and Support Action, 2013-2017). EBN are based on Heckert's Technical Innovation System Analysis, http://www.innovation-system.net/what-is-tis/.

Energy Crops – Crops grown specifically for the production of bio-energy.

Extractivism – Large-scale resource extraction in the 21st Century, often reproducing patterns of past oppression against minority groups. Loose paraphrase of how it is defined on World Ecology 2018 website, https://www.helsinki.fi/en/conferences/world-ecology-2018, Accessed 7.2.2018.

Forest Farming – Growing high-value crops besides timber for human use under the forest canopy. See similar term, Forest Food.[1]

Forest Food – Food that grows in the forest. See video as example: https://www.youtube.com/watch?v=7MIx5q_zbko, Accessed 22.1.2018.

Forest Garden – Mimics function, architecture, and ecosystem of forest, but isn't necessarily grown in the forest.

Forest Landscape Restoration – WRI defines this term as 'the long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. It is about "forests" because it involves increasing the number and/or health of trees in an area. It is about "landscapes" because it involves entire watersheds, jurisdictions, or even countries in which many land uses interact. It is about "restoration" because it involves recovering the biological productivity of an area in order to achieve any number of benefits for people and the planet. Some of these benefits include improved soil fertility and food security, increased natural forest cover for watershed protection, mitigation of climate change, protection of biodiversity, creation of green jobs and more. See Hanson et al. 2016's WRI Blog: http://www.wri.org/blog/2016/02/insider-restoration-diagnostic-can-help-bring-commitments-action-ground, Accessed 7.2.2018.

Geoengineering – Taking bold initiatives to sequester carbon by artificial means.

Intergenerational Equity – A concept of fairness when comparing resource consumption and problem-solving burdens of the current generation with that of future generations.

Land Grabs – When large companies or countries purchase, lease or otherwise obtain land in a way that displaces people and effectively gives the actor control over that land.

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[1] See Zamora & Wyatt (2015) Forest Farming info sheet, UMN Extension. https://www.extension.umn.edu/environment/agroforestry/forest-farming/forest-farming.html (Accessed 22.1.2018); https://farmingthewoods.com/2013/04/04/forest-farming-vs-forest-gardening-whats-the-difference-2/, Accessed 22.1.2018; Agroforestry Practices – Forest Farming, PublicResourceOrg Youtube Channel 31.7.2010, https://www.youtube.com/watch?v=ssFQXgGbwTE , Accessed 22.1.2018.

Landrace Biodiversity – 'A landrace is a variety of domesticated animal or agricultural plant species which has, over a long period of time, adapted to the local natural environment in which it lives.' This adaptation is typically encouraged by 'seed-saving' from the plants that perform the best in local conditions. (Ireland National Biodiversity Database[1]). This term is used in Collins, Biodiversity in Agroecosystems.

Long-term Carbon Storage Value – The carbon storage value of a quantity of biomass compared to the carbon cost for making products from that same biomass.

Negative Emissions Technologies (NETS) – A category of technologies for pulling CO2 out of the air including: BECS, forestation, direct air capture, biochar and soil sequestration, enhanced weathering, and ocean fertilization.

New Adaptionism – A challenge to a commonly held conception of evolution in which organisms and their capacities/characteristics are forged by nature. Instead, New Adaptionism argues that "Organisms are self-building, self-maintaining, purposive systems actively engaged in, commingled with, their conditions of existence. Adaptive evolution is the consequence of a constant dialectical interplay between organisms and their conditions; organisms change them and are changed by them" (Walsh 2014, 232-233).

Marine Biomass – Biomass produced by aquatic lifeforms, such as seaweed or Kelp.

Negative Emission Technologies (NETs) – Technical systems designed to remove CO2 and greenhouse gasses from the atmosphere.

Novel Entity – A man-made entity (e.g. a chemical, nano-partical, etc.) that has been introduced into the natural environment. For example, Environmental Law Institute is conducting a study seeking to map what novel entities might be released over the next 15 years.

Oil, Proven Reserves – Oil fields that have been identified, located and estimated. These reserves are believed to be useable if accessed.

Oil, Unproven Reserves – Oil fields that may exist, but are yet to be specifically identified.

Open Algae Raceway – A laboratory testing system by which algae are raced around a pathed tub by a rotor.

