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LaFed, an Alternative Solution to Present Day Environmental and Energetic Challenges

Analysis of environmental and energetic global state, introduction to biophysical economics, and emergence of a new organization, the Federation of the Shared, based on P2P economy and the sharing economy

Project Master's Thesis submitted by
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Je remercie mes parents de m'avoir soutenu dans mes études et de m'avoir donné la chance d'avoir eu des expériences enrichissantes dans de nombreux pays ; Merci !

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Agenda

Table of Figures

Introduction

A doughnut! A doughnut is a concept used by the American economist Kate Raworth (2017) for representing the economy. This representation (figure 1) is so simple that it provides a striking view of the challenge facing humanity. In simple terms, humanity should be within the 'safe and just space' which is delimited by a social ceiling and an environmental ceiling. According to K.Raworth (2017), by staying within this green zone, humanity would fulfill its social needs without exceeding the carrying capacity of the planet and damaging the vital cycles and the needed balanced ecosystems that sustain human life.

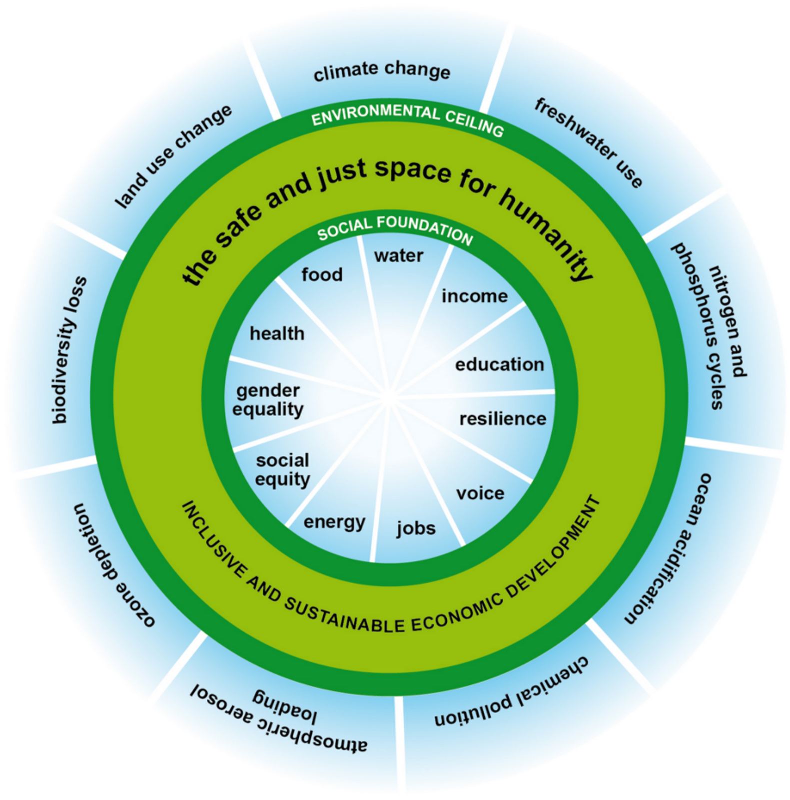

Figure 1: Doughnut Model (Raworth, 2020)

On one side, the doughnut describes a social ceiling which is made up of a quantity of factors, including population access to drinking water and to sanitation (water), the illiteracy rate among adults and the number of children out of schools (education), the degree of social equity, or the access to electricity or cooking facilities (energy). Setting specific measures to account for each of the social factors is helpful in describing the degree at which humanity is successful in fulfilling its social needs. On the other side, the doughnut shows how humanity is limited by an ecological ceiling that humanity should not overshoot in order to safeguard the carrying capacity of the planet as well as the vital cycles and needed balanced ecosystems that sustain human life. This is defined by various indicators as the concentration of atmospheric carbon dioxide (climate change), the rate of species extinctions (biodiversity loss), or the chemical pollution.

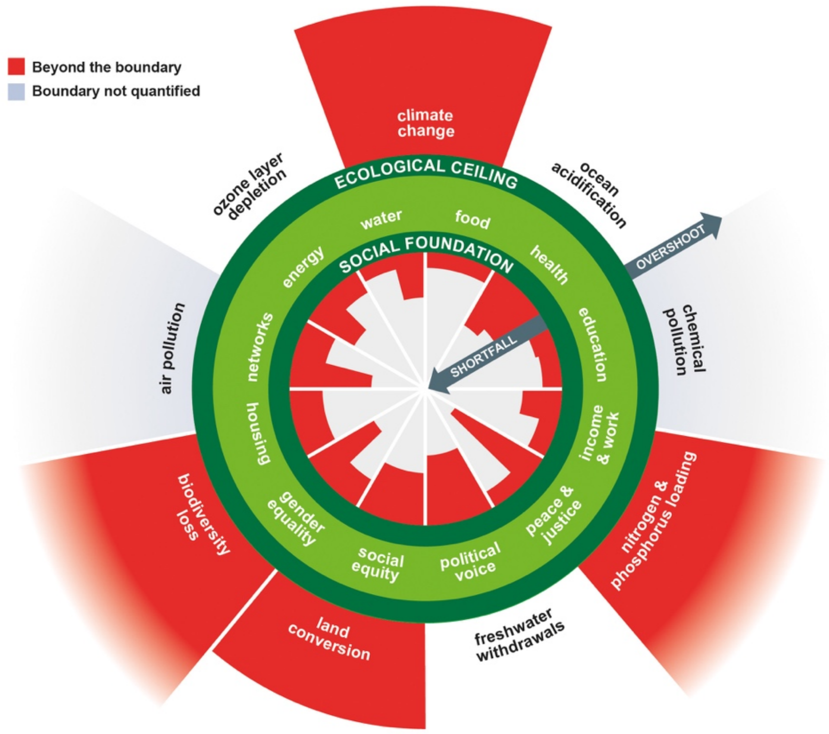

Figure 2: Doughnut Model, Actual Global State (Raworth, 2020)

However, as figure 2 is demonstrating, the nine planetary boundaries beyond which lie unacceptable environmental degradation as well as the twelve social foundations that form the minimum social standard are not met (Raworth, 2020). The Doughnut representation by K.Raworth, which is only used as an introductory element, shows a striking view of the state of the present situation globally for humanity. The conclusion is clear: humanity is overshooting ecological boundaries without fulfilling its global social needs. The immediate questions that this raises are: How may humanity fulfill its social needs globally without compromising the environment? How may environmental issues be tackled? What are the possible solutions to return under the ecological ceiling?

In order to adequately answer these questions, research was focused on the ecological ceiling, with specific attention given to climate change and land degradation. This reduction in scope was a conscious choice as the two subjects encompassed the majority of Raworth's indicators, as well as permitting the research to delve deeper into the subjects.

The question of returning below the ecological ceiling has been the foundation of my research throughout my academic career. I discovered that potential solutions pertain broadly to the technological sphere, such as the development of renewable energy, and to the political sphere, such as the Paris Agreement set in 2015. Furthermore, I discovered that political solutions do not include only governmental or organizational actions; indeed, they also included actions led by the civil society. Indeed, during my student life in Quebec, I uncovered numerous initiatives led by local communities that helped deal with the environmental crisis. For instance, while undertaking a project to understand and promote sustainable mobility in Quebec, I was struck by the actions of two farmers, Nasser Boumenna and Claire Lanctôt, who apply agroecological methods to produce fruit and vegetables to customers in Montreal. This agricultural technique ensured high productivity without impacting land health (Poitout, 2018a). Moreover, in Quebec, I have been struck by the initiative of urban agriculture led by the Granby Community Gardens. In the town of Granby, a group of thirteen individuals of different ages dedicated their time to grow fruit and vegetables for them and the community (Poitout, 2018b). Such as the Granby Community Gardens, I discovered the existence of various initiatives around the world that produce and exchange value according to different methods. Consequently, I understood that it was essential to understand economics and gained interests in comprehending these new economic trends, such as the sharing economy, that set and provide individual ways for interacting with each other. Therefore, this thesis provides an analysis on economic theories as well as on specific economic trends.

As a result, I became convinced of the power of the civil society to answer the environmental crisis. I sought to develop a theoretical structure of an organization that deals with environmental challenges and helps construct a more resilient and sustainable society. This thesis is committed to that goal. This organization would take into consideration the environmental crises and be based on the economic theories and economic trends that this thesis study.

This thesis is constructed into three main parts. (1) The first part includes an analysis of the environmental and energetic context. (2) The second part pertains to the analysis of economics and the link between energy and economics as well as the investigation on two global trends; the sharing economy and the P2P economy. These two parts offer overarching analytical and theoretical frameworks to develop a structure that helps civil society to answer environmental challenges. (3) The last part describes the imagined organization "The Federation of the Shared" (LaFed) and its potential effects on the environment.

Methodology

Before describing the methodology, it is important to note that this thesis is a 'project thesis' which aims to contribute to a solution of a given issue which, in this instance, is the environmental crisis and the solution is the theoretical construction of an institution called: '"The Federation of the Shared" (LaFed). In order to meet this goal, this thesis is composed of three distinctive parts.

For the first part of this thesis, a document analysis was conducted to provide both quantitative data and qualitative data. As scientific research is based on on-going analyses and experiments led by various scientists in the world, main arguments and explanations raised relative to this first part are based upon consensus within the scientific community and backed up by multiple peer-reviewed articles. In order to ensure this scientific rigor, all the major arguments upheld within the first part came from meta-analysis, with specific examples occasionally mobilized in order to defend particular points.

Concerning climate change, all information included in this thesis is aligned with the work of the Intergovernmental Panel on Climate Change (IPCC). The IPCC is the United Nations body for assessing the science related to climate change. The IPCC is currently producing the sixth assessment report (AR6) so that this thesis only relates to the AR5 released in 2014 and other special reports such as the 'Global Warming of 1.5°C' (IPCC, 2018). Concerning land degradation, this thesis relies only on recent documents of reference. In order to reflect scientific consensus for a complex issue, this thesis relies on two main sources that have been elaborated by a plethora of scientists: (1) The IPBES (2018) assessment report on land degradation and restoration, made by the intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2) United Nations Convention to Combat Desertification (2017), an organization that works to achieve land degradation-neutrality worldwide.

Concerning the physics laws described, research was based on this thesis on the works of Ngô (2008), Narbel, Hansen, & Lien (2014), and a report made by the IEA (2019). As energy, and particularly entropy, are topics often evoked within the economic sphere, it was important to retrieve information only from experts within the field of physics. Moreover, this thesis provides a concise overview of two of the three laws of thermodynamics. this thesis. The second law of thermodynamics was firstly enunciated by Sadit Carnot (1824) and was formulated differently through time — Clausius (1850), Boltzmann (1873). In order to explain this law, a classic approach or a statistical approach may be used; a classical approach was chosen in order to facilitate comprehension.

Research was conducted through document analysis within the framework of neo-classical economics and the critical approach made by biophysical economics. This thesis only incorporates recent analyses from documents of reference, such as Hall & Klitgaard (2018). Biophysical economics, which is characterized as heterodox economics, integrates thermodynamics within mainstream economics, so that the majority of the thinkers on which this thesis relies on are both physicists and economists. During research, close attention was given to ensure that authors were both physicist and economist. Concerning the sharing economy, a great number of studies have been dedicated to this topic. Sharing economy, or collaborative economy, is not a well-defined section of our economy; therefore, multiple definitions of the sharing economy are applied throughout the literature. Consequently, this thesis relies on definitions from regulative institutions, and especially, the definition provided by the European Commission. Concerning the P2P economy, a definition of such a concept is blurrier. Indeed, P2P economy is a new trend within our economy. Consequently, the topic has not been heavily studied in the literature yet. As such, the information used to describe P2P economy is mostly derived from the work of M.Bauwens, a thinker of the P2P economy and founder of the P2P foundation. Relying almost exclusively on documentation made by authors that are involved in the P2P economy implies potential bias. However, this lack of critical view is acceptable as the objective of the study is only to introduce the reader to P2P economy. In order to reflect the development through time of P2P economy, this thesis relies an historical approach. In other words, through the works of M.Bauwens, this thesis demonstrated the evolution of P2P economy theories.

The third and last part of this thesis is devoted to the description of the main lines of the project, LaFed, an imagined organization that answers environmental challenges. Consequently, content is highly subjective. In fact, this last part of this thesis has the objective to create the theoretical structure of LaFed that answers to issues described in the first part using principles detailed in the second part of this thesis. Moreover, the last part of this thesis defines additional management tools and methods to maintain and govern interactions within the organization 'LaFed'. Concerning the description of IT Tools used to support the structure, this thesis relies on open source knowledge and the study of past experiences. In regard to the methods of collective intelligence and sociocracy used to govern interactions between peers, this thesis relies on reference documents, such as the Center of Collective Intelligence at the MIT. Lastly and more importantly, in order to describe the potential benefits on the environment of the creation of the imagined organization, resources are scarce. Indeed, according to the author's knowledge, there is no meta-analysis nor analysis available tackling the global, environmental benefits of P2P economy-based organization. Consequently, in order to defend the potential environmental benefits of the organization 'LaFed', this thesis is dependent on sparse local initiatives and their local impacts.

Due to the format of the research as a "project thesis", research was conducted using a combination of careful document analysis from a myriad of vetted, reviewed sources as well as a more subjective approach in the creation of LaFed. This is a conscious choice, as it mobilizes both the plethora of knowledge generated in the scientific field and the highly innovative nature of a newly imagined structure.

A. Global Ecological and Energetic Context

1. Climate Change and Land Degradation: Causes and Consequences

1.1 Climate Change:

Climate change is the regional and global change in climate pattern including global warming, which is a phenomenon of increasing average air temperature. According to the Intergovernmental Panel of Climate Change, "warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia (IPCC, 2014). The graph represents the temperature anomaly based on the period 1961-1990 and confirms the warming of the climate. Overall, the total temperature since pre-industrial times has increased approximately to 1,1 degrees Celsius.

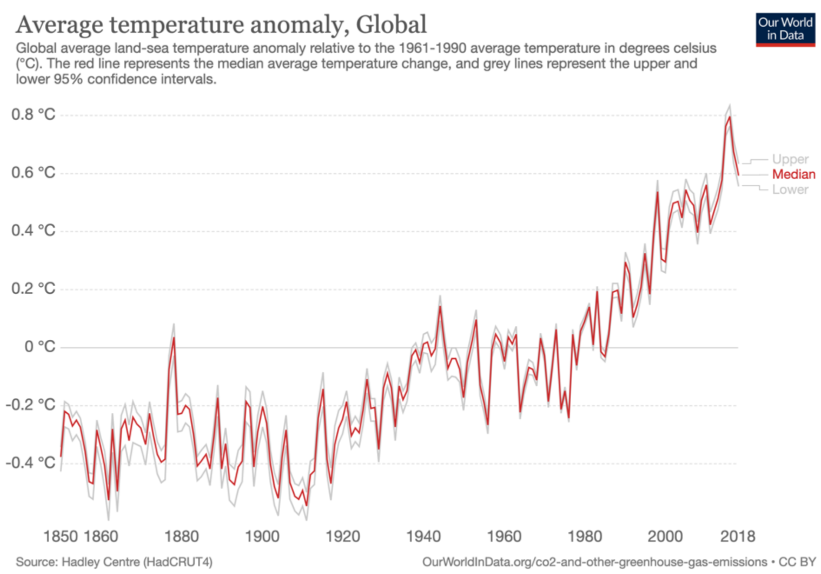

Figure 3: Average Temperature Anomaly, Global (Ritchie & Roser, 2020a)

The dominant cause of climate change since the mid-20th century is the anthropogenic greenhouse gas emissions — GHGs (IPCC,2014). Greenhouse gases are gases, such as carbon dioxide, methane, and nitrous oxide, that are trap into the atmosphere, absorbing infrared radiations emitted by Earth and contributing to the warming of Earth's surface according to the greenhouse effect. In fact, anthropogenic greenhouse gases emitted are stored into natural sinks such as the ocean or the atmosphere (Stocker et al., 2013). As shown in Figure 4, half of the gases are stored into the atmosphere, a quarter into oceans, and the last part into the vegetation (i.e.: photosynthesis). This storing has effects. While the storing of CO2 into oceans causes acidification of oceans, the additional CO2 in the atmosphere causes the rise of atmospheric concentration of such gases in the atmosphere.

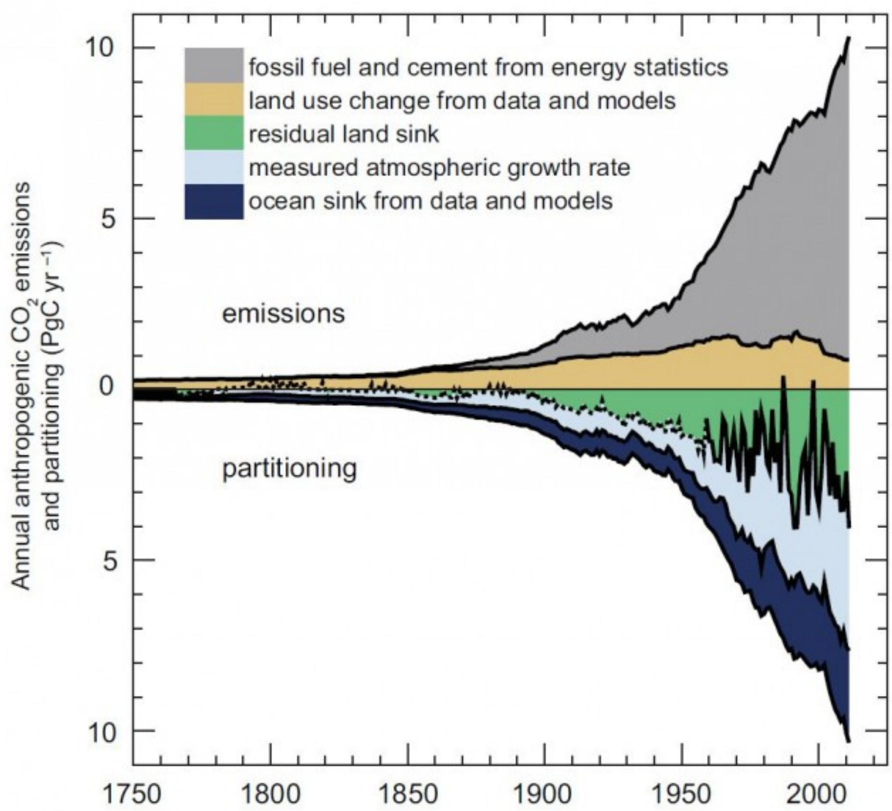

Figure 4: CO2 Emissions and Carbon Sinks: *"Fossil fuel and cement CO2 emissions by category, estimated by the Carbon Dioxide Information Analysis Center (CDIAC). CO2 emissions from net land use change, mainly deforestation, are based on land cover change data. The atmospheric CO2 growth rate prior to 1959 is based on a spline fit to ice core observations and a synthesis of atmospheric measurements from 1959. The ocean CO2 sink is from a combination of models and observations. The residual land sink (term in green in the figure) is computed from the residual of the other terms". (IPCC, 2013, pp51)*

Before describing the context further, it is fundamental to understand that not all GHGs are the equal. Relatively to greenhouse effect, they can be ranked according to different variables: Their concentration in the atmosphere -measured in particles per million (ppm)-, and their lifetime – how long it remains in the atmosphere. Previous variables are used to define the global warming potential of a gas (GWP). GWP is a "measure of the total energy that a gas absorbs over a given period of time (usually 100 years) relative to the emissions of 1 Ton of carbon dioxide" (Denchak M., 2019). For example, emitting one Ton of methane is equivalent of emitting 25 Tons of CO2 and emitting one ton of Nitrous Oxyde is equivalent of emitting 265-298 Tons of CO2 over a period of 100 years (EPA, 2019). Based on these facts, scientists may agglomerate emissions of various gases and speak in CO2 equivalent.