Permaculture – A system for living in harmony with nature promoted by a Permaculture expert in Australia, Patrick Whitefield. A person can be certified in permaculture, a way to signal you are an expert and are a credible educator regarding the system.

Plantationocene – A term coined in "Anthropologists are Talking About the Anthropocene" (in Ethnos) to refer to "devastating transformation of diverse kinds of human-tended farms, pastures, and forests into extractive and enclosed plantations, relying on slave labor and other forms of exploited, alienated, and usually spatially transported labor" (Haraway 2015, 162).

Plasmid Design -- An essential part of a Synthetic Biology workflow. See http://www.eusynbios.org/blog/2017/10/8/introducing-doulix-a-bio-engineering-platform-from-explora-biotech

[1] http://www.biodiversityireland.ie/projects/genetic-resources/other-plant-genetic-resources/landraces/

Portable Carbon Technologies – Technologies for capturing the Carbon from CO2 and storing it in in a portable object such as a 3D printed mesh or capsules. See Lawrence Livermore National Laboratory video 25.1.2018 https://youtu.be/JIvOdfaLWNc?t=5m40s, Accessed 5.2.2018.

Precision Irrigation – Irrigation systems capable of delivering just enough water at just the right time on a granular plant-by-plant basis. (see Galioto et al. 2017)

Radiative Forcing – "Radiative forcing is used to assess and compare the anthropogenic and natural drivers of climate change. The concept arose from early studies of the climate response to changes in solar insolation and CO_2, using simple radiative-convective models." IPCC 4th Assessment Report, www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-2.html, Accessed 7.2.2018.

Restoration Economy – "Businesses that have **landscape restoration** at the core of their customer value proposition" as proposed by the World Resources Institute.

Rewilding – Coined by Dave Foreman in the 1990s, rewilding is 'large-scale wilderness recovery that allows natural processes and native wildlife to flourish.' It is a term used by organizations working to bring wildlife back to its former habitats. One such organization is run by Doug and Kristine Tompkins, former CEOs of Patagonia. (see Franklin 2018). Rewilding Europe has established six 'rewilding entities' to support territorial projects: Rewilding Apennines (2014), Rewilding Velebit (2014), Rewilding Rhodopes (2014) and Rewilding Lapland (2015), Rewilding Ukraine (2016) and Rewilding Danube Delta (2017).

Rewilding Enterprise – Enterprises founded to support rewilding opportunities that arise as populations abandon rural areas to live in cities. : 'a rewilding enterprise generates direct or indirect finance, incentives or engagement for rewilding, and has a positive impact on wilder nature or the comeback of wildlife.' see https://rewildingeurope.com/rewilding-in-action/nature-based-economies/, accessed 26.7.2018

Salt Water Intrusion – When salt water from the ocean or sea enters into freshwater systems along the coasts. (See Epanchin-Niell 2018)

Silviculture – A branch of forestry dealing with the development and care of forests. (Merriam-Webster Dictionary)

Synthetically Modified Organism (SMO) – a term used in this article by Ethical Consumer describing 'future threats' of synthetic biology. http://www.ethicalconsumer.org/commentanalysis/environment/syntheticbiology.aspx, Accessed 17.7.2018.

Spillovers (in R&D) – These "occur when the inventions, designs, and technologies resulting from the R&D activities by one firm or industry spread relatively cheaply and quickly to other firms and industries" (Barbier & Burgess 2018).

Urban Wildlife Management – Managing interactions among wildlife and humans in urban areas.

Viticulture – All agricultural activity related to grapes and wine production.

Appendix 4. Organizations, Research Initiatives, and Relevant or Interesting Actors Identified in Horizon Scanning

Organizations

Algae Biomass Organization (ABO) a non-profit organization whose mission is to promote the development of viable commercial markets for renewable and sustainable commodities derived from algae. https://algaebiomass.org/

Bank for International Settlements. https://www.bis.org/statistics/relcal.htm Coordinates the rates and policies of approx. 60 central banks around the world. For our project, their statistical reports may be of value in terms of discussing relational complexity of the global economy.

Biomimicry Institute – Co-founded by the Janine Benyus author of the 1997 book *Biomimicry: Innovation Inspired by Nature*. It sponsors the startup and social innovation contest called Biomimicry Showcase. https://biomimicry.org. (Its sister organization is a consulting operation called BioMimicry 3.8 https://biomimicry.net/)

BIOS Research Institute – A small Finnish research group founded in 2015 that comments on Finland's progress regarding carbon reduction goals and voices criticism of national bioeconomy plans.

Center for International Climate Research (CICERO) – An institute for interdisciplinary climate research based in Norway aiming to help solve the climate challenge and strengthen international climate cooperation. https://www.cicero.oslo.no/

European Biomimicry Alliance (EBA) is a trans-national network of European experts in the field of innovation driven by biomimetic approaches. https://cidd2015.sciencesconf.org/51652/document

Boyce Thompson Institute for plant sciences, https://btiscience.org/ This institute hosted the work of researchers who restored tropical rainforests in Costa Rica (see Cornell news article in News Section). Their research agenda focuses on basic understanding of plants. The continuation of the Rainforest work might now be part of their research into Arbuscular mycorrhiza.

China Biodiversity Conservation and Green Development Foundation (CBCGDF) – is a leading nationwide non-profit public foundation and a social legal entity dedicated to biodiversity conservation and green development. http://www.cbcgdf.org/English/

Climate Central – A news website 'researching and reporting the science and impacts of climate change.' http://www.climatecentral.org

David Suzuki Foundation – A Canadian NGO with the tagline 'one nature'. "Our **mission** is to protect the diversity of nature and our quality of life, now and for the future. Our **vision** is that within a generation, Canadians will act on the understanding that we are all interconnected and interdependent with nature." https://davidsuzuki.org/about/

Ellen Macarthur Foundation. Funds research initiatives on bioeconomy and circular economy themes. https://www.ellenmacarthurfoundation.org/

The Endangered Landscapes Programme – Focusing on Europe, this programme aims to transform nature conservation and reverse biodiversity loss. https://www.endangeredlandscapes.org

Energy Biosciences Institute, a partnership of U of C Berkley, U. of Illinois Urbana-Champaign, Lawrence National Laboratory, and BP. “300 researchers applying advanced knowledge of biological processes to the energy sector.” Published a newsletter called Bioenergy Connection.

European Academies Science Advisory Council (EASAC) “Science advice for the benefit of Europe.” http://www.easac.eu

EUSTAFOR, the European State Forest Association According to an ad ran in EU Observer magazine: it “gathers together 33 State Forest Management Organizations from across Europe, which are often the largest forest managers and biomass suppliers in their Member States. State Forest Management Organizations provide biomass to a multitude of forest-based value cycles and, thanks to their scale, stability, reliability and openness to cooperation, they can catalyse the development of the bioeconomy.” http://www.eustafor.eu

European Commission, Bioeconomy – A hub for policy, publications, videos, and events about bioeconomy research. http://ec.europa.eu/research/bioeconomy/index.cfm

European Commission Bioeconomy Knowledge Centre – Launched in January 2017, compiles news, events, and data about the bioeconomy. https://biobs.jrc.ec.europa.eu/

FAO – Food and Agriculture Organization of the United Nations – among many important functions, FAO provides an annual detailed list of countries in need of external assistance for food. http://www.fao.org/home/en/

European Forest Institute (EFI) conducts research and provides policy support on issues related to forests. https://www.efi.int/

FERN – FERN’s mission is to achieve greater environmental and social justice, focusing on forests and forest peoples’ rights in the policies and practices of the European Union. https://fern.org/

Frederick S. Pardee Center for International Futures – University of Denver. Conducts research into humanities possible futures using the International Futures model. http://pardee.du.edu/

German Bioeconomy Council – Publishes reports on bioeconomy. Champions bioeconomy in Germany and globally. http://biooekonomierat.de/en/, accessed 22.1.2018

Global Soil Biodiversity Initiative - promote expert knowledge on soil biodiversity into environmental policy and sustainable land management to protect and enhance ecosystem services. Includes vital reading list on Soil https://www.globalsoilbiodiversity.org/books-and-recommended-reading https://www.globalsoilbiodiversity.org/ 11.11.2018

Institute of Crop Science – Biobased Products and Energy Crops, University of Hohenheim, Germany. Researching biomass production and energy crops. Founded in 2010 by Iris Lewandowski. https://www.uni-hohenheim.de/en/organization/institution/fg-nachwachsende-rohstoffe-und-bioenergiepflanzen

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Described as the “IPCC for biodiversity” because it too was launched by the Rio Convention. https://www.ipbes.net/about