According to data from NOAA (2020), the concentration of GHGs has increased from 322,41ppm in 1978 to 449,4 in 2016. This concentration level must be compared with the level of 545ppm which is linked with a 50% chance of an increase of global temperature of 2°C and with the level of 478ppm which is linked with a 50% chance of an increase of global temperature of 1,5°C (NOAA, 2020). The outstanding question is: Where does these anthropogenic greenhouses gases come from? The main sectors that emit greenhouse gases in the world are the energy sector, industry, and agriculture. Within the energy sector, figure 5 shows that electricity, manufacturing, and transportation are the three main sectors that are responsible for the emissions of global greenhouse gases.

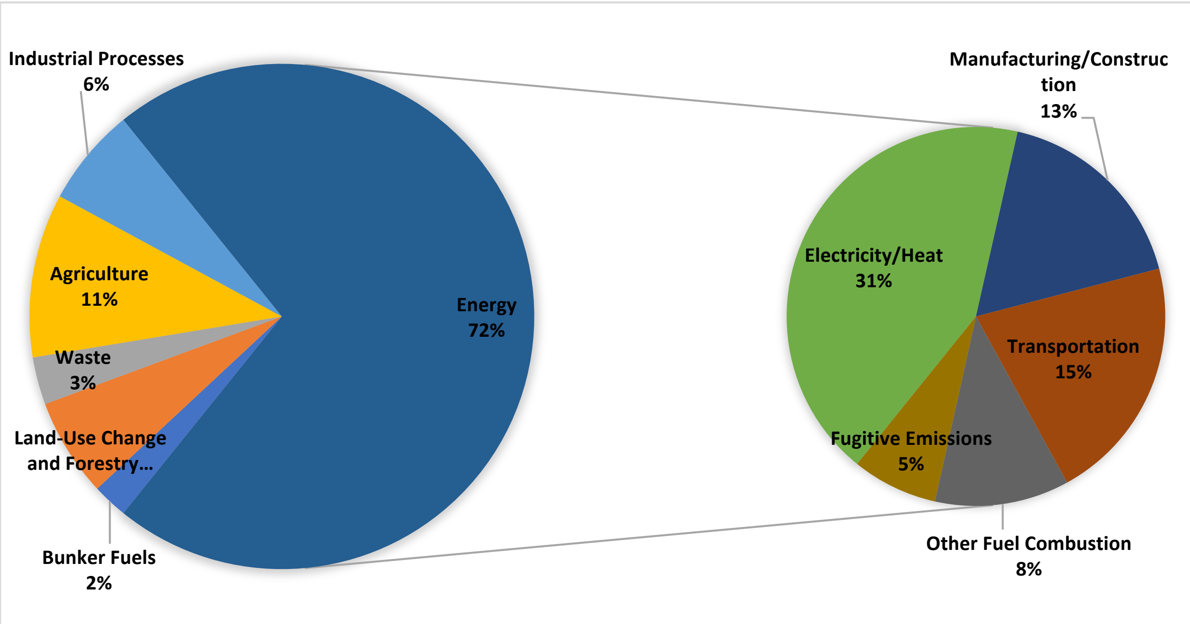

Figure 5: Global Greenhouse Gas Emissions by Sectors, 2014 (CAIT,2020)

Therefore, there is higher emission of GHGs that has as a direct consequence the increasing of GHGs concentrations in the atmosphere. Consequently, there is a heating effect due to the additional greenhouse effect. This heating effect has a measure called radiative forcing. Indeed, energy transfer between the Earth and the Sun is normally at equilibrium; anything that causes the Earth to leave this thermal equilibrium, whether natural (sun, volcanoes) or anthropogenic (aerosols, GHGs), is called radiative forcing. Formally, radiative forcing is “the net change in the energy balance of the Earth system due to some imposed perturbation. It is usually expressed in watts per square meter" (Myhre et.al, 2013). Radiative forcing may be positive such as for the greenhouse effect; and, therefore participating to the warming of the oceans and atmosphere. It could also be negative such that the aerosol effect, therefore, participating to the cooling of the atmosphere during a period of time. To state, aerosol effect is caused by various local pollutions such as the recent Australian forest cloud of smoke. As represented in the figure 6, when aggregating all effects, there is a radiative imbalance, with more energy from the sun entering than exiting (IPCC, 2013). In fact, estimations uphold that the Earth has gained, from 1971 to 2010 274.10^21 joules of energy (Stocker et al., 2013). This surplus of energy heats our Earth in an uneven way. Indeed, the warming of the ocean accounts for 93% of the total heating rate, melting ice and warming of the continents for 3% respectively, and warming of the atmosphere makes up the remaining 1% (Stocker et al., 2013). Briefly, the 1% warming of the atmosphere explained the global increase of the temperature.

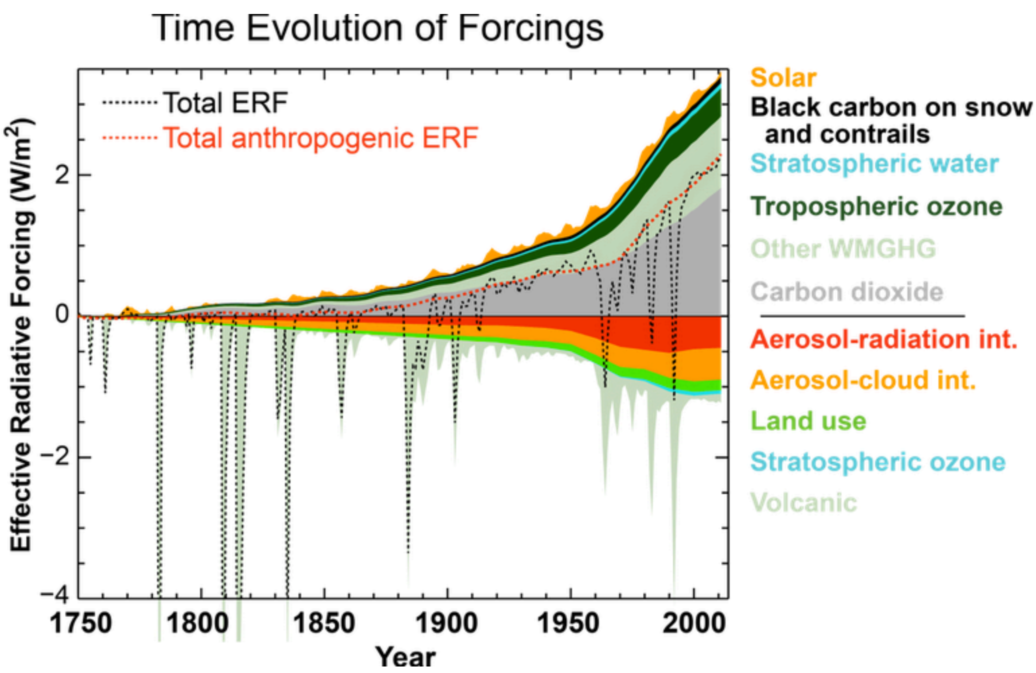

Figure 6: Effective Radiative Forcing (ERF), Time Evolution (IPCC,2013): *The factor of effective radiative forcing is given on the right of the chart. It can be natural phenomena (Solar, Volcanic) or mostly anthropogenic causes (Carbon dioxide. The dotted black line represents the total ERF while the dotted red line represents the total anthropogenic ERF.*

The concept of radiative forcing is a key element in the creation of the four possible climate scenarios studied by the IPCC AR5; they are called Representative Concentration Pathway - RCP- (IPCC, 2019). They range from the lowest radiative forcing imbalance (RCP 2.5) to the highest radiative forcing imbalance (RCP8.5). According to figure 7, the RCP 2.5 scenario is linked with a temperature change in 2100 lower than 2°C relative to the period 1861-80; while, the RCP 8.5 scenario is linked with an increase of the temperature of more than 4°C. The four scenarios can be examined to analyze the impacts of climate change, adaptation options, and the vulnerability of human societies to climate change and as such this thesis mainly refers to these scenarios (IPCC, 2019).

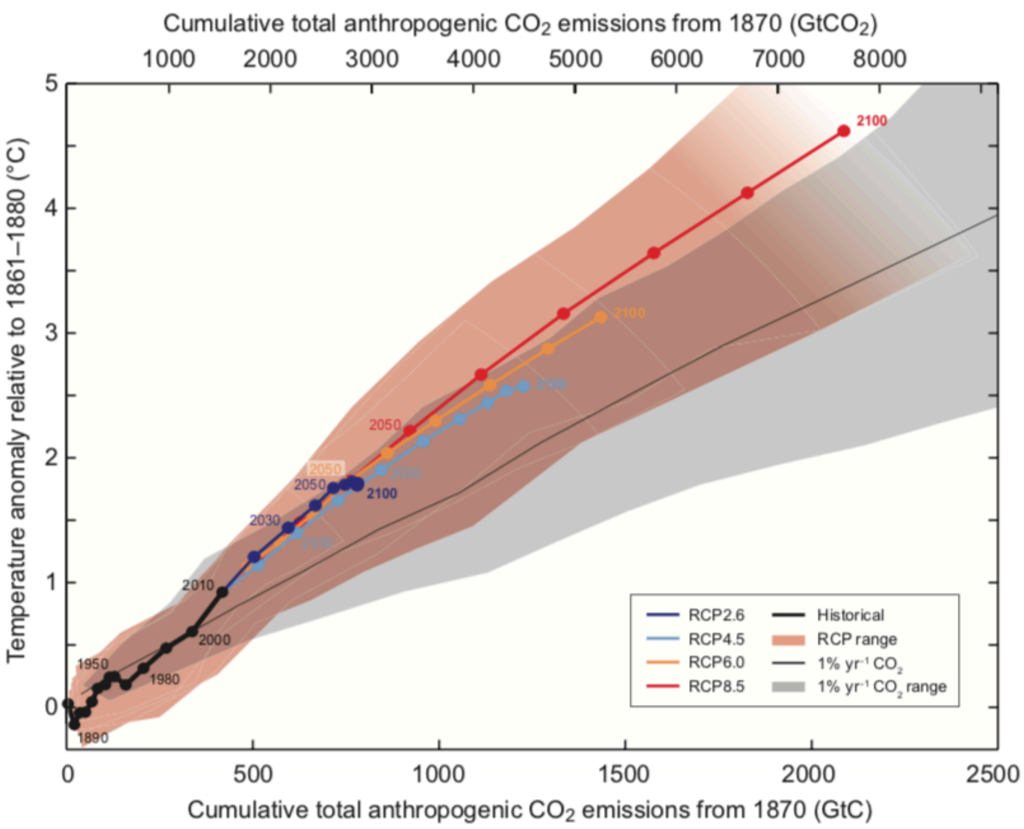

Figure 7: Global Climate Scenarios (IPCC,2013): *"Global mean surface temperature increase as a function of cumulative total global CO2 emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown with coloured lines and decadal means (dots). Some decadal means are labeled for clarity (e.g., 2050 indicating the decade 2040−2049). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. The multi-model mean and range simulated by CMIP5 models, forced by a CO2 increase of 1% per year (1% yr–1 CO2 simulations), is given by the thin black line and grey area. Temperature values are given relative to the 1861−1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines" (IPCC, 2013. pp28)*

Humanity and the Climate Change Challenge: In 2015, the Paris Agreement inscribes in article 2 the goal of humanity as "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (UN, 2015). Consequently, this agreement compels all signatories' countries to pursue efforts to achieve "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (article 4, UN, 2015).

According to previous knowledge from the study of IPCC scenarios, it is interesting to express in terms of carbon what the Paris Agreement is aiming at. Using the model of IPCC AR5, in order to attain a 50% chance to the increase in temperature of 2°C relatively to pre-industrial time, GHGs concentration should not pass over 507ppm (Met Office, 2019). Another perspective to understand the climate change issue that faces humanity is to think in terms of budget: how much carbon dioxide can humanity emits in order to have a 50% chance of not exceeding the increase of 2°C in temperature? In order to answer this question, various studies have been led (Millar, R. et al., 2017; Goodwin P. et al., 2018; Richardson et al., 2018); however, for greater understanding and to keep consistency throughout this thesis, we will rely on estimates based on the IPCC special report of 2018. The remaining carbon budget, excluding additional earth system feedbacks, such as the CO2 released by permafrost thawing, reaches 1500GtCO2 from the year 2018 until 2100 (IPCC, 2018). The carbon budget for limiting global warming at 1,5C° is 580GtCO2 (IPCC, 2018). Knowing that the current rate of emission is 42 GtCO2 per year in the world, it means that the carbon budget for 2°C will be entirely depleted after 36 years at current emission rate. Although uncertainties due to earth system feedbacks and other factors may change the carbon budget, the latter provides a useful view to describe the challenge set by the Paris Agreement.

1.2 Land Degradation:

Climate change is only a facet of the changes on Earth. Indeed, another fundamental biophysical component that humans have been changing is land. Land is defined according to the special report on climate change and land as "the terrestrial portion of the biosphere that comprises the natural resources (soil, near surface air, vegetation and other biota, and water), the ecological processes, topography, and human settlements and infrastructure that operate

within that system" (IPPC, 2019b-pp.1). Land has forever been intertwined with human development. It is "a unique, valuable, and immovable resource of limited quantity, providing multiple benefits to society" (UNCCD, 2017). However, over the past decades, humans have made critical transformations to the terrestrial biosphere leading to land degradation.
Land degradation is a global issue, costing the world an estimated 10-17% of the global Gross Domestic Product (GDP) annually (Fisher et al., 2018). "Land degradation is defined as a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity, or value to humans" (IPPC, 2019b-pp.186). While measuring the extent of land degradation is difficult as "experts disagree about both the status and trends even in well-studied areas like Europe and North America" (UNCCD, 2017), this part of this thesis is dedicated to a concise study of the state of land degradation, its drivers, and its present and future states.

Land degradation can take various forms such as desertification, soil salinization, erosion, soil salinity… In fact, we can aggregate all the various forms into three broad processes that are (1) biological degradation, (2) chemical degradation, and (3) physical degradation. The biological degradation is the state in which the structure of the soil is disrupted. The consequence of such degradation may be the excessive activity of the soil biota or excessive mineralization of organic matter (UNCCD, 2017). The chemical degradation is defined as "processes leading to soil chemical imbalances" such as salinization or acidification (UNCCD, 2017, pp.44). The physical degradation, or the death of the soil according to Claude and Lydia Bourguignon, is "the structural breakdown of the soil through the disruption of aggregates" (UNCCD, 2017, pp.44); it includes erosion, sealing and crusting, or compaction.

All the processes described are due to various factors. Direct drivers can be natural, such as landslides or earthquakes, or human-induced. It is essential to underline that human-induced drivers may influence natural direct drivers. Concerning the anthropogenic direct drivers, they are numerous. We will focus on the most significant direct drivers which are (1) grazing land and cropland management, (2) forest and tree plantation, (3) extractive industries and energy development, and (4) urban and infrastructure development. All direct drivers have underlying causes that are called indirect drivers, such as population growth or economic development. In fact, indirect drivers interact in a "complex, inter- dependent ways, reaching across both short- and long-term periods and geographic distances whilst also being subject to feedback effects from the direct drivers that they influence in the form of changes to ecosystem services and human wellbeing" (Barger et al., 2018, pp.182).

Grazing Land Management and Cropland Management:

The first direct driver, and the most influential one, is the grazing land and cropland management. Both have been increasing in size tremendously as illustrated by figure 8. "Agriculture is by far the largest human use of land, covering roughly 38 per cent of land surface, not including Greenland and Antarctica" (UNCCD, 2017, pp.43). In regard to agriculture, we will focus on grazing land and cropland management.

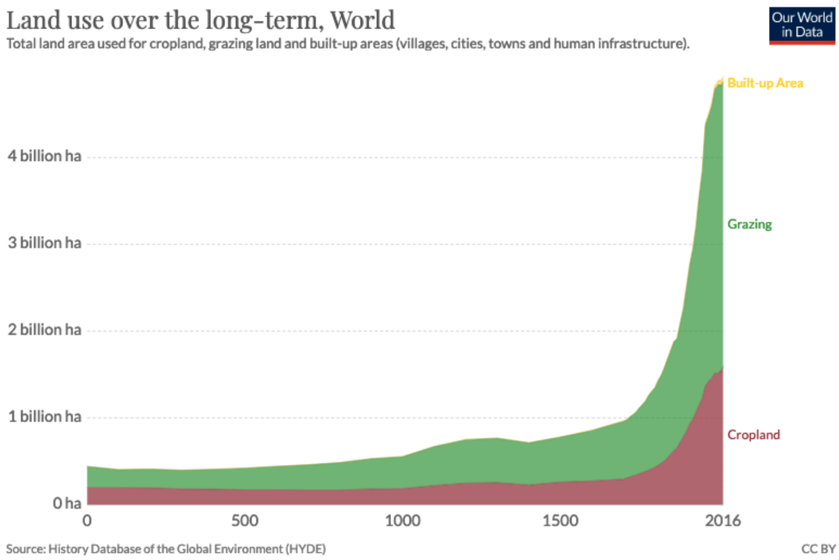

Figure 8: Global Land Use over the Long Term (Ritchie & Roser, 2020b)

On the first hand, according to the IPBES report (2018), livestock grazing represents the single largest human use of the natural environment supporting one-sixth of the global population and using 50% of agricultural land and 69% of drylands (Barger et al., 2018). There are two broad types of grazing that are the (1) extensive grazing lands, which accounts for 91% of the grazing land, and (2) the intensive grazing. On the other hand, "the second extensive human activity on the planet" are croplands (Barger et al., 2018). According to the same report, 15,8 million km^2 of natural ecosystems have been converted to cropland as of 2014; it is comparable to the area of all the South American continent. 4,7 million km^2 of this area is only dedicated to animal feed and meat production, which represent between 33 and 39% of all crop production (Barger et al., 2018). To illustrate how croplands may degrade the land, the report raised the arguments that croplands may degrade inadvertently ecosystem services on which they rely through eutrophication of water bodies by fertilizers, use of profound tillage, toxic effects of pesticides and fungicides, pest and disease control on non-target species and erosion (Prince S., 2018). In fact, it is estimated that "25% of the present agricultural land to be highly degraded, about 44% to be slightly-moderately degraded, and about 10% to be recovering from degradation" (Gomiero, 2016, pp.8). Therefore, grazing land and cropland management arise as two major direct causes of land degradation. There is a need to deepen the analysis and look at the indirect drivers of both factors. Indirect drivers are human population, household income and dietary changes as well as other factors such as the increase in bioenergy, cultural aspects, and land tenure regime.

Human population growth and consumption patterns are key drivers in the increasing demand for livestock products and cropland production. Concerning livestock products, rising household lead to the changing of consumption pattern (Barger et al., 2018). For instance, meat consumption has been increasing at a great pace in developing countries in Asia, which have seen an increase of "3% in meat consumption and 5% in dairy consumption per year from 2000 to 2010", according to the Food and Agriculture Organization (FAO) in 2013 (Barger et al., 2018, p.146). Concerning crop production, between 1963 and 2005 the expansion of croplands for food were due by 26% to the dietary change while 74% were due to the rising population; It is important to underline that these two drivers have a tendency to equalize over time with rising incomes (Barger et al., 2018). While others indirect drivers are included into the equation, the two stated factors are keys.

Concerning the predictions, grazing lands will continue to increase globally until 2030 after declining until 2050 (Barger et al., 2018). Such tendency is based on the assumption that livestock will increasingly be supported by crops rather than grazing lands. Consequently, land degradation will shift toward cropland and agricultural systems. Overall, "further extensification and further intensification of croplands are both likely", led by a growing population and an increasing per capita consumption rates (Barger et al., 2018, p.153).

Forest and Tree Plantations:

A second direct driver of land degradation globally is forest activities. Indeed, forest is a key regulator of ecosystem services in the planet, permitting regulation of groundwater levels, the increase in water yields, the maintenance of water quality, and the protection against erosion or flooding (Achard, 2009). While the clearance of forest is often a precursor to the establishment of plantations, intensive management practices of natural forest or its conversion to plantations have great impacts on the ecology and hydrology (UNCCD, 2017). According to the global forest assessment of the FAO in 2014, the "total forest area declined by 3% between 1990 and 2015" (Barger et al., 2018, p.158). A more detailed analysis shows that natural forests have declined by 6% over the same period —2,4M km2 or around five times the area of metropolitan France —while planted forests have increased by 66% — 1,1M km2 — (Barger et al., 2018). Therefore, it appears to have a substitution of natural forest by other land uses globally. According to the IPBES report (2018), the main indirect drivers are the demand for energy and for forest products as raw materials (Barger et al., 2018).

As economic development is increasing, the demand for forest products is increasing. Such correlation has been verified through history. Indeed, as Debeir, Deléage, & Hémery (2013) highlight, the supremacy of the Roman Empire was due in part to a great use of wood for carpentry (construction) — 'materia' in latin— and firewood (energy) — 'lignum'; and as local resources became insufficient, trade of wood appeared to keep up with the expansion of the Roman power. In the XVIII and in the early XIX centuries in France and United Kingdom, due to economic development and a search for a greater living standard, the price of wood has been increasing in the context of global fall in prices, which led to a search for other forms of energy, the coal (Debeir, Deléage, & Hémery, 2013). In the 20th century, as economic development continued in Europe, consumption of forest products rose, illustrated by an approximately 50% increase in demand in Europe (Barger et al., 2018). Following historical trends, forecasts support the continuing increase in demand for forest products over the coming decades, which is principally caused by the economic development of lower-income countries (Barger et al., 2018).

Extractive Industry and Energy Development

A third direct driver of land degradation globally is the extractive industries and energy development. There has been and will continue to have investments in mineral extraction due to the positive variations of standard of living (Kesler, 2007). This increasing demand will result in "land and soil degradation from deforestation, vegetation burning, and mining operations" (UNCCD, 2017). We can enumerate three broad extractive techniques which are (1) underground mining, (2) surface and open pit mining that is correlated with a much larger footprint, and (3) well extraction (Barger et al., 2018). Such operations may cause environmental damages such that harming the provision of clean water to biomass production as well as significant declining of biodiversity (Barger et al., 2018).

The fundamental indirect driver of extractive industry is the demand for specific commodities in the global economy (Barger et al., 2018). From rare earths to basic metals, the demand is led more by the increase of standard of living rather than the increase of the population (Kesler, 2007). To meet this demand, major technological shift happens, which directly affect land degradation negatively. The first is the declining cost of earth-moving equipment that conduct the extractive industry to prefer surface mining instead of underground mining (Barger et al., 2018). Such operations are particularly destructive as it substantially harms topsoil of land and create large quantities of waste. Secondly, in the oil and gas sector, the industry observed a rapid deployment of hydraulic fracturing and horizontal drilling. In addition, the footprint of well drilling is reinforcing due to the infrastructure (pipelines, roads…) that are needed to support the activity (Barger et al., 2018).

Infrastructure, Industrial Development and Urbanization

A fourth direct driver of land degradation is the growth of urbanization and infrastructure development. Urban land area is generally defined by administrative boundaries. Within the urban land areas, it exists "build-up" areas, which are defined as the presence of buildings; and within this build-up area we can define impervious surfaces such as buildings, asphalt, and concrete (Barger et al., 2018). Such infrastructures is causing soil sealing which is one of the "most severe form of land degradation, with a near total loss of soil biological, hydrological, and biogeochemical functions" (Barger et al., 2018, p.164). In 2000, built-up areas represented over 0,4% of the planet land area and 4% of all arable land (Barger et al., 2018).

There are three key indirect drivers that lead to the growth of urbanization: (1) Human population growth that is projected to attain 9,7 billion in 2050 compared to 7,3 billion today; (2) The migration of people from rural to urban areas, illustrated by the fact that in 1900 only 13% of people lived in urban areas while it is around 54% today, and will be around 66% in 2050; (3) the decline in urban density due to the sub-urban expansion (Barger et al., 2018; UNCCD, 2017). Concerning the predictions, urban areas will largely depend on the future of urban density. If urban density stagnates, Angel et al. (2011) forecast an urban land cover in 2030 of 0,62% of all land (+32% over 2010 level), and 0,76% in 2050 (Angel et al.,2011).

However, if urban density continues to decline at a rate of 2% per annum, urban areas may attain 1,14% in 2030 and 2,07% in 2050 (Angel et al., 2011).

1.3 Direct Consequences

According to what previously demonstrated, which is the causes and existence of climate change and land degradation, it is essential to analyze potential consequences for human societies. Therefore, the following paragraphs will be dedicated to explain a concise but not exhaustive direct consequence of land degradation and climate change by focusing on earth's ecosystems services and biodiversity, food security, and water resources.

1.3.1 Biodiversity and Ecosystem Services

Climate change and land degradation affect biodiversity, which is the diversity within species, between species and of ecosystems, and ecosystem services, which are natural processes benefiting humanity (IPEBS, 2019). In fact, land degradation is the main cause of ecosystems while climate change and pollution have lower but accelerating relative impact on ecosystem services and biodiversity (IPEBS, 2019). Biodiversity and ecosystem services are complex so that this part of this thesis has the goal to concisely provide key information on status and possible trends of ecosystem services and biodiversity. It is fundamental to understand that biodiversity and ecosystem services underpins basic life support for humanity and that most nature's contributions are not fully replaceable, and some are irreplaceable (IPBES, 2019). Focus is on the state of (1) soils biodiversity, (2) biodiversity loss and species extinctions, and (3) ecosystem services.

The immediate effect of land degradation is the loss of soil biodiversity, which puts at stake critical ecosystems services. Soil hosts a large part of the world's total biodiversity, from soil bacteria and fungi, to numerous forms of fauna, such as earthworms (UNCCD, 2017). This biodiversity is essential to preserve various ecosystem functions. For illustration, biological degradation in agriculture led to a drop-in abundance of organic matter so that there is a drop in fauna abundance; in Europe, population of earthworms drops from 2 Tons per hectare to 100kg/ha in 50 years (Bourguignon, L.&C., 2015). Hence, land degradation negatively affects soil biodiversity, impairing ecosystems functions, such as decomposition processes or nutrient retention (UNCCD, 2017). Secondly, land degradations and climate change impact biodiversity as a whole so that it has been even said that humanity faces a sixth mass extinction of the Earth's species (Prince S., 2019). In fact, about 25% of species (fauna and flora) are already threatened with extinction, with an 82% decrease in the global biomass of wild mammals since prehistory (IPBES, 2019). Climate change will increase the risk of extinction for at least 20-40% of assessed species if mean global temperature increases by 1,5-2,5C° (Barnosky et al. (2013). However, extinction of species is only the last step in biodiversity loss. Critical variables of biodiversity are the richness of species, which is the number of species in an area, and the evenness, which is the measure of the relative abundance of the different species. Combining both variables (i.e: Simpson's Diversity Index), we can estimate the biodiversity loss. It has been estimated that, in 2010, the biodiversity loss globally reached 34% compared to the natural state (Brink et al., 2018). Looking at forecasts, under optimist scenarios —that are linked with possible 2°C increase scenarios —, biodiversity loss is projected to increase to 38% and 43% respectively. To illustrate this biodiversity loss, the example of acidification of oceans is interesting: When CO2 is absorbed into the ocean, it is transformed into HCO3- that have a direct effect on ocean acidification. This acidification impeaches the production of calcareous membranes of the pteropods and coccolithophores, two types of phytoplankton that are at the base of the marine biodiversity; as the result, it jeopardizes the marine biodiversity. Henceforth, both on land and in the oceans, biodiversity is said to be at risk (Bernard, 2018). Thirdly, in consequence of this biodiversity loss and in conjunction with other factors, ecosystem services are disrupted. Indeed, natural ecosystems have declined by 47% on average relative to their natural baseline (IPBES, 2019). For example, only 13% of wetlands, which protect water quality or provide wildlife habitats, are present in 2000 relatively to 1700 (IPBES, 2019). Therefore, the loss of ecosystem functions and biodiversity, which are both observable on land and at sea, deteriorate ecosystem services, such as flood protection or soil productivity, on which humans rely.

1.3.2 Food Security

Climate change and land degradation have a direct effect on food insecurity. Food security is met ''when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life'' according to the FAO (Rojas et al., 2016, pp.179). In addition to other issues linked with the distribution, consumption, and waste of food that are not covered, climate change and soils degradations pose a major threat to food security (IPCC, 2013; Gomiero, 2016; ECA, 2015; Rojas et al., 2016).

While the 'green revolution' has permitted the rose of agricultural productivity globally, it may have caused the acceleration of land degradation. Indeed, since 1961, food supply per capita has increased by more than 30% (IPCC, 2019b). According to the Gomeiro (2016), the productivity increases is due by 70% to the intensification of agriculture, based on greater use of fertilizers, pesticides, and energy, and the remaining 30% comes from new lands being used by agriculture. However, this intense utilization of soils has led to the impoverishment of soils and the degradation of the health of soils through processes previously stated, such as chemical or biological soil degradations (UNCCD, 2017). Following, Lydia & Claude Bourguignon (2015) even like to use the words "death of soils" to characterize the results of modern agricultural systems. Hence, due to land degradations, there is a reduction of both actual and potential yields. One may raise the argument that this decrease in yields may be compensated by an increase in land use. However, possibilities for expansion are now limited as the remaining possible areas are covered by tropical forests, which beneficially take up CO2, and a growing part is taken by the extension of urban areas (Gomiero, 2016; Utuk & Daniel, 2015). In addition to the effect of soil degradation, it is necessary to indicate that food insecurity will also be affected by climate change in the future. The effect will not only be the decrease of production and increase of food prices but also the drop of nutritional quality of cropland (IPCC, 2018; Servigne, 2013). Indeed, the IPCC (2019b, 5-5) revealed that "increased CO2 is projected to lower nutritional quality (e.g., wheat grown at 546-586 ppm CO2 has 5.9–12.7% less protein, 3.7–6.5% less zinc, and 5.2–7.5% less iron)".

1.3.3 Water Resources

Climate change and land degradation affect water security globally. Freshwater is a vital resource, representing only 2,5% of global water, that is unevenly distributed (USGS, 2020). Interestingly, surface freshwater sources that supply most people (lakes and rivers) represents only about 1/150th of 1% of water on earth — 93 100km3 (USGS, 2020).

Water security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UNCCD, 2017 – p.162). First, land degradation and its direct drivers have substantial negative consequences on both the quantity and quality of water available for communities and biodiversity; secondly, climate change as well will affect water resources.

Looking at the quantity of freshwater, a global analysis estimates that 43-47% of the global population will live in water stressed regions, with the highest proportion —91%— in Asia (Brink et al., 2018). Water stresses counts various causes at a regional level; however, the main causes are the growth of population, the increasing demand, as well as the loss of water retention and supply capacity of wetlands (UNCCD, 2017). Indeed, in the last century, "the world population tripled while water consumption increased six-fold" (UNCCD, 2017 – p.163). Expansion of agriculture and irrigated lands exert water shortages as irrigation accounts for 70% of water withdrawals (UNCCD, 2017). Because surface freshwater is increasingly scarce, groundwater has been increasingly exploited as it supplies today half of the world's irrigation and the need for two billion people (Brink et al., 2018). Consequently, even groundwater has been depleted by approximately 4500km^3 from 1900 to 2008 (Brink et al., 2018). In top of higher demand for freshwater, there is a deficit of water retention due to soil degradations (Brink et al., 2018). On the other hand, water quality is also affected. Indeed, both surface water and groundwater are contaminated by human and livestock wastes, by the increasing use of fertilizers and pesticides, and by heavy metals and other industrial pollutants (UNCCD, 2017). For example, the use of synthetic fertilizers has grown since the 1960s by ninefold, knowing that misapplication of such products may affect greatly water resources (UNCCD, 2017). In addition to the effect of land degradation on water resources, climate change will also affect water cycle and reduce the renewable surface water and groundwater resources in most dry subtropical regions (IPCC, 2014). In coordination with this fact, there is a greater emergence of extreme events such as rainfalls that escalate the risks of flooding (UNCCD,2017).

Therefore, climate change and land degradation may affect both water quality and water quantity so that competition for freshwater will exacerbate between urban, industrial, agricultural, and environmental water needs, under the assumptions of continuing climate change and land degradations.

1.4 Environmental Context and Effects on Human's societies

The environmental context was fundamental to study as the environment is the base of human societies. As demonstrated, climate change in coordination with land degradation may have strong effects globally. Concerning climate change alone, the planet will experience "a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions" (IPCC, 2014). Concerning land degradation, as pinpointed by José Graziano da Silva (2014), FAO Director-General, soils, though vital, are often forgotten.

Therefore, combining climate change and land degradation, this analysis introduces to the direct, negative consequences of human activities on biodiversity and ecosystem services, water quantity and quality, and food supply. While humanity relies on Earth's ecosystems, human societies seem to jeopardize them. Consequently, it raises a global risk defined by the appearance of famine, negative consequences on human health, greater possibility of climactic refugees, and, in coordination with others, a greater risk of emergence of military conflicts.

2. Energy: Fundamental Concepts and Energetic Context:

As underlined in the previous part on climate change, the energy sector is the key sector which needs to be transformed to meet the Paris Agreement. Beyond climatic reasons, it is fundamental to understand that energy is essential to our societies as the story of humanity has been substantially changed according to energy sources that have been exploited. Today, modern energy services fuel economic activities, provide comfort and mobility, and contribute to health and well-being (OECD, 2012). This section therefore focuses on (1) defining the fundamental concepts linked with the topic of 'energy' and (2) providing a concise summary of the global present and forecasted energy context.

2.1 Fundamental Concepts

Energy can be defined as the ability to modify a state or to produce work (Ngô, 2008). The measure of the international system for energy is the joule (J) which equals to [1 kg × 1 m2/s2].

However, this unit is not suited for studying human societies so that other measures will often be used, such as the kilowatt-hour (1kWh = 3,6MJ). Early in this discussion, it is useful to distinguish the energy (Watt-hour) from the power (Watt). The energy is a quantity while the power is the rate at which we use or produce energy (MacKay, 2008). Therefore, energy is the power multiplied by the amount of time. It is essential to characterize further the concept of energy so that this thesis will (1) define the concept of 'energy', (2) introduce the reader to the laws of thermodynamic, and (3) develop further the concept of 'entropy'.

What is energy? Let us focus on the main forms of energy relevant to our economy according to Narbel, Hansen & Lien (2014). (1) Mechanical Energy is energy due to masses such as potential energy, which is energy possessed by a body at rest due to forces that applied to it, or kinetic energy, which is the energy possessed by an object due to its motion. Such type of energy can be encountered in dams for hydropower, which keeps a mass of water upward so as to store potential energy. (2) Chemical energy is the amount of useful energy stored in molecules. Such energy can be met during the combustion of a material which is a chemical reaction with oxygen, releasing energy in the form of heat. (3) Electrical energy is the energy carried by the motion of electrons. (4) Nuclear energy refers to the energy stored between subatomic particles. (5) Thermal energy or heat represents an energy transfer due to mechanical energy of atoms and molecules. Last but not least, (6) electromagnetic energy is the energy carried by photons, which are massless particles defining light.

Energy can also be classified through an anthropogenic approach as either primary or secondary energy. Primary energy is the energy extracted directly from the environment such as nonrenewable energy —coal, crude oil, nuclear fuel, etc.— or renewable energy —biomass, wind, hydropower, etc.— (Demirel, 2012). Secondary energy is primary energy that has been transformed, such as electricity and fuel, to be used to meet human needs (Demirel, 2012). Adding to this classification is 'useful energy', which is the specific amount of energy that has been dedicated to provide to human a specific service, such as mobility or lighting. This conversion of energy implies the presence of a convertor, which can be a wind turbine, an engine, a human body... These conversions or transformations of energy into different form are not integral as demonstrated by figure 9 (Connaissance des Energies, 2020). Indeed, as shown in figure 9, which describes the world energy balance in 2005, only 169EJ (out of 496EJ of primary energy) is intrinsically dedicated to fulfill human needs. Understanding the physical limit of energy conversion that this exemplifies requires an explanation of the laws of thermodynamics.

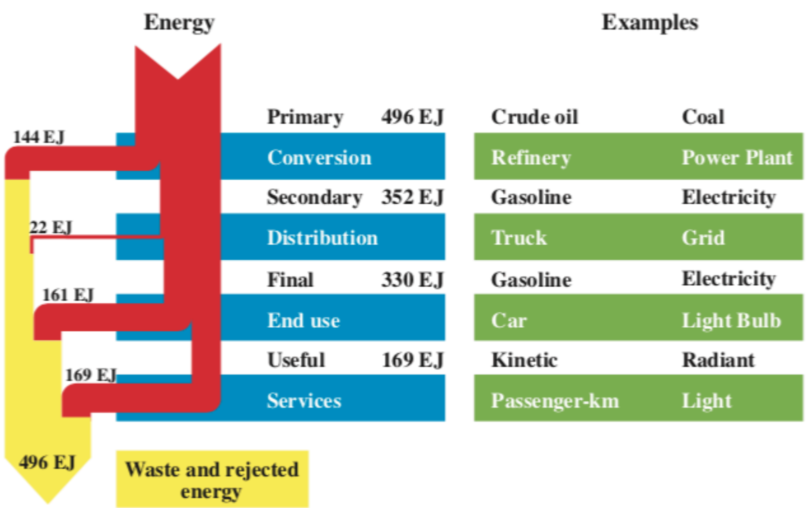

Figure 9: Global energy flows of primary to useful energy, including losses, in EJ for 2005 (GEA,2012)

Laws of thermodynamics can be explained with a classical approach or using a statistical approach; this thesis will rely mostly on the classical approach. Before defining the two fundamental laws of thermodynamics, it is essential to say that thermodynamics can be applied to materials systems. A system is simply a “set of objects, defined by a macroscopic geometrical envelope” (Schwartzentruber, 2007). A system undergoes a transformation when it passes from a state to another state, such as from electricity to light. A closed system may exchange energy but no matter while an open system exchanges both energy and matter, such as living organisms (Tame, 2019). Firstly, the discussion will only be in regard to closed systems. Within the closed system of Earth and with an anthropogenic approach, human beings rely both on the stock of primary energy such as fossils and uranium resources as well as on renewable energy flows that mainly derived from solar radiation. Quantitatively, the stock of fossil resources, including uranium, is substantially lower than the flow of renewable energy (GEA, 2012). For illustration, the upper estimation of aggregate stock (reserves and resources) of conventional fossil and uranium energy amounts to 495 560EJ compared to the 3,9 Million EJ of solar radiation that reaches Earth’s surface each year (GEA, 2012). Having understood the concept of system, laws of thermodynamics can be defined.

The first law of thermodynamics is the law of energy conservation; it (1) defines the heat as a particular form of energy, (2) defines the concept of internal energy, and finally, (3) declares that energy cannot be created nor destroyed. Firstly, this first law implies ‘heat’ to be a particular form of energy (Nolting, 2018); indeed, heat is rather referring to ‘energy being transferred’ as it is transferred between two bodies of different temperature until thermal equilibrium is reached — zeroth law of thermodynamics (Struchtrup, 2014). This energy transfer is not random but can only move from a high temperature body to a lower temperature body. Secondly, the first law of thermodynamics defines another variable, internal energy, that is the internal energy of the system. Formally, the first law states that if internal energy of a closed system changes, the energy change is equal to the sum of the heat energy supplied to or removed from the system and the work done by or on the system (Saggion, Faraldo, & Pierno, 2019). Last but not least, the first law states that energy cannot be created nor destroyed (Struchtrup, 2014). Consequently, humans create only convertors of energy to transform one form of energy into another form. For instance, humans do not create electricity, they transform energy contained into something, such as a kilogram of coal, into electricity following multiple converting processes. Accounting for this law and the development of heat engines during the 18th century explains why thermodynamics have been receiving increasing attention. Indeed, heat engines convert heat, derived from the burning of fuel, into work. In the 18th century, the question was if a perpetual motion were feasible? In other words: Is it possible to manufacture an engine in which, in the absence of friction, the amount of work equals the amount of heat supplied?