IPCC – Tasked by the Rio Convention to monitor climate change. https://www.ipcc.ch/

International Renewable Energy Agency (IRENA) – “an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy." https://www.irena.org/

Leonardo DiCaprio Institute, a foundation focused on Bio-Mimicry, Bio-Recovery and Bio-Equality themes (and one of many funders of the BioMimicry Institute. https://www.leonardodicaprio.org/reports/

OPEC – Provides annual statistical reports about oil supply, production, and consumption around the world. http://www.opec.org/opec_web/en/data_graphs/

Ray C. Anderson Foundation – Named after the founder of Interface Inc., a pioneer in sustainable business, this foundation funds initiatives aimed at creating businesses that do good for the ecology. https://www.raycandersonfoundation.org/grants/

Stockholm Resilience Institute, are the founders of the planetary boundaries concept, updating the data periodically and publicizing its value. A key link for graphics, etc: http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries-data.html

Swedish Forest Industries Federation – Represents the interests of Swedish forest sector to the public and currently placing heavy emphasis on bioeconomy themes. See website section BioEconomy Life: https://www.forestindustries.se/bioeconomylife/

Syke – Finnish Environment Institute – Hosts to various projects including RECIBI (about circular bioeconomy and innovation policy), carbon neutrality, and PEER-GE about green engineering. http://www.syke.fi/en-US

THÜNEN Institute – Researches relationships among various bioeconomy activities (e.g. food production vs. energy production) and continually monitors the situation. https://www.thuenen.de/en/

Transparency International: The global coalition against corruption - Prepares an annual index of 'perceived corruption'. The more corruption there is in a country, the more barriers there will be to the development of the Bioeconomy. https://www.transparency.org/

Tropical Forest Alliance 2020 has been coordinating several efforts to restore rainforest in the context of broader societal concerns such as economy, etc. In the project exemplifies a combination of Bio-Recovery and BioUtilization categories. https://www.tfa2020.org/en/

UN CCD – **Convention to Combat Desertification** publishes the Global Land Outlook (https://www.unccd.int/actions/global-land-outlook-glo) and is custodian of SDG about land degradation. Their work sheds light on the competing interests and overall concerns related to land use, a key variable in the bioeconomy.

UN DESA Population Division – Publishes population forecasts, including national, regional, and global forecasts. See: https://esa.un.org/unpd/wpp/Publications

USDA Agroforestry Center – The United States Department of Agriculture has a center dedicated to publishing information about agroforestry. It contains very practical information about how to implement Alley Cropping, Forest Farming, Riparian Forest Buffers, Silvopasture, Windbreaks, and Special Applications. https://www.fs.usda.gov/nac/

U.S. Dept. of Energy's Energy Efficiency & Renewable Energy program – This part of the US DOE houses the **Bioenergy Technologies Office**, which researches, funds, and advances bioenergy technologies and concepts.

U.S. Dept. of Energy Knowledge Discovery Framework – Bioenergy – "access to a variety of data sets, publications, and collaboration and mapping tools that support bioenergy research, analysis, and decision making." https://www.bioenergykdf.net/

World Resources Forum – Promotes circular economy and greater efficiency in industrial processes. Part of Paul Scherrer Institute (PSI), Switzerland. https://www.wrforum.org/

World Resource Institute – WRI's Forest program is and Forest Restoration Potential atlas are sources of alternative visions for bioeconomy. eg. http://www.wri.org/our-work/project/global-restoration-initiative

Research Initiatives

ARPA-E MARINER (Advanced Research Projects Agency's Macroalgae Research Inspiring Novel Energy Resources Program) – Funded a project by Ocean Rainforest, Catalina Sea Ranch, Patagonia Seaweed and Hortimare to develop techniques for cultivating seaweed. https://arpa-e.energy.gov/?q=arpa-e-programs/mariner

Atlas at the End of the World – A website showcasing a variety of maps and illustrations depicting biodiversity pressure points around the world. The materials are researched and produced by Richard J. Weller, Claire Hoch, and Chieh Huang. http://atlas-for-the-end-of-the-world.com

Baltic Blue Biotechnology Alliance https://www.submariner-network.eu/projects/balticbluebioalliance

Biotsunami According to its website, the project tests two research hypotheses: The "waves" of change + Converging technologies 1) Socio-technical change comes in waves, small or big ("tsunamis"); 2) Converging technologies driving previous (info-) and new bio-tsunamis. 1.10.2016–12.31.2017. http://www.biotsunami.itee.radom.pl/index.php

Bioeconomy Research Programme Baden-Wurttemberg developed the competence network modelling approach of linking several bioeconomy models together – EFEM, ESIM, TIMES PanEU, BiOLoCaTe, Gabi a LCA Software, CGE model PACE and CarboMoG. The goal was to "compare and evaluate both the direct and indirect economic, material and ecological effects" of various scenarios. (mentioned in Box 9.2 and Fig 9.7 of book Lewandowski 2017, book chapter Angenendt et al.)