The second law of thermodynamics provides an answer by revealing the impossibility to convert heat completely into another form of energy, such as mechanical energy. Therefore, perpetual motion is infeasible in a closed system. In other words, even for an ideal, frictionless heat engine, only a fraction of the heat can be converted into mechanical energy (Saggion, Faraldo, & Pierno, 2019). In fact, the second law of thermodynamics, which was firstly enunciated by Sadit Carnot (1824) and was formulated differently through time — Clausius (1850), Boltzmann (1873)—, has remarkable consequences. Indeed, the law (1) defines a new concept called entropy, (2) sets the irreversibility of macroscopic events, and (3) sets the arrow of time. Firstly, this law sets a new measure, called entropy. Entropy can be viewed as a degree of orderliness in a system (Narbel, Hansen, & Lien, 2014); in energy, entropy can also be viewed as the degree of degradation of energy (Couix, 2015). Entropy, which is measured by comparing the final state to the initial state of a system, can only increase and cannot be destroyed (Struchtrup, 2014; Tame, 2019). In a simple formulation, greater the entropy, the greater the degree of 'disorder' of the energy and the lower its quality (Jancovici, 2018). Therefore, as the number of energy transformations is multiplying, there is an increase in entropy. The low entropy energy type is occupied by mechanical energy while the high entropy energy type is linked with low temperature thermal energy (Jancovici, 2018). The entropy is increasing until it reaches a maximum in which no work can be performed and no change in macroscopic parameter such as volume, temperature, and pressure are happening (Kümmel, 2011). This state is called thermodynamic equilibrium. In fact, closed systems left alone strive for equilibrium (Kümmel, 2011). Secondly, the second law of thermodynamics characterizes the irreversibility of some processes and sets a direction of macroscopic processes (Connaissance des Energies, 2015). Indeed, events are irreversible processes in disequilibrium situations; therefore, "all natural and technical processes we observe are irreversible processes" (Kümmel, 2011- pp.130). Natural processes are set as irreversible: why does milk spills but not unspill, why do waves break but not unbreak, why do humans grow older but never younger? (Lebowitz, 2007). The answer lies in the increase in entropy in disequilibrium process that determines the thermodynamic arrow of time (Kümmel, 2011). Hence, the second law of thermodynamics by defining the entropy, setting irreversibility of macroscopic events, and defining the arrow of time represents one of the most important law that will be referred numerous times in this thesis.

Because the laws of thermodynamics and the concept of entropy are essential for later discussions, a simpler generalization to any macroscopic transformation process is undergone:

$$\text{Energy} = \text{Exergy} + \text{Anergy}$$

"The exergy is the useful 'stuff' which can be transformed to other forms of energy while the anergy is the low quality part which cannot be further transformed" (Narbel, Hansen, & Lien, 2014, p.8). A high entropy means that the system has evolved to a thermodynamic state in which there is little exergy to dispose, unless energy is added to the system. It is valuable to specify that the amount of exergy in a transformation process depends on the type of technology used (Narbel, Hansen, & Lien, 2014). For example, early steam engines efficiency of heat to work conversion (exergy) was only of a few percent compared to up to 60% for modern combined cycle turbine/steam power plants (Struchtrup, 2014).

While previous discussions were focused on closed systems, the concept of entropy can also be generalized to living things —open systems— relying mostly on the works of Schrödinger and Prigogine, Nobel Prized of Physics (1933) and Chemistry (1977). Schrödinger (1945, pp72) states that “a living organism continually increases its entropy and thus tend to approach the dangerous state of maximum entropy”; consequently, “it can only keep from it (i.e. alive), by continually drawing from the environment negative entropy”. Negative entropy or negentropy can be thought as ‘information’ or as a factor of orderness. In other words, living organisms consume ‘information’, such as food to stay alive, but also store structural information, such as genetic material (Ayres, 2016); consequently, negative entropy structures the systems. Interestingly, the statement of Schrödinger does not contradict the second law of thermodynamics. Indeed, the price to pay for attaining a lower entropy within a system is an entropy increase in the other systems that interact with the subject system (Kümmel, 2011). In other words, the amount of negative entropy entering a system is at the cost of a greater production of entropy in its environment; so that, overall, it has been an increase of entropy. This fact led Ilya Prigogine to define ‘dissipative structures’ far from thermodynamic equilibrium. These structures maintain their integrity — growing or copying themselves—, in a disequilibrium state, by utilizing exergy supplied from the outside (Ayres, 2016). This use of exergy to ‘drawing from the environment negative entropy’ is counterbalanced in a greater way by ‘exergy destruction’ or ‘entropy production’ within the environment (Ayres, 2016). Therefore, one can understand that by applying the model of dissipative structures, the very existence of humans, as others open systems, is inevitably associated with “dissipation and increasing disorder” (Kümmel, 2011 – pp.133). It is scientifically necessary to say that while Prigogine and his colleagues have provided in a detailed language of thermodynamics processes of ‘dissipative structures, they did not succeed in providing a detailed quantitative thermodynamic explanation (Ayres, 2016).

Henceforth, referring back to figure 9, which describes the world energy balance in 2005, the laws of thermodynamics provide insights not only on why humans needs this 169 EJ of energy (dissipative structures) but also on why 327 EJ of energy have been lost throughout the multiple conversion processes. While greater information on the link between entropy and human societies will be provided in the economic part of this thesis, there is a need to understand the present and forecasted global energy context.

2.2 Energetic Context:

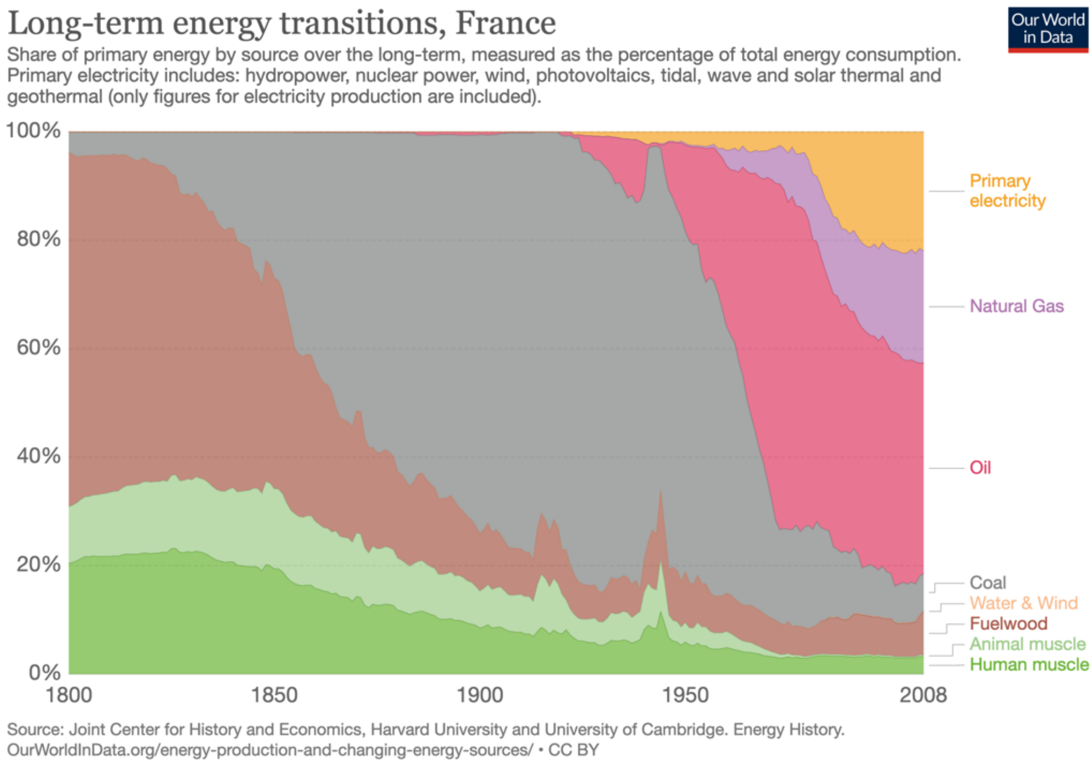

Figure 10: Long-term Energy Transitions, France (Ritchie & Roser, 2020c)

Limited by the laws of thermodynamics, humanity has seen the emergence of various convertors through history, from muscle power to heat engine. The emergence and expansion within a society of a convertor and the corresponding energy system depends on (1) the ecological and technological state as well as (2) the social structure governing the extraction and management of resources within a society (Debeir, Deléage, & Hémery, 2013). Indeed, both factors are interdependent and allow the emergence and domination of a specific energy system, which is "all components related to the production, conversion, delivery, and use of energy" (Allwood et al., 2014, pp.1261). For instance, "the Industrial Revolution has catapulted humanity onto an explosive development path, whereby, reliance on muscle power and traditional biomass was replaced mostly by fossil fuels" (GEA, 2012, pp.4). This transition is well demonstrated by figure 10 hereinabove that describes the primary energy by source for France from 1800 to 2008. The first industrial revolution (around 1830 in France) has led to the domination of coal while the second industrial revolution (1880-1914) has led to the emergence of oil and gas. This energy systems' transition can be generalized to various developed countries in Europe that experienced similar industrial revolutions according to studies led by Kander, Malanima, & Wade (2015). Therefore, constrained by the laws of thermodynamics and the stock and flow of primary energy globally, humanity has been growing based on the construction of various energy systems. Given this fact, the following paragraphs will be dedicated to providing a global picture of the present and potential future states of global energy as well as the description of the energy challenge facing humanity.

Global energy since 1800 has been substantially changed. As underlined earlier, humanity has discovered and become able to use various forms of primary energy, from coal to nuclear based energy. Interestingly, as the chart below is showing, instead of changing from one form of primary energy for another, humanity as a whole has been added the various forms of primary energy. Indeed, while at a regional scale energy transition, such as moving from coal to nuclear energy, can be observed, globally, energy sources are accumulating. Such a fact is explained mostly by people searching for higher living standards, and to a smaller extent by population growth (BP, 2019). In 2018, world primary energy demand reached 14,414Mtoe with 41% from developed economies and 35% from developing economies including China (IEA, 2019). Interestingly, Africa without South Africa represented only 5% of the total primary energy demand in 2018. (IEA, 2019). Regionally, looking at the period 2000-2018, the world can be characterized as dual with developed countries stabilizing or decreasing their consumptions of energy while developing countries demanding more and more energy, relying

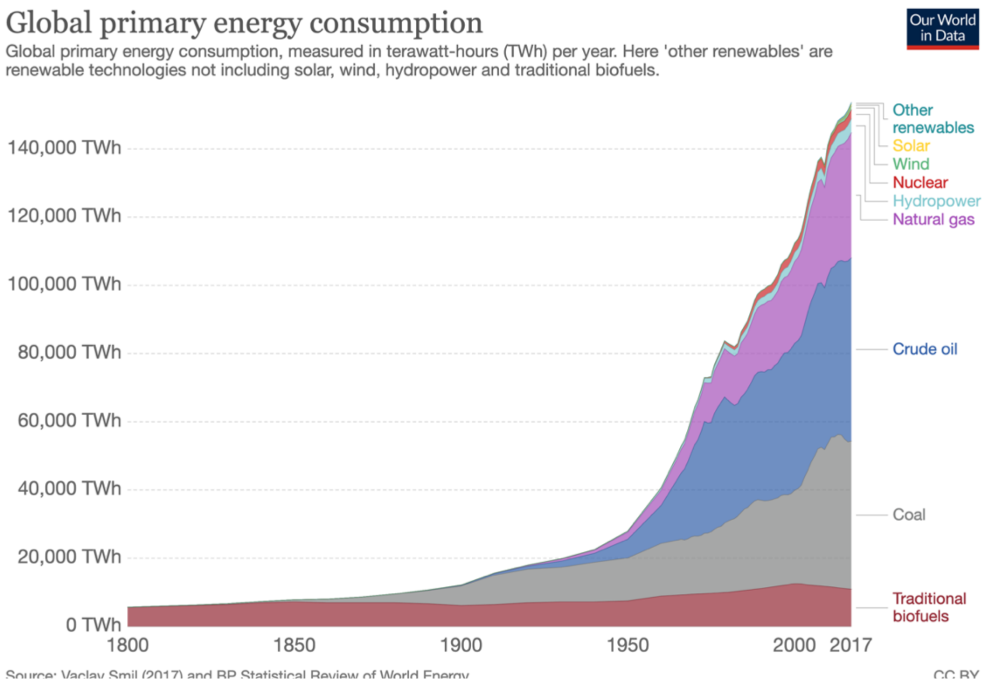

Figure 11: Global Primary Energy Consumption (Ritchie & Roser, 2020c)

mostly on fossil fuels (Appendix 1). Therefore, while one part of the world has experienced a stagnation in energy demand, the other part of the world has experienced an expansion in energy demand. Studying the type of primary energy demand globally, the share of energy from fossil fuels amounts to 81% of the total in 2018 compared to 80% in 2000 (IEA, 2019). While renewable energy from 2000 to 2018 has more than doubled globally, the world stays highly dependent on fossil fuels (IEA,2019). Before looking at the global outlook, it is essential to understand why there is such dependency on fossil fuels.

The dependency on fossils fuels may be summarized by two main characteristics which are the power as well as the intermittency and dispatchability. Firstly, human societies not only ask for a large amount of energy as input, they also ask that this energy be available on a short period of time. In other words, a key characteristic is the power. Indeed, while one liter of essence can release its 10kWh of energy content in a short amount of time, a wind turbine will need a longer time to provide the same quantity of energy. Consequently, while 3.9 Million EJ of solar radiation reaches Earth's surface each year, this energy is dispersed over a great surface; in other words, there is little power per unit of surface. Because of modern lifestyles, humanity is deeply interested in energy sources that have 'concentrated energy' as these sources can deliver a great quantity of energy in a small amount of time. Secondly, the concepts of intermittency and dispatchability have a negative effect on the use of increasing renewable energy in humans' energy systems. Intermittent sources of energy are not permanent or continuous; for example, the sun does not shine continuously and uniformly. On the other hand, the characteristics of non-dispatchability is the ability of a power plant to be turned on quickly to a desired level of output; for example, the engine of a gas power plant can be turned on when desired and the power generation can be controlled. However, wind and sun cannot be controlled. Both of these characteristics are inadequate with modern lifestyle. Greater management of energy usage or energy storage solutions must be developed to compensate for these two characteristics. Henceforth, due to the need of a great power potential as well as the characteristics of intermittency and dispatchability of renewable sources of energy, humanity became and stays highly dependent on fossil fuels.

Concerning the trends in global energy demand, this thesis relies on scenarios developed by the IEA (2019). The Stated Policies Scenario (STEPS), which reflects the scenario considering the policies that governments have put in place or announced, will be compared to the

Sustainable Development Scenario (SDS), which reflects a scenario in adequation with a 66% chance of limiting temperature rise to 1,8°C (IEA, 2019).

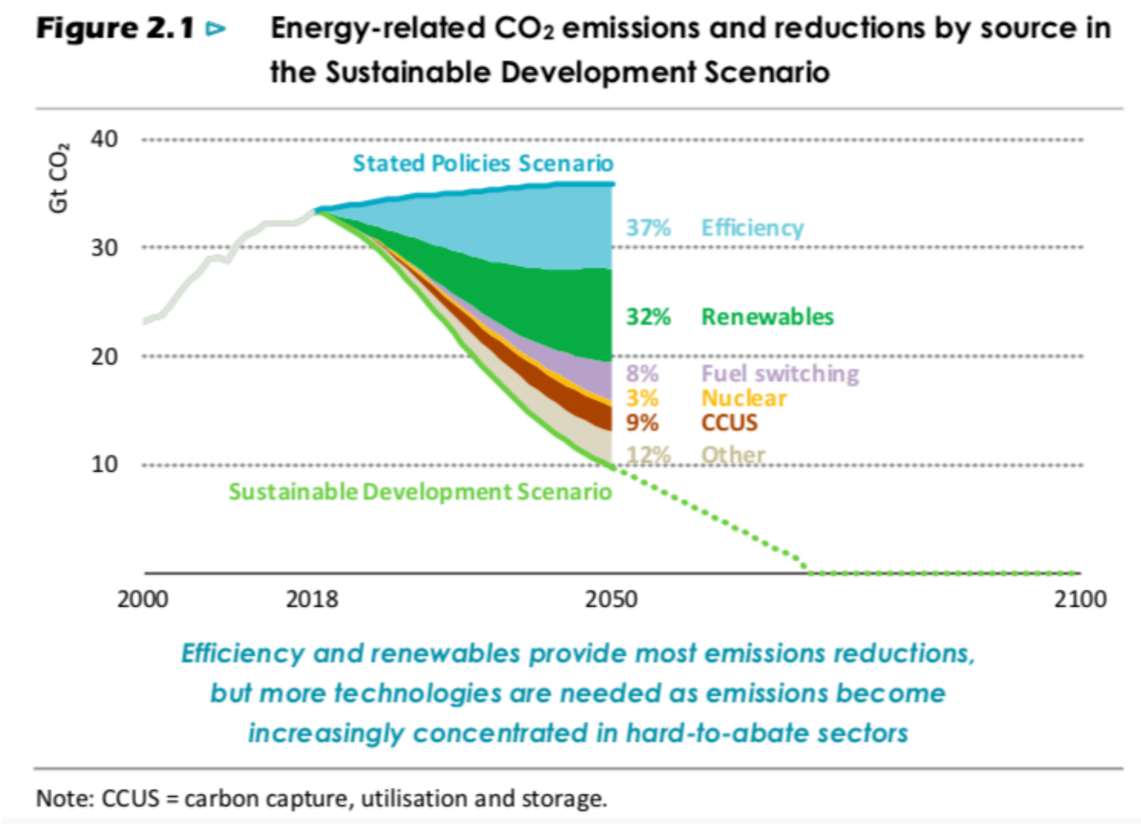

Figure 12: Energy-related CO2 emissions by scenarios (IEA,2019)

The STEPS conducts to limit temperature rise below 2,7°C or 3,2°c above pre-industrial average with a probability of 50% and 66% respectively (IEA, 2019). Therefore, a great effort should be undergone to have the chance to take the road of the SDS path. The IEA (2019) sets various methods such as the increase in energy efficiency, the transition to renewables, or the development of nuclear power in order to join the SDS path. Overall, the total primary energy demand would reach 17,723 Mtoe in 2040 for STEPS and a 13,279 Mtoe for SDS compared to the 14,314Mtoe in 2018 (IEA,2019). Regionally, the sustainable development scenario relies on a decrease in energy demand from developed economies, stagnation and small decrease in energy demand from developing countries and increase and stagnation for the rest of human economies toward 2040 (IEA, 2019). Therefore, while the global energy system is large and typically slow moving, this system must transform itself in order to reduce the annual average annual emissions from the energy sector by approximately 800Mt CO2 (IEA, 2019; GEA, 2012).

3. Conclusion: Environmental and Energetic Context

This part of this thesis was dedicated to provide a global picture of the state of the world by describing the causes and effects of climate change and land degradation as well as defining a key concepts for the rest of this thesis which are the energy and the entropy.

Climate change is driven largely by anthropogenic emissions of greenhouses gases that lead to a radiative imbalance affecting the earth's energy budget. The consequences of climate change are unprecedented and are combined with the effects of land degradation. Indeed, due to improper grazing land and cropland management, to disturbance of forests, to development of extractive industries, and finally to expansion of urban and infrastructure, our societies has caused land degradation. In coordination with climate change, land degradation distorts earth's ecosystems on which humans rely, degrade water resources, and impair global food security. Underlying causes of such consequences are often economical, technological, and institutional (Barger et al.,2018).