CIARD Ring – Open data platform for sharing datasets about food and agriculture. http://ring.ciard.net/

Carbon Action pilot at Sitra – Piloting soil-based carbon sequestration at 100 farms around Finland. Led by Hanna Mattila, Noora Lindroos and Merja Rehn. https://www.sitra.fi/en/projects/carbon-pilot/ (Accessed 11.10.2018.)

DARPA Living Foundries – the Defence Advanced Research Projeccts Agencie's (U.S.) Living Foundries program aims to enable adaptable, scalable, and on-demand production of such molecules by programming the fundamental metabolic processes of biological systems to generate a vast number of complex molecules that are not otherwise accessible. Through Living Foundries, DARPA is transforming synthetic biomanufacturing into a predictable engineering practice supportive of a broad range of national security objectives. https://www.darpa.mil/program/living-foundries

"Design Driven Value Chains in the World of Cellulose (DWoC) is a multidisciplinary research collaboration project funded by Tekes (the Finnish Funding Agency for Innovation) focused on finding new and innovative applications for cellulosic materials. The DWoC project combines design thinking and design-driven prototyping with a strong competence in technology development. The project took place 1.4.2013–31.3.2018. https://cellulosefromfinland.fi/design-driven-value-chains-in-the-world-of-cellulose/

ECO Potential – An EU project developing space-based monitoring systems for tracking biodiversity and ecological indicators. http://www.ecopotential-project.eu/project/mission.html

FORBIO – "This research project is implemented by **University of Eastern Finland**, School of Forest Sciences and Department of Chemistry, **Finnish Meteorological Institute**, **Natural Resources Institute Finland**, **European Forest Institute** and **Finnish Environment institute**. http://www.uef.fi/en/web/forbio

Food Revolution 5.0 – A food themed art exhibit that premiered in Hamburg Germany in the summer of 2017. https://www.domusweb.it/en/news/2017/06/07/food_revolution_5_0.html & https://www.gewerbemuseum.ch/en/exhibitions/food-revolution

Green Stuff – Interdisciplinary initiative at University of Technology Sydney (Climate Change C and Business School) researching entrepreneurship based on algae. They estimate this sector of the Bio-economy could be valued at 23B USD by 2023. https://www.uts.edu.au/about/uts-business-school/our-research/think/green-stuff

HoneyDrones – Researchers at Harvard are developing robot bees that can be operated as a swarm to pollinate crops. This is an example of synergy between BioMimicry and BioRecovery worlds (see Chapter). See Brown 2018 under News and Online Articles: http://www.digilyfe.co/2018/08/scientists-developing-robot-bees-to-pollinate-crops-as-bee-populations-decline/

KoMpass – Fraunhofer partnered with Senckenberg natural museum to investigate futures of bioeonomy. See http://www.senckenberg.de/root/index.php?page_id=18878&PHPSESSID=3e5gl2o4cr6jbi3nf1pms2nq35 & https://www.isi.fraunhofer.de/en/presse/2018/presseinfo-01-2018-biokompass.html

Land Art Generator The goal is to “accelerate the transition to post-carbon economies by providing models of renewable energy infrastructure that add value to public space, inspire, and educate—while providing equitable power to thousands of homes around the world.” A design competition as well as projects based. This site offers a source of novel and innovative approaches to land use and design, through the merging of art. Featuring for example ‘symbiotic ecologies’ http://landartgenerator.org/blagi/archives/1094 accessed 2.2.2019.

Living Factories (IBC & VTT, 2014–2016) "The goal of Living Factories [project 2014–2016] is to realise the full potential of Synthetic Biology in Finland. Synthetic Biology is considered one of the key breakthrough technologies that will have a major impact on our future. It is based on the design and engineering of new-to-nature biological systems."