While the development of human society as whole has been strongly beneficial for humans, the environmental consequences that have been experienced and analyzed since past decades have been unprecedented. In fact, the experienced development rate of humans' societies has been mainly possible by the creation of an exo-skeleton (machines) based on rising primary energy demand with fossil fuels in front. In a simple way, this exo-skeleton that runs on fossil fuels has conducted great benefits for humanity but long-term, substantial, and negative consequences for the planet.

Climate change, land degradation, and other related issues facing humanity are closely linked and interdependent, so that addressing them simultaneously is imperative (GEA, 2012). Energy and its management offer a useful entry point into many of the challenges. While humanity has the resources, ingenuity, and the technologies to respond to present challenges, it lacks appropriate institutions and governance structures (GEA, 2012). Consequently, the rest of this thesis is dedicated to an economic analysis and finally to the scheme of a new possible institution that might help the resolution of present environmental challenges.

B. Biophysical Economics, Sharing Economy, and P2P Economy

1. Mainstream Economics and Biophysical economics

Economy was first defined in the Ancient Greece by Xenophon in Oeconomicus as an art of household management (Raworth, 2017). To comprehend this system, Economy has evolved into a science under the term 'Economics', or the science of economy, and gained attention mostly after the 19th century. In fact, the economy, consisting of people, machines, and natural resources, is one of the most complex systems that science has been trying to understand. In modern times, Economics has taken a central place in our society. Lord Keynes even said that "ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than it is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist." (Keynes, 1936, pp.386). Therefore, the following part of this thesis is dedicated on economics.

Economics is now commonly defined as "the science which studies human behavior as a relationship between ends and scarce means which have alternative uses" (Robbins, 1969-pp16). Economics today is mainly applied according to the neoclassical school, which is rooted in Keynesian economics with influences from diverse schools such as the Austrian School of Friedrich Hayek. Economics has been concentrated on social issues with the idea to focus on "deriving maximum well-being, as defined subjectively by each individual, and the resources available to each individual" (Hall & Klitgaard, 2018 – pp.6).

The following discussions on economics is dedicated to a summary of the tenants of neoclassical economics and the critique raised by biophysical economics. Biophysical economics attempts to reform economics without discarding all of what neoclassical economics states; it aims only at providing a more comprehensive view on the interactions between the natural world and the economy. Therefore, while the following discussion has neither the ambition nor the objective to deeply critique mainstream economics, it will underline key critiques raised by biophysical economics. Biophysical economics, which is separated from ecological economics, is a relatively new school of thoughts that can be retraced to the physiocrats (François Quesnay, 18th century), who maintained that economic value derives from land and its uses (Hall & Klitgaard). Consequently, this thesis (1) highlights essential criteria that defines neoclassical economics, (2) summaries key critiques raised by biophysical economics, and (3) details a major argument which is the link between entropy and economics.

1.1 Mainstream Economics

Mainstream economics is dedicated to the analysis of individuals, which are presumed self-interested, rational, and independent from each other (Cochet, 2015). Simply, these individuals form a system of two entities: (1) Households, which sell or rent lands, labor, natural resources, and capital to firms in exchange for something; (2) Firms, which combine factors of production in order to produce goods and services in return for something (Hall & Klitgaard, 2018). Consequently, there are two markets. The first is dedicated to the exchange of goods and services and is called the product market; the second is the factor market in which factors of production are exchanged (Hall & Klitgaard, 2018). On both markets, the interaction of supply and demand determines simultaneously equilibrium levels of price and quantity, which is said efficient and fair (Hall & Klitgaard, 2018). This mechanist view of economics led Stanley Jevons to define economics as "the mechanics of utility and self-interest" (Jevons, 1879, pp23).

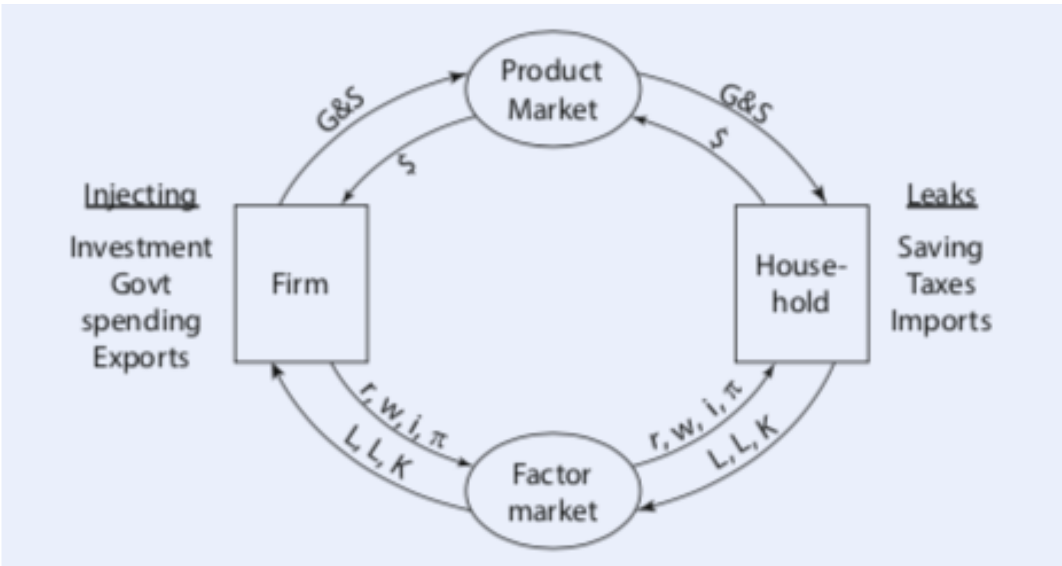

Figure 13; Circule flow with leaks and injections: *In this model the factors of production are: Land (L), Labor (L), and Capital (K). Factor payments are indicated by: Rent (r), Wages (W), Interest (i), and Profit (π). The top flow from firm to households represents Goods and Services (G&S), while the top flow from household to firm takes the form of Money ($)" (Hall & Klitgaard, 2018, pp.9)*

Two fundamental points should be raised. First, if optimality within the market is not met, interventions from the institutions are applied to the market to achieved economic equilibrium; in other words, to get the right price (Ruth, 2011). Instruments for interventions range from the imposition of taxes to monopoly deregulation. Second, according to hereinabove theory, things of value to people have a price, and things that lack value are not included in the market (Hall & Klitgaard, 2018). Well understood by economics, this system gives rise to externalities, which refer to a gain and more generally a loss associated with a market transformation (Hall & Klitgaard, 2018). For example, pollution of fine particles within urban areas is an externality of economic activities. In this vein, concerning the environment, a sub-discipline of neoclassical economics is dedicated to the study of reducing negative environmental externalities using market interventions. The discipline is named 'environmental economics'. This discipline studies interventions such as carbon taxes to reduce environmental damages from economic activities.

Another aspect of economics is the study of economic growth. Economic growth may be defined as "an increase in the production of goods and services in an economy" (Chappelow, 2019). According to the values of goods and services exchanged, in real terms, one can calculate the Gross Domestic Product (GDP). Comparison of GDP along the years, commonly defines the economic growth (Chappelow, 2019). Economic growth is an economic phenomenon that has been heavily studied and stays at the heart of economics. Based on the Cobb-Douglas function, one common view of neoclassical economics, raised by Solow in 1956, is to explain economic growth by the continuing advancement of the technical progress.

1.2 Critiques from Biophysical Economics

While biophysical economics is a relatively new discipline and is not at an affirmed theoretical and practical stage, it raises essential issues on mainstream economics (Cochet, 2015). This economics school is mainly derived from the work of Nicholas Georgescu-Roegen with his studies of thermodynamic applied to economics and from Howard T.Odum with his work on ecological systems in the 70s. The key message from biophysical economics is that economics have to balance social science with physical science by integrating stock and flow of matter and energy within the economic system (Cochet, 2015). Indeed, Hall & Klitgaard (2018, pp.68) raised that neoclassical economics (NCE) « does not recognize or reflect the fact that economic activity requires the inputs and services of a finite biophysical world which is usually diminished and degraded by that activity". Thus, major critiques of (1) derecognition of the biophysical matrix and (2) the need to refer to physical work will be studied.

On the one hand, biophysical economics' main critique is that mainstream economics does not include the biophysical matrix, in terms of laws and boundaries. Concerning laws, the NCE system depicted previously can be compared to a perpetual motion machine, without energy inputs nor entropic loss (Hall & Klitgaard, 2018). According to the laws of thermodynamics such machine cannot exist. There is a need for inputs; indeed, the economy associated with the human superorganism 'eats' exergy and resources. Consequently, Georgescu-Roegen's student, Hermann Daly (1977), criticized the conceptual model of the economic process by underlining that the circular flow of exchange value is coupled with a physical flow of matter-energy which is not circular. In the same vein, Ayres (1978) described as inconstant the closed, cyclic standard economic model; using a material-energy balance model, he emphasized that low-entropy matter and energy were entering the economic process and ultimately left it as high-entropy waste (Cleveland, 1999). Another similar approach was raised by Kümmel (2016) with its capital-labor-energy-creativity model (KLEC). An illustration to the importance of the biophysical matrix, and especially energy, for the economy is given by Rifkin (1980 – pp.123) that raises the argument that "inflation is tied directly to the depletion of our nonrenewable energy base". Verifying this statement, a study from the European Central Bank (ECB), in 2008, shows that 0,9 percentage point of the 2% inflation rate was due to energy prices (Rubene, 2018). It is relevant to see the difference between 'energy prices', ranged from renewable to nonrenewable sources, of the study from the ECB and the idea of depletion of 'nonrenewable energy base' defended by J.Rifkin. In conjunction with these critiques about the mainstream economic model, biophysical economics also criticized the absence of boundaries in the model. While neoclassical speaks about scarcity, the term refers only to relative scarcity rather than absolute scarcity, as materials are taken as substitutable (Hall & Klitgaard, 2018). Biophysical economics establishes that resources are legitimate and are a key topic in economics and that energy, or in fact exergy, is the ultimate resource (Ayres, 2016). For illustrating the dominant importance of exergy, it is interesting to compare conclusions of Barnett, H., and C. Morse (1963) to Cleveland (1991). The first, while affirming a 'new' form of resource scarcity due to problems of space and nature preservation, maintain that there was no increasing scarcity of raw materials as determined by their inflation corrected price between 1900 and 1950 in the US. Such conclusion was again supported by

Barnett in 1979 and by most economists (Hall & Klitgaard, 2018). On its counterpart, Cleveland (1991) showed that the only reason why there was no increasing scarcity within the same period in the US was explained by the decreasing price of energy; expressly, while there were decreasing concentrations and qualities of resources, the low price of energy has permitted to produce constant quality materials at the same price. Hence, according to biophysical economics, because the second law of thermodynamics maintains that Nature places limits on the amount of energy that can be withdrawn, economists should recognize at least bare boundaries to reflect the physical requirements of any economic activity (Rosa et al. 1988 ; Hall & Klitgaard, 2018).

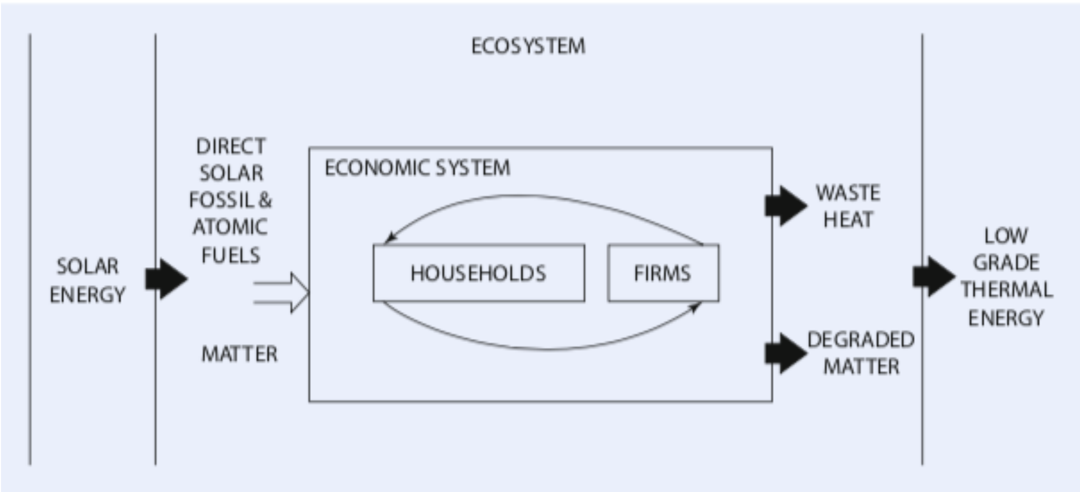

Figure 14: Circular flow with leaks and injections according to Biophysical Economics: *Addition of the basic energy and material inputs and outputs to the economic processes represented in figure.13 (Hall & Klitgaard, 2018)*

On the other hand, biophysical economics critiques that NCE does not refer to physical work. Indeed, as underlined by Cook (1971, pp.135), "the success of an industrial society, the growth of its economy, the quality of the life of its people and its impact on other societies and on the total environment are determined in large part by the quantities and the kinds of energy resources it exploits and by the efficiency of its systems for converting potential energy into work and heat". Interestingly, in addition of stressing the role of energy that is the source of the physical works for modern societies, Cook puts into relation economic growth and energy. Commonly and as shown previously, energy is not included in growth theory. In fact, according to Solow's theory of growth based on Cobb-Douglas function, technological change is the main factor of long-term economic growth. In depth, Cobb-Douglas function defined the quantity (Q) of output in function of capital (K) and labor (L), which are multiplied by a constant (A), the technological change.

$$Q = AK^{\alpha}L^{\beta}$$

In this function, the technological change (A) is independent of the two other factors and is calculated as a “residual left when the contributions of the measured factors (i.e. capital and labor) are subtracted from the growth rate of total economic output” (Hall & Klitgaard, 2018 – pp.70). For illustration, an analysis of Sollow (1957) over the period 1909-1949 in the US shows that capital-labor factors could not explain nearly 90% of the observed growth. This fact led Sollow (1957) to argue that such residual may be explained by ‘technical progress’; while admitting that it may be a ‘measure of our ignorance’ (Ayres & Warr, 2010). Continuing the illustration, in relative opposition to the technological view, Ayres & Warr (2005) tried to account for exergy used to explain US economic growth since 1900. Based on their model, they concluded that it was exergy converted to useful work that drives long-term economic growth, as no residual were present before 1975 and only 12% of the economic growth were still unexplained after 1975 when integrating the variable ‘exergy’ (Ayres & Warr, 2005). This illustration shows, therefore, the importance of exergy used as physical work to explain economic growth. Careful, Ayres and Warr do not support that technical progress does not account; however, they establish that technological change has permitted humans’ societies to use increasingly exergy converted into physical work. Globally, while other factors are surely present to explain economic growth, such as information technology, studies led by Ayres and Warr demonstrate the importance of accounting for physical work. Consequently, due to the incapacity of creating an economy that functions as a perpetual machine with exponential long term growth, Kümmel (2011) heavily argues against the assumption made by the ‘Stern Review report on the Economics of Climate Change’(2006) of a 1,9% growth rate for 200 years in the future.

Henceforth, biophysical economics major critiques pinpoint the need for neoclassical economics to integrate the biophysical matrix as well as to account further the concept of physical work within economics. According to hereinabove, one can understand that energy, and precisely exergy converted to physical work, may take a preeminent place in the discussion on economics. However, remember that “all energy conversion processes produce entropy" (Kümmel, 2011 -pp.113). Consequently, instead of speaking only about energy, it may be compelling to give more attention to the link between entropy and economics.

1.3 Focus: Entropy and Economics

Looking at the link between entropy and economics within the system considered by biophysical economics, we have low-entropy energy and material that is degraded to produce work which, in turn, produces not only low-entropy configurations of molecules (goods, capital plant…) but also information (services, technological know-how) (Ruth, 2011). However, this localized production of low-entropy and information is accompanied by a greater increase in the entropy of the surroundings (Rifkin, 1980). This idea was firstly defended by Georgescu-Roegen (1975 – pp.353), which established that "all economics process does is to transform valuable matter and energy into waste"; waste being energy and material of high entropy. In other words, referring to the 'dissipative structure' of Prigogine, human societies are, at least, compensating their own entropic degradation by continuously assimilating low entropy within their system while rejecting greater amount of higher entropy in their environment. Yet, human societies have not been compensating but accumulating low-entropy to maintain rapid economic growth; consequently, links (1) between entropy and economic processes and (2) entropy and pollution are studied.

On the one side, one can be interested in the direct link between entropy and the economic process. Rifkin (1980) argues that mainstream economics went to the other way of entropy. Indeed, while the Entropy Law establishes that all things can only be transformed from an usable to an unusable state, J.Locke, father of the Liberalism, argues that everything in Nature was waste until humans have transformed it into usable things (Rifkin, 1980). In addition to this point that elevates human societies to the rank of 'dissipative structures', remember that the Entropy Law sets only the irreversibility of our action by establishing the direction of time; it does not set the speed by which the entropy process is advancing (Rifkin, 1980). This is a crucial point in regard to the development rate experienced by human societies as we have seen that humanity has been increasingly consuming energy — mainly fossil resources. While Rifkin (1980 – pp.50) states that "the faster the energy of the world is used up, the fewer are the possible occurrences left that can unfold", it is in fact the 'exergy converted to useful work' that matter. Two consequences derive from this fact. (1) By asserting that economic value is closely related to negentropy added, the higher the negentropy added to the open system of human societies, the better will be the economic state on the short run. Because, negentropy is not a substitute to exergy but only the consequence of human societies to efficiently transform exergy into physical work, the technological progress can play a key role. Indeed, better will be the technology, greater will be the exergy converted into physical work. Concerning technologies, a combustion engine has an energetic efficiency between 10 and 50%, the natural process of photosynthesis can amount up to 6%, wind turbines cannot surpass 59%, and photovoltaic cells may attain 85% theoretically but often reach today only 15 to 20% (Hisour, 2020). In fact, Rifkin (2012 – pp.299) even stated that "for the past 30 years, we have wasted 86% of the energy we use to produce goods and services". Consequently, technological progress can play a key role in maintaining and improving the value added by the economic process while respectively maintaining or decreasing 'how fast the energy of the world is used up'. (2) Suppose now that exergy is not endlessly available and that both labor and capital depend on the availability of exergy as supported by biophysical economics, it is exergy that becomes the limiting factor of economic processes (Ayres, 2016). As stated in the first part of this thesis, energy sources can come from stock (fossil fuels) or flow (solar-based energy and Earth's heat). Less easily to use for human societies, the energy sources from flow are, to a great extent, greater in volume than energy sources from stock but represent a relatively small part of the energy used globally as shown in the first part of this thesis. The on-going use of energy source from stock is, by definition, limited to the stock available; or in other words, by using rapidly these types of energy, "the fewer are the possible occurrences left that can unfold". Henceforth, economic value creation is directly linked with 'how' and 'from what' is consumed exergy. In other words, human capacity to strive negentropy within its systems relying mostly on energy stock (fossil fuels) has been defining the underlying process of economic value creation for human societies.

Another view to analyze the link between entropy and economics is to look at the consequence of entropy production within the closed system of 'Earth'. As stated earlier, economic process comes with the release of high-entropy into the environment which affects negatively and on a long-term basis the environment. This effect is called pollution. This fact must be placed into relation with the fact that humanity has experienced a great acceleration in the use of energy since the last two centuries due to the extraction of energy stock (fossil fuels…). This growing consumption of useful energy from stock has triggered greater dissipation and disorder. In other words, pollution rate has been growing and humanity feels even today the consequences of it as enumerated in the first part of this thesis. Following, an instinctive reaction would be to say that by changing from nonrenewable sources of energy to renewable sources of energy, the pollution problem would be set. However, the problem is not about energy per say but about entropy production. Indeed, going deeper into the analysis, even in the case of increasing and massive reliance on energy sources from flow, assuming similar modern lifestyles, entropy creation into the environment will still be a reality. Therefore, according to Rifkin (2012) in its book 'the Third Industrial Revolution', a complete transition toward 'green' energy would not be a solution. Consequently, in the same book, Rifkin (2012) urges to the budgeting of energy consumption devices to meet the natural recycling rhythm that is constrained by Nature. This goal is arduous! It asks humanity to monitor the global rate of resource depletion and the pollution rate that result (Georgescu-Roegen, 1995). Yet, according to Georgescu-Roegen (1995), humanity can only prevent the unnecessary waste of resources and the unnecessary degradation of the environment without knowing exactly, even with today advanced prospective studies, the signification of the adjective 'unnecessary'. The idea raised by Georgescu-Roegen is, then, interesting as it raises the concept that future needs and future technological state are hard to predict. Last, for more completeness, while this thesis associates a number of time Georgecu-Roegen and Rifkin, it is important to say that Rifkin's view pull away from the vision of Georgecu-Roegen but get closer to the view of Daly (1977), who defends a steady-state economics paradigm (SSE). SSE is defined as "an economy with constant stock of people and artefacts, maintained at some desired, sufficient levels by low rates of maintenance 'throughput', that is, by the lowest feasible flows of matters and energy from the first stage of production to the last stage of consumption" (Daly, 1977 – pp.17).

Henceforth, studying the link between entropy and economics opens new ways of analyzing economics. Only looking at entropy, it seems that an economic process is, on the one hand, bounded internally by its capacity to extract, transform, and use energy in terms of exergy converted to physical work. This physical work permits to produce low-entropy configurations of molecules (goods…) and information (technological know-how…) in the economy of human societies. On the other hand, the economic process may be bounded externally due to the long-term effects of the released of high-entropy energy and matter into the environment, called pollution.

Consequently, while "dissipation and increasing disorder are inevitably associated with our very existence" (Kümmel, 2011 – pp.133), potential paths do not all lead to increasing disorder at increasing rate. Indeed, modern times have led per capita energy use per day to grow from

30kWh in A.D 1400 globally to 76kWh in the US in 1850 and to 216 kWh in 2015 in the US; however, other paths may exist for increasing disorder at lower rates. This possibility conducts Rifkin (1980) to state that "on the whole, Homo Sapiens should move from a colonizing state (maximizing the flow of energy) to a climactic phase (minimizing flow-through of energy). In other words, human societies have to pursue the aim to rationalize its actions in (1) minimizing the use of energy and (2) maximizing the efficiency of energy convertors in order to (1) maximize the localized production of low entropy products and information to the benefits of short term economic processes while (2) minimizing the release of high-entropy matter and energy into the environment to reduce long term effects on economic processes.

1.4 Economics Conclusion

This section on economics had the objective to provide the reader an introduction to this thesis holds by the biophysical school of thoughts and insights to the link between entropy and economics. Greater information and in depth biophysical economic studies were led by Hall & Klitgaard (2018), Ayres (2016), and Kümmel (2011); but, because "ideas of economist are more powerful that it is commonly understood", it was important to overview economic theories that not only takes into account the social sphere but also the biophysical sphere (Keynes, 1936, pp.386). The idea that humanity should move to a climactic phase, considering entropy, is an interesting, valuable, and defended paradigm that the present thesis upholds.

In order to do the transition to the two other components that form this section, which is the study of the state of the sharing economy and the emergence of the peer-to-peer economy, we will cite at length Jeremy Rifkin's words from 'The Third Industrial Revolution'.

> *"We are witnessing the emergence of a new scientific vision of the world, whose premises and postulates are more compatible with the networked ways of thinking that underpin an economic model of the third industrial revolution. Old science sees Nature as a set of objects; new science sees it as a set of relationships. The old science is characterized by detachment, expropriation of resources, dissection and reductionism; the new science is defined by commitment, replenishment, integration and holism […] The old science wants power over Nature; the new science wants partnership with Nature. (Rifkin, 2012 -pp.318, Translated with www.DeepL.com)*

2. Sharing Economy and P2P Economy

While this thesis has been so far focusing on scientific and economic concepts, this thesis will be dedicated to the study of two trends that characterized in part what Rifkin names ‘the age of access’. These trends are emerging mostly in modern societies and are linked with new (or reborn) cultural values. Consequently, there is then the integration of cultural values within this thesis, which was sporadically raised throughout this thesis and underlined through the citation of Rifkin but will take a greater importance in the following part of this thesis. Indeed, the rest of this thesis is rooted in the ‘new science’ view, to restate Rifkin. Moreover, the focus of this thesis narrows to the observations of trends that are mostly observable in Europe, North America, and others advanced economies.

The age of access is led by the growing importance of networks linked with a logic that avoids long-term ownership in favor of short-term access (Rifkin, 2000). Consequently, the second part of this second section of this thesis is dedicated to define (1) the sharing economy and the Peer-to-Peer (P2P) economy, (2) the status and critique of the sharing economy, and finally, (3) the state and challenges ahead for the development of the P2P economy.

2.1 Definitions of Concepts

For a decade the sharing economy and the peer-to-peer economy are two trends that partly define the new economy of modern societies. It is, therefore, essential to define these two trends, identify the causes of their emergence, and outline their effects on the economy.

On the one side, the Sharing Economy or Collaborative Economy may have various definitions, therefore, this thesis will only account definition of the European Commission: “A collaborative economy builds on business models, where private individuals (service providers) offer their unused goods, services or resources, with or without compensation, to other private individuals or businesses (customer) via an online collaborative platform, which facilitates contacts and transactions between them.” (EU, 2017, pp.10). This definition has the benefits to stress the characteristic of the sharing economy that relies on online platforms, which become a two-sided market in the sense of Rochet and Tirole (2003). Because the success of platforms depends on reaching a critical mass of users on both sides, various determinants should be met by platforms to hope to succeed (Evans, 2009). The determinants are the level of confidence developed by the platforms, the geographic surroundings of potential users, age and education level of the population, and finally, the equipment and numerical skills of the population (Malardé, Pénard, 2019). All of these determinants may influence the success of attaining a critical mass of users in order for the platform to ensure sharing economy practices to prosper. Illustrations of platforms of the sharing economy within modern societies are named AirBnb, Blablacar, Koko, ShareyourMeal… Because this thesis excludes platforms in which transactions entail a change of ownership, platforms such as Ebay or Leboncoin are excluded. On the other side, the peer-to-peer economy is "an intersubjective dynamic characteristic of distributed networks" (Bauwens & Sussan, 2005). In fact, the peer-to-peer economy takes its root within the computer science area that has seen the emergence of open-source software. P2P economy is not well defined as its boundaries may be characterized as 'blurry'. Consequently, this thesis will rely on the view of M.Bauwens that created the P2P foundation and stresses that the peer-to-peer economy is linked with the production of shared value (Roussel, 2015). Therefore, this thesis will distinguish the peer-to-peer economy to the sharing economy, which may rely on peer-to-peer models. The P2P economy processes are associated with the production of value (peer production), are self-governed (peer governance), and does not have profit as the main goal but the value in use (Bauwens & Sussan, 2005). The P2P processes are mostly illustrated within the sphere of nonmaterial goods and services such as all the family of the Wiki, Enspiral (initially in New-Zealand), or Sensoria (initially in Canada). On the material and service side, large-scale P2P economy processes have marginally appeared due to challenges to overcome, which will be explained later.

The strong and sustain growth of the sharing economy as well as the emergence of the P2P economy are due to a bundle of factors according to Goudin (2016) and Basselier, Langenus, and Walravens (2018): (1) The technological development — and the advance of digitization— is the greatest force that facilitates access to various services and goods for everyone. (2) The evolving economic behavior, in the wake of the financial crisis of 2008, has been changing due to significant and durable impact on household purchasing power. Consequently, the sharing economy arise as a mean to save money while permitting access to various goods and services. (3) The urbanization has been also a cause for the rise of the sharing economy; indeed, the high density of population favors the emergence of a community. (4) Last but not least, the societal and environmental factors are predominant. Cultural values and social norms are evolving toward increasing environmental considerations, which are partly defined by less consumption and increasing exchange. These four causes explain the development of the sharing economy in the advanced economies. A study made by PWC (2016) forecast in Europe that the revenues from the sharing platforms may attain $85billion in 2025 compared to $4 billion in 2016 and $1 billion in 2013. However, the rapid development of the sharing economy comes with downside, which advanced economies have been experiencing according to Goudin (2016) and Basselier, Langenus, and Walravens (2018): (1) Traditional players of the economy have been suffering from the emergence of the sharing economy, as illustrated by the case of entities part of the hotel industry against AirBnB. Indeed, the sharing economy players often substitute rather than add to the offers of traditional players. (2) Taxation is another issue that is linked with the sharing economy platforms. Because taxation is playing a crucial role into the conduct of the national, regional, and municipal institutions, the amputated revenue represents a threat to these institutions. (3) Another issue pertaining to the social dimension is the reconsideration of the idea of 'work'. Indeed, in traditional economy, 'work' is well defined and is linked with obligations and rights both for the employee and employer. However, the sharing economy pushes to rethink the salary system and to determine other social protection. (4) Another aspect of the sharing economy is its impact on the environment. While considered overall as beneficial, studies of ADEME (2012) and Demailly & Novel (2014) reveal that the sharing economy may have negative feedback effects. For example, they raised that a different consumption may not necessarily mean the reduction of the consumption.

2.2 Sharing Economy: State and Critique

Sharing economy is increasingly present in advanced economies but tends to walk away from its initial vision. After showing this fact, this thesis will focus on the environmental consequences of the sharing economy by relying on a study from France led by the French public organization ADEME et al. (2016).

In the EU-28 in 2016 the size of the sharing economy was estimated to 26,5 billion euros and represented 394000 jobs or 0,15% of the total employment in EU-28 (EU, 2017). The major sectors of the sharing are represented by the finance, accommodation, online skills, and transportation sectors (EU, 2017). The level of development of the sharing economy varies a lot through the European countries, with large markets in France, the UK, Poland, Spain, Germany, Italy, Denmark representing 80% of the total collaborative revenues in 2016 in Europe (EU, 2017). The sharing economy is based on activities of the youngest generations, as illustrated by the case of France in which where a large majority of users are younger than 35-year-old (PIPAME, 2016). Moreover, the sharing economy is expected to continue to increase at 35% yearly until 2025 (PWC, 2016). This development of the collaborative economy is not only present in Europe but is a worldwide trend. Indeed, according to the Nielsen report (2014) relative to 60 countries, the concept of the sharing economy attracts people. It turns out that 68% of global respondents affirm that they are willing to share their own goods and 66% are willing to use or rent from others. Therefore, it seems that the collaborative economy, by valuing individual autonomy and contributing to creation communities, is a profound trend within the economy.

However, the sharing economy tends to walk away from its initial vision. Indeed, the sharing economy appeared based on a vision of inclusivity and sustainability; yet, the dominant online platforms are far away from this vision. Bauwens and Kostakis (2017) define the dominant platforms of the sharing economy, such as AirbnB, as based on an 'extractive model'. Theses platforms extract values from transactions passed through their platforms without reinvesting the value within the community. Therefore, there is a global tendency of the sharing economy to be linked with a 'winner takes it all' combined with a structure of rent-geared-to-own capitalism (PIPAME, 2016). Moreover, it is valuable to stress that the dominant platforms are focusing on the upper-middle class rather than the lower income households (Crespo & Olalla, 2019). The concept of 'sharing' is then only becoming a "marketing claim" according to Bauwens and Kostakis (2017, pp.60) or an "oxymoron" according to Crespo and Olalla (2019). In other words, while the sharing economy may have huge potential to help people in meeting their needs and creating resilient communities, these 'extractive models' that dominate the market does not, or only marginally, unlock the potential benefits of the sharing economy. Relatively to this critique, the BSR organization and the Rockefeller Foundation (2016) calls for increasing collaboration and inclusivity that can be attempted around three main axes: (1) Creation of higher quality employment opportunities; (2) Greater access to goods and services to permit individuals to increase their well-being as well as to unlock their potential; (3) Higher investments made within the community to develop their resilience.

Finally, in addition to the social side, the rise of the sharing economy may provide solutions to the environmental crisis. Indeed, the sharing economy is intrinsically linked with the idea of optimization of the use of a resource and publicly raised as a great action for sustainable development; however, the sharing economy opens a material desire of consumers by giving them access to a greater number of goods that can be consumed (Moati, 2009). Then, does the sharing economy have a beneficial consequence on the environment and to which degree? The report from ADEME et al. (2016) provides valuable information on the impact tendency of practices of the sharing economy in regard to the environment. To state, following discussed numbers are the impact change rate relative to conventional practices (hotel, buying, not using…). Concerning mobility practices, carpooling for short distances, and especially concerning trips work-home, are considered 'pertinent' for the environment as it reduces by 49% the impact on the warming of the climate. On the other hand, long distance carpooling might be considered positive only under certain conditions. In fact, there is the consideration of other modes of transportation and the positive feedback effect of an increase demand for mobility which may negatively impact this practice. Concerning practices relative to real estate assets, the effect of making available its good has relatively fewer impacts than the availability of a hotel room, at the equivalent surface area. For greater surface area, sharing economy practices have a relative slight positive environmental effect compared to a hotel room. However, these findings depend heavily on the energy mix of the host country. In addition, the report raised that sharing economy may increase the chance of travelling; and consequently, the additional transport demand may negatively impact the benefits of sharing economy direct practices. Looking at collocation, outcomes are always positive for the environment, decreasing by 24% the energy consumption and reducing by the same rate the effect on climate. Concerning food items, sharing economy practices may have better environmental impacts relatively to traditional practices with a decrease of 89% regarding resource depletion. Yet, taking account transport needs, depending on the choice of the consumer for ensuring its mobility, sharing economy food practices may be negatively influenced and evenly inverted (Servigne, 2013). Concerning material goods, sharing economy practices may have great impacts by increasing the reuse rate of goods. However, always according to the report, the modality of exchange may strongly reduce the benefit of the sharing economy practices. For example, taking into account exchange modality, exchanging its drill or lawnmower may increase by 160% the impact on climate warming relatively to keeping the good at home and mostly unused. Local exchanges should be then privileged. Finally, the influence of technology that permits sharing economy practices only negligibly affects the benefits of the sharing economy on the environment. Consequently, according to ADEME et al. (2016), while factors of exchange modality and feedback effects must be accounted, the sharing economy offers, overall, a potential solution for the environmental crisis. In the future, the greatest benefits will come from mobility practices and the reuse of goods; yet, analysis of others sharing practices may not provide sufficient robust conclusions (ADEME, 2016).

Overall, the sharing economy is increasing globally and at a great rate in modern economies; however, dominant practices are far away from the sharing economy's initial vision of inclusivity and sustainability. In an environmental perspective, while the sharing economy is providing some solutions to the environmental crisis, they stay yet minimal in importance relative to other trends, such as the technological change and the social evolution (ADEME, 2016). In this vein, Demailly and Novel (2014) underlined that alone the sharing economy is not sustainable; there is a need to rely further on eco-designed goods of high quality, to optimize transports of goods, and to have the capacity to change individuals' lifestyles. Consequently, the sharing economy is appearing as a positive trend with environmental effects that may be decupled if and only if profound changes are appearing within modern societies. In this vein, the P2P economy, as defined in this thesis, may provide powerful combined effects.

2.3 P2P Economy: State, Challenges, and Potential Future

P2P Economy, as defined in this thesis, is distinct from the sharing economy as it suggests the presence of an auto-organization of interconnected individuals that not only mutualize production resources but also produce shared value (Bauwens & Kostakis, 2017). Yochai Benkler (2006), formally, called it 'commons-based peer production' (CBPP). After defining succinctly, the state of the P2P economy, this thesis is dedicated to the analysis of the challenges and the potential development of the CBPP organizations.

P2P economy processes lie on a threshold of concepts. The first is the concept of 'productive community', which refers to the aggregation of contributors on a certain project; the second is the 'entrepreneurial partnership' which refers to the goal of producing value; the third is the idea of 'welfare association' which refers to institutions that govern and support collaboration (Bauwens & Kostakis, 2017). Based on this threshold of concepts, 'generative models' of the P2P economy have been appearing on a global (Wikipedia) or at a local (time bank initiatives) scale. By 'generative models', Bauwens and Kostakis (2017) describe organizations that work for creating and protecting commons as well as increasing the resilience of their community (Bauwens & Kostakis, 2017). But, where could we find P2P economic practices? On one side, global initiatives in regard to immaterial goods are the most widespread form pertaining to the P2P economy. For example, the family of the Wiki or the open-source software is a production of the P2P economy that is common at a global scale. Their productions were due to voluntary actions of individuals within a community; indeed, everyone is free to contribute to Wikipedia. The strong reliance of P2P economy within the immaterial sphere is due to the ease to work online on an immaterial project, the characteristics of production that are non-rivals, and the altruist motivation of contributors (Bacache-Beauvallet and Cagé, 2016). The last characteristic must be criticized as the quality 'altruist' is not the explaining component that leads individuals to cooperate; indeed, the study from Benkler et al. (2014) shows higher correlation of contributions with reputation (social image). On the other side, local initiatives are springing, such as time banking initiatives, resilience-building practices, city in transition movements. These initiatives are often based on reciprocity, which is needed to incite cooperative actions (Bacache-Beauvallet and Cagé, 2016). While these flourishing local initiatives create values for communities, they are characterized, for a vast majority, by none or low global interconnections; therefore, they produce only marginally global commons (Bauwens & Kostakis, 2017). This fact led Bauwens and Kostakis (2017) to define these local actions as positive but not sufficient for responding to the environmental crisis. Still, on an environmental perspective, local initiatives are linked with positive effects. In order to illustrate it, because, to the knowledge of the author, no regional or global analysis have appeared in the literature, only examples will be used to illustrate these positive effects regarding the environment. Two illustrations will be used which are initiatives within the city of Ghent, Belgium, and an initiative in France. The city of Ghent has been experiencing more than 500 common urban projects that mostly function on P2P models (Bauwens and Onzia, 2017). In terms of mobility, with the help of two associations, the city of Ghent created a car-pooling initiative that has reduced by 80% environmental externalities (energy consumption, traffic, pollution) (Barbazan, 2020). Interestingly, this initiative does not create any negative environmental feedback effects according to M.Bauwens. Another illustration is the case of the French association 'Terre de Liens' that buys lands and donates them to farmers applying organic practices. As the number of organic farming is increasing in the region, the need to depollute water from nitrate and pesticide is decreasing, so that both the civil society and the regional government are saving money according to an analysis focusing on France by

Sautereau and Benoit (2016). In fact, the analysis evaluates in France the extra cost of pollution due to conventional modern farming practices to 839-1139 million euros per year for the civil society and to 100-150 million euros per year for the regional governments (Sautereau & Benoit, 2016). Both examples are great illustrations of local P2P economy practices that lead to direct or indirect production of local commons, which have positive effects on the environment. Henceforth, based on a 'generative model', P2P economy practices are present both at a local and global scales and seems to develop further (Appendix 2).