Naturvation – Urban Nature Atlas From the website’s description: “[It] contains almost 1000 examples of Nature-Based Solutions from across 100 European cities.” https://naturvation.eu/explore, accessed 2.4.2018.

NSW Deep Green Biotech Hub based at UTS – An algae-based biotechnology networking hub established at University of Technology Sydney. It runs a Biotech accelerator program called Green Light. https://deepgreenhub.uts.edu.au/

Open Agriculture Initiative (OpenAg) has an ambitious goal of building a ‘food computer’ -- meaning a computer that can grow food for an individual or household. https://www-prod.media.mit.edu/groups/open-agriculture-openag/overview/

PREP Data – The Partnership for Resilience and Preparedness (PREP) believe that climate and socio-economic data should be accessible and usable for everyone. They endeavor to make this data available. https://prepdata.org/

Radical Ocean Futures ‘blends art and science and merges scientific fact with creative speculation’ in “four short 'Radical Ocean Futures.' These are scientifically grounded narratives of potential future oceans.” (See Futures article https://doi.org/10.1016/j.futures.2017.09.005) https://radicaloceanfutures.earth/home/#about-project

ReCreate D4.1 – An EU-funded research project which applies the concept of using Evidence-Based Narratives to generate future insights regarding evolving technology. (See Evidence-based Narratives No.1, http://www.recreate-net.eu/dweb/results/d41-evidence-based-narratives-no1)

Scenarios of the Bioeconomy 2050: Potentials, trade-offs, solution strategies, Thunen Institute. A similar approach to the BioEcoJust, but on a shorter time horizon: "The research project aims at developing several scenarios of the change to a bio-based economy in 2050 and at presenting acceptable transition paths. Thereby, (political) responsibilities, options for action and control devices will be identified." https://www.thuenen.de/en/institutsuebergreifende-projekte/scenarios-of-the-bio-economy-2050-potentials-trade-offs-solution-strategies/, accessed 11.1.2018.

Synergene – "A four-year mobilization and mutual learning action plan" focused on RRI (Responsible Research and Innovation) in synthetic biology. It ran from 2014-2017 and was funded by the 7th Framework Programme of the EU. https://www.synenergene.eu/about.html

Welcome to the Anthropocene, the first educational web portal on the Anthropocene, developed by Commonwealth Scientific and Industrial Research Organization (CSIRO), Globaïa, International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme on Global Environmental Change (IHDB), Stockholm Resilience Centre and Stockholm Environment Institute. http://www.anthropocene.info/about.php

Woodrow Wilson Institute - **Synthetic Biology Project**–Uses a sophisticated news scanning method to maintain a database of companies, products, stakeholders, news, and services in the synthetic biology market mapping key actors and emerging risks. http://synbioproject.org

World-Ecology Research Network – A research network coordinated by Jason W. Moore, the scholar who champions the term 'Capitalocene' in contrast to the term Anthropocene. https://worldecologynetwork.wordpress.com/

VTT 'The Making of Tomorrow' – A website championing bioeconomy innovations being developed at VTT in the sectors of Energy, Chemicals, Materials and Food. Frequent members are also part of this communication initiative. https://makingoftomorrow.com

Appendix 5. Delphi Expert Panel Matrix

The expert panel is being assembled according to Bio-Worlds (see Chapter 4.5) and Organization types along three different scales of Finland, Europe, or Global. With all cells filled, there would be 120 invited participants in the Delphi surveys.

		Bio-Worlds				
Organization Type	**Scale**	**Bio-Utilization**	**Bio-Up-grade**	**Biomimicry**	**Bio-Recovery**	**Bio-Equality**
Industry Leaders	National					
	Europe					
	Global					
Consumer Groups	National					
	Europe					
	Global					
Government, Agencies, Policymakers	National					
	Europe					
	Global					
Big Research & Think Tanks	National					
	Europe					
	Global					
Academics	National					
	Europe					
	Global					
Startups / SMEs	National					
	Europe					
	Global					
Environmental NGOs	National					
	Europe					
	Global					
Investors & Funders	National					
	Europe					
	Global					

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6/2017 Heikkilä, Katariina – Nevala, Tuulia – Ahokas, Ira – Hyttinen, Liisa & Ollila, Johanna: Nuorten tulevaisuuskuvat 2067. Näkökulma suomalaisen yhteiskunnan kehittämiseksi.

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