However, the P2P economy is challenged for growing in the material sphere. Indeed, when describing P2P economy Bauwens and Sussan (2005 – pp.207) are stated that "where production is purely material and where capital investment plays a major role, the extension of the P2P mode seems difficult, if not impossible". In top of the cultural challenge of accepting 'new science' views, the dominant cause of this difficulty is due to the donation system on which P2P economy relies, that pushes for the exhibition of the free rider effect. In fact, Adar and Huberman (2000) shows that 70% of users of Gnutella, a platform based on P2P models to ease the share of files, are free riding. First, overall, when goods are non-exclusive on the offer view and non-rival on the demand view, the P2P economy is functioning well even in the case of free riding as exemplified by Wikipedia (Bacache-Beauvallet & Cagé, 2016). Second, when the goods are non-exhaustive and rivals, the P2P model may still function for immaterial goods but need incitation for greater collaboration. For example, imagine the situation in which online files are rivals, as the bandwidth allowing the download of files is not unlimited: Potential incitation to reduce free riding may focus on the mechanism of reciprocity or reputational mechanism. Concerning reciprocity, in the immaterial sphere, for instance, the P2P file-sharing software eMule awards collaborative users by reducing their download time (Bacache-Beauvallet & Cagé, 2016). Concerning reputational mechanisms, some platforms set full transparence so that peers could rate or at least see past behaviors of other peers to analyze their attitude in regard of collaboration with the community. The question is now in respect to the material sphere for rival goods: Does mechanisms that have been applied in the immaterial sphere may run in the material sphere? It seems that Bauwens and Kostakis (2017) have changed their views about the impossibility of extension of P2P models within the purely material production of value. Indeed, accepting the need for reciprocity mechanisms applied to CBPP organizations opens the potential for P2P economy practices within the material sphere. To illustrate this possibility, this thesis relies on the case of Sensorica, a Canadian based firm. Sensorica defines itself as an open value network (OVN)

and a pilot project for commons-based peer production applied to hardware, designed to operate at large scale. In other words, it is an open network of freelancers that co-manage and coordinate their work using IT tools and some special governance (Brastaviceanu, Laughlin, & Anastassiou, 2019). One project that succeeded the production of a material-based good was the 'characterization of photovoltaic material project'. In other words, this project, requested by a professor for Queen's University, led to the building of an engine that permits, among other applications, photovoltaic cells to follow sun light. Therefore, Sensorica brings great hopes for the transition of the P2P economy within the material-production sphere.
Hence, the P2P economy may develop in the coming years; yet, it is facing a dual challenge that is: (1) A cultural change within modern societies to accept these new kinds of organizations based on generative models. In other words, while this cultural change is not precisely defined in this thesis as discussions relative to values is out of the scope of this thesis, the dominance of the 'extractive models' in regard to 'generative model' would be an interesting indicator of the state of cultural values shared among individuals. Consequently, human societies should increasingly incorporate the values linked with the 'new science' of Rifkin in order for the P2P economy to expand. (2) Creation of organizational structures and mechanisms to incite and safeguard collaboration for production of shared value — reducing appearance of free riding.

With both challenges in mind, one potential development of P2P economy is the creation of (a) trans-local and trans-national organizations and (b) open cooperatives (c) that takes States has partners in order to succeed social and environmental goal. Firstly, aside with the continuing trend of emergence of CBPP organizations at the local and global scale, Bauwens and Kostakis (2017) urge for a rapid emergence of CBPP trans-local and trans-national structures such as Sensorica. These new kinds of structures would not only allow the civil society to create commons at the local level but also at the global level. In order to achieve this creation of shared value, Bauwens and Kostakis (2017) suggest combining non-reciprocal mechanisms in the immaterial sphere with reciprocal mechanisms in the material, production sphere. Formally, Ramos et al. (2017) define this combination as 'cosmolocalism' in which there is the presence of global digital commons and the capacity for local manufacturing. Secondly, on the contrary of Sensorica's organization, which is an open network of free-lancers without any legal entity, Bauwens and Kostakis (2017) are proposing the development of 'open cooperative'. These structures will be "entities that would be legally and statutorily bound to the creation of common and open resources" (Bauwens and Kostakis, 2017 - pp.76).

All these structures will have a sole objective to enhance the capacity and autonomy of citizens while reinforcing the resilience of communities. Thirdly, an enduring question may still tick over in the mind: What would be the relationships of these organization with the markets and the State? Concerning the market, Bauwens, Kostakis, & Pazaitis (2019) raised the possibility of emergence of 'commons-oriented entrepreneurial coalitions' that create values for the market while gaining a profit or livelihoods. As stated previously, this type of coalition will be at the side of 'productive communities' and 'infrastructural organizations' in order to form an ecosystem of organizations. For example, in the immaterial sphere, 'Linux' represents the 'productive communities' in which all individuals may cooperate; the Linux Foundation represents the for-benefit foundation that support the infrastructure for securing cooperation; and, the 'Linux Professional Institute' represents an illustration of commons-oriented entrepreneurial coalitions. Concerning the State and its associated institutions, the thinkers of the P2P economy suggest the evolution of the State toward a form of 'Partnering-State' (Bauwens & Sussan, 2005). In this vein, the State not only ensure its redistributionist welfare role but also become a partner for the emergence of the three structures raised previously and support the creation of value by the civil society (Bauwens, Kostakis, & Pazaitis, 2019). One can imagine that the State, by supporting the creativity autonomy of its redistributive citizens, may be partly alleviated from its role of redistributor as the bottom income would be less in needs. In fact, the development of CBPP organizations advocates for the rise of a triangular social conception, allowing avoidance of an all-market, all-State, or even an all P2P economy (Bauwens & Sussan, 2005). Following, the project 'Cosmolocalism', started in January 2019, will study ways, based on P2P economy, to create a sustainable economy through the commons.

Henceforth, even if P2P processes are well diffused within the economy as exemplified by IBM and other companies that rely on P2P models to increase their efficacy, P2P economy as defined in this thesis is at its early stage. While CBPP organizations raise great hopes for the production and management of commons by the civil society, there are a number of challenges that must be resolved. Indeed, in addition to the need for a cultural change, which is the acceptance of the 'new science', there is the need to improve organizational structures and mechanisms that incite and safeguard collaboration. Even in the presence of these dual challenges, the P2P economy is still emerging. Interestingly, P2P economy does not raise itself as a destructive force nor as a substitute system but as a complementary model that adds to the system in place. On the environmental perspective, the emergence of P2P economy processes is associated with potential strong benefits as illustrated by various examples through the world, including the cases of the city of Ghent or the French initiative of the association 'Terre de Liens'.

3. Conclusion of on Economics and Economic trends

This second part of this thesis was dedicated to economics and economic trends that are perceived globally, and to a greater extent in advanced economies.

The science of economy, or economics, is a complex science whose theories have deep effects on individuals. Indeed, economics influence every individuals' behaviors within human societies; yet, cultural values may influence economics. Neoclassical economics, today's mainstream economics, are upheld by all international organizations such as the International Monetary Fund (IMF). Mainstream economics, which have the objective to derive maximum well-being to each individual, are based on a powerful mechanical model. While great short-term benefits for human societies have emerged from applying this model, long term and negative effects on the environment have been and will be experienced. Consequently, biophysical economics question the foundations of the model by interrogating the notion of perpetual motion machine and the indefinite growth defended by the neoclassical model. In this vein, biophysical economics urge to apply the laws of thermodynamics and integrate the biophysical matrix within the neoclassical model. One valuable insight of biophysical economics is the accentuation on the link between economics and entropy. Following the works of Georgecu-Roegen, Rifkin, and others, it has been raised that the short-term benefits of the economic processes by integrating negentropy within the system were at the cost of high-entropy creation outside the economic system. This high-entropy production can be defined as pollution, which is the trigger of the global environmental crisis. Therefore, J.Rifkin advocates that human societies pass from a colonizing state (maximizing the flow of energy) to a climactic phase (minimizing flow-through of energy) in order to answer social humans needs while minimizing long term effects on the environment.

This transition will be a considerable challenge facing humanity, and particularly advanced societies which rely to a greater extent on a high flow of energy. This transition is today highly regarded. Potential leveraged actions are linked with technological change and with a change in cultural values. The importance of technological change is commonly accepted, but certainly too much defended. Indeed, technological progress may permit the creation of value for humans while minimizing the flow-through of energy; however, as supported by the United Nation (UNCDD, 2017 – pp.32) the belief that technological progress could overcome any limitations by Nature should be criticized. Consequently, technological progress seems to represent only a part of the solution. A second leverage, driven by a cultural change toward Rifkin's 'new science', is the evolution of production and consumption habits of individuals, and specifically habits of individuals of developed and developing countries. The sharing economy and the P2P economy represent two key elements defining this leverage.

The sharing economy, while being a relative powerful trend, did not embrace its first vision. Indeed, dominant practices of the sharing economy are based on 'extractive models' that does not, or only marginally, benefit communities. Overall, the sharing economy is, in belief, a great solution to the environmental crisis; but, as practiced today, it affects positively the environment only marginally. On the other hand, the P2P economy, as defined in this thesis, is well spread in the immaterial sphere and is emerging in the material world. From Wikipedia to local actions such as time banking practices, P2P economy models open news way of interacting and producing value for communities. However, while P2P economy-based initiatives have strong positive environmental effects due to initiatives led at the local level, greater potential benefits in regard to the environment may appear if P2P economy were expanding itself into the material world at the global scale. Indeed, common-based peer production (CBPP) may produce goods and services at lower thermodynamic cost than capitalist production models according to Piques, Rizos, & Bauwens (2017).

Hence, in order to derive all the potential benefits of the sharing economy, one can imagine the combination of the P2P economy and the Sharing Economy in order to help the transition from the colonizing state of modern societies to a potential climactic phase. Indeed, combination of both concepts may not only lead to mutualization of goods and resources unused, keeping private property, but also lead to the achievement of production of commons at a lower entropic cost. The combination of the P2P economy models and the sharing economy is at the root of the idea developed in the last section of this thesis.

C. LaFed, The Federation of the Shared

This thesis has been dedicated to various topics that may not, at first sight, be interlinked. Therefore, this part has the objective to link them through the description of a new institution that uses P2P economy and sharing economy models. The institution should apply a biophysical economics' vision in order to help responding to the environmental crisis.

To summarize, the first part of this thesis demonstrated that humanity was facing an unprecedented environmental crisis led by climate change and land degradation. In an anthropocentric view, this environmental crisis will affect deeply our societies due to the deterioration of ecosystem services, impairment of water provision, and risk of food insecurity. Secondly, this thesis analyzed the link between entropy and economics and shows that humanity should transit from a colonizing state to a climactic phase in order to hope to alleviate our societies from the environmental risks while answering humans' social needs. This thesis demonstrated that economics were at the center of this transition. Last, this thesis introduced the reader to the sharing economy and the P2P economy as two trends that may provide tools for this transition. However, it has been shown that the first has diverted from its initial vision and the second was facing challenges to continue its development.

How can economics succeed the setup of the transition towards a climactic phase? As stated by the International Institute for Applied Systems Analysis, while humanity has the resources, ingenuity, and technologies to proceed to such transition, it lacks appropriate institutions and governance structures (GEA, 2012). Then, rooted in the sharing economy and the P2P economy, the idea supported by this thesis is the creation of a new organization, called 'The Federation of the Shared' (LaFed), which has the objective to help answering the environmental crisis. Shortly, LaFed would be an ecosystem of structures that facilitate exchanges between individuals and provide the opportunity to create shared values globally at low thermodynamic costs.

Before going further, it is essential to say that this last part of this thesis is highly subjective and only introduces the reader to a potential institution that might be beneficial in the view of the author. Consequently, I invite the reader to see this part as a 'bottle into the sea' containing the description of an idea of an institution. Firstly, this thesis will concentrate itself at defining the history, mission, and objectives of the idea of the new organization, as well as describing the overall operation of LaFed. Secondly, this thesis will describe thoroughly the operations of LaFed. Indeed, this thesis (1) describes IT tools that may permit such organization to operate, (2) defines the concept of 'collective intelligence' and sociocracy that will oversee interactions between members of the organization, (3) and details the potential environmental benefits of such institution.

1. History, Mission, Objectives, and Overall Operations of 'LaFed'.

1.1 History of the Idea

The idea of LaFed has been emerging due to my interest in the sharing economy during my studies in Canada. An important step of the crystallization of the idea was triggered by the readings of the works of Edgar Morin — 'Introduction to complex thinking' (2015), 'La Voie: Pour l'avenir de l'Humanité' (2011), 'La Méthode: La vie de la vie' (2013)—, Jacques Blamont — 'Réseaux' (2018)—, and Pablo Servigne. Citations of such books and authors are essential as they are the substrate of the idea of LaFed.

Concerning the work of Edgar Morin, the author applies a systemic thinking, which may be summarized by the enunciation of few principles which are: (1) inseparability between the subject and the object; (2) importance of the structure, which is defined as an open system and is composed of interdependent elements such as a human being that is composed of multiple interdependent organs; (3) conceptualization of auto-organization of systems, which stresses the possibility for systems to stabilize or develop themselves in function of the interactions with their environment and their final goal. This thesis stresses the last concept that has been further defined according to the work of E.Morin on complexity. Indeed, E.Morin defines the principle of auto-eco-organization. As each auto-organization strives for energy and information —negentropy— from the environment, as underlined by the second law of thermodynamics, the auto-organization is dependent on its environment; consequently, the auto-organization becomes auto-eco-organization. In addition and in conjunction with its theoretical work on complexity, E.Morin proposes in 'La Voie: Pour l'avenir de l'Humanité' (2011), a new path for modern societies. In his book, the author first, critiques the state that has become a "philanthropic ogre"; indeed, E.Morin underlines that "the insurance state is more and more indispensable, but contributes to the degradation of concrete solidarity without responding to the ever more crying needs of human solidarity" (Morin, 2011 -pp.89). This point of view must be put in parallel with the work of Servigne & Chapelle (2017) on the concept of 'mutual assistance' that has been eroded but still animates each human being. Second, E.Morin underlines the advent of a 'creative bubbling', which are a multitude of local initiatives in the sense of economic, social, or political existential regeneration (Morin, 2011). Because all these initiatives are dispersed, unconnected and compartmentalized, E.Morin urges for collating them in order to open a plurality of reforming paths (Morin, 2011). Concerning the work of Jacques Blamont, in his essay 'Reseaux, Le Pari de l'Intelligence collective' (2018), the author questions how can the power of networks be turned around for the benefit of all? As E.Morin, J.Blamont observes a flurry of local initiatives that are appearing as well as mass movements triggered by a strong connectedness. However, according to the author, local initiatives stood separated and mass movements, such as political movements of 'Occupy Wall Street' or 'Marche pour le Climat', remained disorganized. Consequently, J.Blamont pushes for the emergence of an organization that "establishes a functional link between the exuberance of the crowd and the rigour of the norm, between horizontal chaos and vertical organization, between bottom-up and top-down" (Blamont, 2018 -p.260). A comparable organization has appeared in the domain of space called the 'Federation of OpenSpaceMaker'. This federation merges various established spatial organizations with the activity of the crowd in order to "open up the world of space infrastructure to as many people as possible so that each citizen can anchor his or her action in a process of creating a future world" (Blamont, 2018 – p.230).

Interestingly, one can link the work of E.Morin on complexity and its definition of auto-eco-organization with the concept of 'dissipative structures' and with the work in economics of the biophysical economics school. Moreover, it is valuable to compare the present 'philanthropic ogre' that has become the State relatively to the desired 'state as partner' defended by M.Bauwens. In addition, one can also make a parallel between the work of J.Blamont on networks with what previously said on the sharing economy and P2P economy. Henceforth, while the works of E.Morin, J.Blamont, and P.Servigne forged the appearance of the idea, the study within this thesis on the biophysical economics, sharing economy, and P2P economy provides me tools and concepts to imagine the dynamic institution of 'LaFed' described in the following paragraphs. An institution that wishes to federate local initiatives that have positive effects on the environment. An institution that wishes to be in line with the idea of auto-eco-organization defended by E.Morin. An institution that wishes to help production of commons at lower thermodynamic costs. After understanding the foundation of the idea, the following paragraphs are dedicated to the definition of the mission, the objectives, and the overall operation of LaFed.

1.2 Mission and Objectives of the Organization

The mission of Lafed is 'Sparsa Colligo', which means "I gather the scattered'. During a long time, I thought that this mission was directed to individuals that are activating themselves in a disorganized way; in other words, I thought that the creation of such organization would be a valuable institution to help the auto-organization of individuals. However, as my research deepens while working on my thesis, the mission took another vision. Indeed, the mission aims, in fact, at providing a governance structure, rooted in the P2P economy, for all local projects already awaken in Europe. In other words, the mission of LaFed would not only be to federate all the separated initiatives that have appeared but also to help further initiatives in the future. Consequently, 'Sparsa Colligo' is not subject to individuals or to the crowd but instead to groups of people that are already activating themselves for the creation of solutions that answer social and environmental issues.

The objectives aimed by LaFed are:

- To offer a general platform in order to facilitate exchanges of goods and services as well as to help the production of shared values at lower entropic costs.
- To enable local communities to respond to local problems.
- To help the transition toward an entropic climactic phase and build up resilience of communities.

LaFed is met to become an aggregation of open cooperatives. A cooperative is an "autonomous association of people voluntarily united to meet their common economic, social and cultural needs and aspirations, through an enterprise whose ownership is collective and where power is exercised democratically"(COOP, 2020). In the sense of Bauwens and Kostakis (2017-pp.76), an open cooperative is a type of "entities that would be legally and statutorily bound to the creation of common and open resources". The choice of the open cooperative is not only an ethical but strategic choice. First, it makes possible to transform the consumer into a consumer-actor; and thus, possibly reward her/his activity by receiving dividends. Second, it allows the integration of different actors, driven by the same objective. And last, it allows the integration of sharing economy companies and local initiatives. By this, LaFed may grow faster by possibly reaching faster a critical mass.

1.3 Overall Operation

LaFed represents an ecosystem of structures; or in the sense of E.Morin, an auto-eco-organization. Applying the model of the P2P economy defined previously, the ecosystem of LaFed would be composed of three open macro-structures which are (1) the platform, (2) the for-benefit 'LaFed' association, and (3) the for-benefit local open cooperatives (Appendix 3&4).

Firstly, the idea of LaFed is supported by the creation of an online platform. This platform would have the dual mission to (1) ease exchanges of goods and services between individuals and to (2) produce shared value such as digital commons that are protected by a CopyFaire Licence. It is a type of "licensing or agreement that aims to re-introduce the principle and practice of reciprocity in markets that use mutualized knowledge (commons), by regulating contributions to these commons for those that commercialize it" (P2PF, 2020). Consequently, the platform embraces not only the sharing economy but also the P2P economy. Further, in regard to the environmental side, the platform should give advantage to exchanges that can be realized at the local sphere. For illustration, through the platform one individual may rent or donate, without change of ownership, its drill to another person. In other words, LaFed platform wants to aggregate all various sharing economy practices, from car-sharing to know-how, on one and unique platform. Another illustration concerning P2P economy activities would be the design of a good that can be printed in a locality using a 3D-printer. In other words, the platform becomes an online place to produce digital commons that are freely available to members of the open-cooperative.

Secondly, the idea of 'Lafed' is supported by the emergence of an association that aims at empowering the contributive communities of the platform and the 'LaFed local houses' that will be described later. In addition, this structure oversees and protects the stabilization or the development of the ecosystem without directing it. Indeed, the association does not represent the head of the ecosystem that would direct and send orders but only an interdependent part of the system that protects the ecosystem. Consequently, actions of this structure encompass

(1) the maintenance of the IT tools that support the exchange of goods and the production of shared value, (2) the management of the financing operations of the ecosystem, and (3) the protection of the application of collective intelligence within the ecosystem. For comparison, the association 'LaFed' may be thought as the Wikimedia Foundation of the platform Wikipedia or the 'Linux Foundation' of Linux. Moreover, this association may define a chart, describing the ambition of the ecosystem, the scope of its actions, and fundamental rules to respect; all members of the ecosystems must comply with this chart.

Thirdly, local 'LaFed Houses' represents the open-cooperatives and are created in accordance to the will of a local community. In other words, their creations are independent of the desire of the global association; inversely, their creations are only dictated by the decision of a local group of individuals. The 'LaFed House' must be linked with a specific location; however, this 'LaFed House' can be created without physical location linked with the structure. These local houses have the aims to build up resilient local community by multiplying local exchanges of goods and services as well as to produce local shared or market value goods and services. For illustration, a local community could set up a repairment service of IT hardware that can be free for members of the local 'LaFed house' and payable for non-members. These 'LaFed Houses' are essential for the application of 'cosmolocalism' as they provide a place to manufacture real goods; and therefore, ensuring production of goods and services at low entropic cost. In this vein, it is important to stress links with the other structures. On the one hand, all the local exchanges must firstly pass through the platform before being exercised physically; in addition, all contents on the platform are freely available to the local 'LaFed houses'. On the other hand, the 'LaFed House' is receiving automatic or on request financial and moral aids from the 'LaFed Association'. Indeed, as 'LaFed Association' extracts a given percentage of value on online transactions, 'LaFed Association' will be able to improve the platform and other systems as well as to redistribute a part of the collected fund to local 'LaFed Houses'. Consequently, aligned with the concept of 'cosmolocalism', local production of goods and services can be accomplished at low entropic cost while developing greater resilient communities.

Henceforth, the idea of creating the organization 'LaFed, the Federation of the Shared' is intrinsically aligned with the concept of sharing economy and P2P economy. Concerning the sharing economy, as the organization would accelerate the optimization of resources, the organization aims at having local and global positive impacts on the environment. Besides, the organization will defend the initial vision of the sharing economy of inclusivity and sustainability as a given percentage of actions should be targeting the bottom of the pyramid, which are the poorest two-thirds of the economic human pyramid. Concerning the P2P economy, the organization, by creating shared and market values as well as ensuring the redistribution of the value within communities, follows the application of a ‘generative model’. Henceforth, the imagined organization could become a valuable institution to succeed the transition toward a climactic phase.

Having defined the mission and objectives as well as having described the overall operation of the organization ‘LaFed, the Federation of the shared’, it is important to further characterize (1) the open value network IT tools that will structure all interactions, (2) the collective intelligence that will govern and animate the ecosystems, and (3) the environmental benefits potential of the organization.

2. Information Technology Tools Supporting the Organization

Previously introduced, the case of Canadian firm Sensorica provides valuable insights to IT tools that may govern interactions within the ecosystem of ‘Lafed’. Again, Sensorica defines itself as an Open Value Network (OVN) organization. According to Pazaitis (2020), the OVN is characterized by three principles: (1) Open membership, which means that members can freely join or leave the network. (2) Transparency, which ensures that all members have access to information, knowledge, and processes. (3) Variety of contributions, from material to nonmaterial, can emerge. Accordingly, Pazaitis (2020) underlines that the OVN model used by Sensorica permits to the firm to offer valuable solutions to customers, distribute financial rewards to the contributors of a project according to the value created, and formulate and apply a business strategy. But, how can a decentralized, complex organization as Sensorica succeed in achieving such outcomes? The good operation of the ecosystems at Sensorica is due to the reliance on a dynamic IT tool formed by (1) a Contribution Accounting System and (2) a Resources-Events-Agents (REA) model, which is the basis of Sensorica’s Network Resource Planning (NRP). Both systems form together the NRP-CAS model that supports the activities of Sensorica. Greater insights on these systems would be given as they provide valuable tools for the creation of the organization ‘LaFed’.

The Contribution Accounting System (CAS) constitutes a contribution-based reward mechanism that enables Sensorica's participants to be evaluated and reattributed according to their contributions (Sensorica, 2020). Using a benefit redistribution equation, contributions are turn into benefits for the participants, proportionally to the value created by him/her and the revenue of the project (Value Network, 2019). In other words, using a visual presentation, benefits for the participant are illustrated by a portion of a pie-chart, which depicts its share of the potential revenue of a project (Pazaitis, 2020). Following, within the context of one project, member's contributions dilutes as other affiliates add value to the project. In fact, according to the study led by Pazaitis (2020), the CAS is interlocking with two other systems: (1) a reputation system that determines the behavior of each member "within the community and attributes merit in accordance with the collective interest" (Pazaitis, 2020 – pp.9) and (2) a role system « which allocates the arrangement and interrelation of the different activities among the agents, based on their skills and interests" (Pazaitis, 2020 – pp.9). The CAS system aggregates all records of who is doing what (role), how well (reputation), and how much (value) in a particular project (Value Network, 2019). Henceforth, the Contribution Accounting system arises as a highly valuable tool for common-based peer production. Indeed, it answers to the previously described challenge related to P2P economy of safeguarding collaboration for production of shared value — reducing appearance of free riding.

In complements to the CAS, in order to facilitate interoperability of the resources in different projects, Sensorica is using a Network Resource Planning (NRP). This NRP is based on Resources-Event-Agents (REA) model to support the complexity of operations.

REA was first established by McCarthy (1982) as an alternative structure for a shared data environment that is the digital economy. McCarthy's (1982) main critiques of common accounting system were its independency and non-integrated information system. Indeed, he analyzed that aggregation of accounting data were taking place at high level for executive decision making but never for lower levels due to the structure of the database (Pazaitis, 2020). This insufficient use of data impeaches a business to reach full productivity at all levels of its organization. In addition, McCarthy (1982) critiqued the double-entry bookkeeping that expresses only monetary representations and let other valuable data such as productivity and performance not represented (Pazaitis, 2020). In reaction, McCarthy (1982-pp.559) established the REA accounting system that aims to be a "constituent part of an enterprise database system". The model creates fictional objects that represent: (1) 'Economic

Resources' which are things that are scare and has utility for economic agents (e.g: cash, goods, services…); (2) 'Economic Agent' which is an "individual or organization capable of having control over economic resources" (e.g: customers, vendors, enterprises…); (3) 'Economic Event' which "represents either an increment or a decrement in the value of economic resources" (e.g: processes, contracts…) (Hruby, 2006 – pp.4). After a great number of studies on the REA model by Geerts, Graham, Mauldin, McCarthy, the REA transformed from a framework to a design theory for "inter-organizational exchange transactions and a foundation for inter-organizational enterprise systems that facilitate the digitization of the enterprise " (Dunn, Gerard, & Grabski, 2016 – pp.313). In this direction, based on REA, an NRP may be created, which is an Enterprise Resource Planning (ERP) type of software. In fact, the NRP connects everything together. "It collects, stores, and interprets data from all the different types of activities in the network and connects them to specific resources, events, and agents to keep track of the contributed value on resource level" (Pazaitis, 2020 – pp.10). Specifically, according to Pazaitis (2020), REA operates at three levels in the NRP. (1) Firstly, REA model defines resources, agents, or events associated with an activity in the network. It is called the 'type' or 'recipes' level. (2) Secondly, REA characterizes the forms of commitment made by economic agents to perform an economic event in the future. This level refers to 'plans' and, for example, can include productive processes, orders, or purchases. (3) The last level encompasses all the various economic occurrences performed by an economic agent affecting the quantity or ownership of resources; it is referred as the level of 'event' or 'actuals'. All three interconnected levels permit the accounting of each physical operation. Consequently, the information system based on REA arises as a constituent part of an enterprise database system that coordinates diverse agents and performs traditional business functions, from production to sales. According to these features, NRP not only appears to be a precious tool for network type of organization, but also allows the re-use and evolution of resources in different context and through time.

Together the NRP-CAS model that is applying Sensorica is particularly relevant for the creation of LaFed. Indeed, it provides first a valuable model to account and manage multiple agents that are working according to P2P economy principles. Secondly, as LaFed may rely on the circulation of digital commons, it allows the re-use and development of resources in different context, simultaneously. For illustration, imagine that a number of active members worked on a project of designing a good that can be printed in 3D. This resource, which is a digital common, can be used within multiple 'LaFed House' in order to manufacture the good to create shared value within the community or to create market value. Using the NRP, it would be possible to take into account, in a systemic way, all the events that are occurring through time, at different place. In the meantime, the IT tool provides a fair and efficient method to retribute each agent according to the value created. Indeed, imagine that the good produced by 3D printing is sold on the market. The revenue from the sale can be fairly redistributed between all the economic agents, from the 'LaFed House' that manufactured and sold the good to the members that help at the creation of the digital common on the 'LaFed platform'. Henceforth, according to hereinabove description, the NRP-CAS model developed by Sensorica would be highly valuable to govern interactions within the ecosystem of 'LaFed'.

3. Collective Intelligence and Sociocracy

In conjunction with IT tools that provide valuable devices to govern and manage all the interactions within the ecosystem of 'LaFed', it is important to tackle human interactions. Indeed, how can LaFed make sure to tap into crowd's wisdom and not its madness? How can LaFed balance diversity with expertise, decentralized with distributed decision-making? In order to answer these essential questions, this thesis first describes the concept of Collective Intelligence and then, the paradigm of sociocracy.

LaFed would be intrinsically an organization in the realm of the 4th industrial revolution's based on the opportunities opened by the internet. In 1997, within its book '*Collective Intelligence: Mankind's emerging world in cyberspace'*, Levy,P. already believed that the internet would mobilize and coordinate the intelligence and other knowledge resources of the crowd in an innovative way. His beliefs have been crystalized with the appearance of the concept of 'Collective intelligence' (Lichtenstein, & Parker, 2009). In simple terms, collective intelligence is the capacity of a group to mobilize knowledge and intelligence towards the accomplishment of a specific goal. This thesis heavily uses the article 'the collective intelligence genome' developed by the Center of Collective Intelligence at the MIT in order to regulate interactions within 'LaFed' (Malone, Laubacher, & Dellarocas, 2010). To classify the various type of Collective Intelligence, the article uses four questions which are (Malone, Laubacher, & Dellarocas, 2010):

- ***What is being done?*** For a particular event, the actors may either create (e.g: a piece of software, a 3D design, a good…) or decide to choose something among various alternatives. In order to fully realize a project, there is a series of ‘Create’ and ‘Decide’ events that may follow various types of collective intelligence.

- ***Who is doing it ?*** There are two possibilities which are the reliance on hierarchy or the crowd. On the first hand, hierarchy may be defined as a situation in which “people in authority make decisions that their subordinates are required to follow” (Malone, 2018). On the other hand, an activity can also be undertaken by the crowd, which is “anyone in a large group who chooses to do so” (Malone, Laubacher, & Dellarocas, 2010- pp.26). The study defends the exploitation of the crowd as soon as many people have the resources and skills to perform a given activity, and in situations where the organization cannot know in advance where are the resources and skills located.
- ***Why are they doing it***? As an echo with what has been stated in the second part of this thesis, the article raises that the motivation of participants may be (1) the promise of financial gain (money), (2) the enjoyment linked with the activity (love), and (3) the recognition of the participant’s work (glory). While the appeal on glory and love may reduce costs, reliance on both does not always work. Concerning the reliance on glory and money, it helps the crowd to move faster as soon as a goal is well defined.
- ***How is it being done?*** The article focuses only on the crowd as the ‘How’ in regard to hierarchy follows the common management practices. Following, depending on the ‘What’ (create or decide), the authors enumerate various mechanisms. This thesis describes the four main types of ‘How’ that depend on the level of independency between members of the crowd and their contributions. (1) Firstly, concerning the ‘create’, there is possibility of practicing ‘collection’. This type of practice is linked with the independent contributions of members of the crowd; for illustration, the platform ‘Youtube’ collects all independent contributions (videos). (2) Secondly, again concerning the ‘create’, another possibility is to ‘collaborate’. Collaboration occurs when members of a crowd work together to create something. Collaboration is useful as soon as there is no satisfactory ways (a) to divide a project into independent pieces as well as no satisfactory ways (b) to manage dependent contributions of members of the crowd. (3) Thirdly, concerning now the ‘Decide’, the first scheme underlined by the article is to apply ‘Group Decision’. A group decision occurs when a decision is defended after the integration of all inputs of members. Following, the decision holds for the group as a whole. Group decisions may be reached by vote, consensus, or averaging, for example. (4) Last, also concerning ‘Decide’, the article raises ‘individual decisions’. This individual decision occurs when members of

the crowd make decision based on other inputs from the crowd. For example, one decides to trust a member of car-sharing based on recommendations of others.

Applying this framework to ‘Lafed’, one can scheme the broad lines of the governance modes within the ecosystem of LaFed. Concerning the for-benefit ‘LaFed association’, the essential activity of the ‘LaFed association’ will be to decide things, such as what are the administrative works, financial decisions, aids to give to local houses, or what must be improved on the platform. Consequently, interactions within the association follows a hierarchical scheme motivated mostly by ‘money’ and ‘love’. In regard to the local open-cooperatives named ‘LaFed houses’, we have to apply two points of view which are (1) considering the dynamic governance within the open-cooperative and (2) considering actions of the ‘LaFed House’ as an unity. On the one hand, within the local open-cooperatives, interactions for ‘Decide’ may apply group decision framework while interactions for ‘Create’ follow a hierarchical model motivated by money, love, and glory. For example, as soon an action is decided at the local level in accordance with all the members of the LaFed House (citizens, associations, partner’s city…), the action is pursued following a hierarchical model (elected manager manage the project and other members pursue tasks that have been decided). Hence, the goal of this house of creating goods or services at a low entropic cost to solve local problems and build local resilience may be attained. On the other hand, taking ‘local houses’ as individual units, interactions with the environment will be crowd-based. For example, the aggregation of ‘LaFed House’ may influence actions of ‘LaFed Association’ according to individual decision-making models. Last, concerning the ‘LaFed platform’, only the crowd contributes to the platform. Concerning sharing practices, individual decisions will influence the crowd; for example, the implementation of peers-grading will influence each member to use the service of another member. Concerning P2P economy practices, after choosing a project according to an individual decision model, a group decision within each project may be used to decide how to handle such project. For example, a periodic vote system may pinpoint which project to implement; secondly, members of the project’s group will decide how to achieve the project. Consequently, in regard to projects, collaboration within projects and collection of various projects will appear on the platform. In other words, multiple projects may be freely accessible online; and, a certain number of members may be collaborating on a specific project.

Hence, the concept and framework of collective Intelligence would be highly valuable to operate within the ecosystem of 'LaFed'. However, collective intelligence, which can be hierarchical or based on the crowd, provides only the semantical structure that governs human interactions; there is also a need to provide methods of interactions. The paradigm of 'sociocracy' provide valuable insights that can be implemented within the multiple local open cooperatives and within the 'LaFed association'.

Sociocracy "is a decision-making and governance method that allows an organization to manage itself as an organic whole" (Buck & Endenburg, 2012). Theoretically, this method of governance derives from the concept of self-organizing system; according to the works of Prigogine and Haken (1978), self-organized systems must meet two conditions to be constituted: first, as stated in the second part of this thesis, a system must withdraw energy from its environment. Second, components of a system cannot limit and control each other. According to these two conditions, fundamental rules that are at the heart of sociocracy were established.

- ***The first rule is the consent***. The consent obliges the group to consider all the objections raised by a member of the group; in other words, a policy decision can only be implemented if all the objections were answered (Buck & Endenburg, 2012). Consequently 'Consent' is based on the absence of 'no' while consensus is based on the 'yes' of all members.
- ***The second rule is the creation of 'Circle'***. These circles are semi-autonomous and are constituted of individuals that are functionally linked (Buck & Endenburg, 2012). Circles have each other a unique aim that explains the existence of each circle; if the goal disappears, the circle must disappear. For example, one can imagine a simple organization with a unique circle such as a pharmacy; the goal of this circle is to provide counsel and medication to their patients. Interestingly, these circles can be integrated within all existing organizations as the decision made and consented does not regard day-to-day decisions but only strategical or tactical decisions. Moreover, circles have three basic functions that are leading, doing, and measuring/feedback which runs as a closed loop. This closed loop represents the dynamic governance within the circle and is universally present in each circle. But, while circle respects a common dynamic, they evolve independently. Indeed, each circle evolves with time as each circle creates its own policy decisions by consent and develops itself from research, teaching, and learning (Buck & Endenburg, 2012).

Following the example of the Pharmacy, imagine the circle to be made of the Pharmacist/Manager and four pharmacy technicians. The goal of the circle being to answer as best as possible to patients questions while being profitable, the circle may decide to train pharmacy technicians to counsel better patients on specific subjects or train the pharmacist/manager to new management practices. All these training decisions must by adopted by consent and feedback must be implemented.

- (3) ***<u>The last rule is the 'double linking' rule</u>***. Indeed, at least two persons of a circle, one being the functional leader and one being the representative of the circle, are full members of the next higher circle (Buck & Endenburg, 2012). This rule ensures continuity between levels within the hierarchy of an organization, as the members of one circle would not take any decisions without consent of the representing leader of above and under circles.

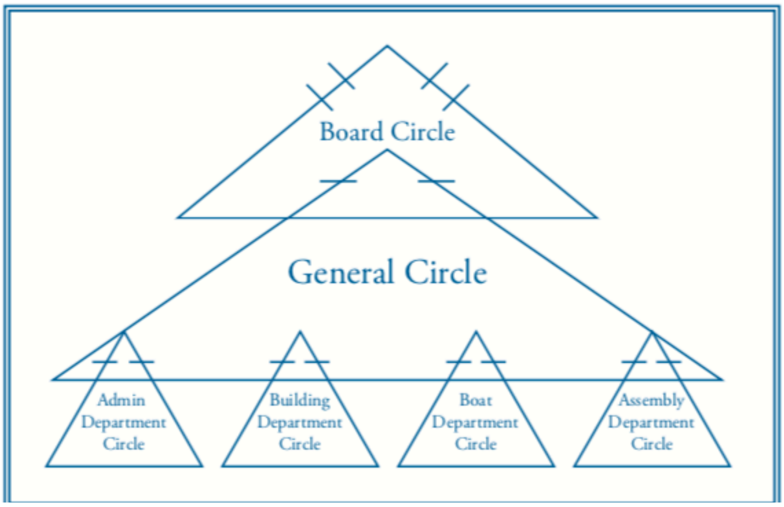

Figure 15: Dynamic 'Circle' Structure, Example of Electrical Company*: Each triangles reprensents a 'circle' made of individual from the same functional area. Two individuals of each circle - represented by short horizontal lines- are present in the above circle (Double Linking Rule)*

- (***<u>4) The 'Consent rule' has a corollary in regard to election</u>***. Indeed, during an election of a representative, there is no candidate. The group must choose, based on consent, a person that fits a function. Consequently, this election method does not lead to feeling of victory or lose but provides satisfaction to the group that 'chooses the right person for the right function'.

In fact, the rule of 'circle' ensures the realization of the first condition to create self-organizing system. Indeed, the obligation for a group to implement, in top of their goal, the objective of the higher circle, creates a tension within the circle. In other words, the common goal set by the upper organization is the energy needed for initiating the self-organization within lower levels circles. Moreover, the rules of ‘consent’ and ‘double linking’ are protecting the realization of the second condition, which is ‘not controlling each other’. While sociocracy may seem to be theoretically complicated, it is practically simple to integrate and implement to any type of organization. The last question that may arise is why doing it? Buck & Endenburg (2012) provides a summary answer which is: “self-organizing process spurs creative thinking and catalyzes new structures and ideas”. Concerning ‘LaFed’, sociocracy arise, therefore, as a valuable method of interactions not only within each structure of LaFed but also between LaFed structures. Indeed, applying this governance methods will ensure links between structures. One example within local ‘LaFed houses’ is that the application of sociocracy will not only provide a framework for interactions, but also ensure creative thinking, which is essential at local levels. Another example looking at interactions between LaFed Houses and the LaFed association is: The chart of the LaFed association provides the ‘energy’ into LaFed houses to pursue various actions, which can be common-driven or market-driven, that help the achievement of the overall mission of LaFed. On the counterpart, feedbacks from LaFed House into LaFed association may force the association to improve constantly its actions.

Henceforth, collective intelligence and sociocracy provide both the structure and methods for the system to interact within each unit of the ecosystem of LaFed but also between the various structures. Allying both concepts could be highly valuable for the ecosystem of ‘LaFed’.

4. Environmental Benefits

This thesis describes essential features of the ecosystem ‘LaFed, the Federation of the Shared’. Indeed, this thesis depicts the overall operational processes of the organization, the IT tools that support all processes, and the method of interactions governing interactions. The description of the main lines of these features are only initial scheme based on the work of one author; it would be valuable to use structures of collective intelligence in order to improve all these features. However, there is an important aspect to describe which is directly related to the goal of this thesis: what would be the environmental consequences of the creation of ‘LaFed, the Federation of the Shared’? ‘LaFed’ may affect positively the environment according to two broad actions: (1) federate and help to create local initiatives that provide solutions for building local resilient communities. And (2) help local exchanges of goods and services and increase the production of shared values at low entropic cost.

In order to illustrate effects of local initiatives, this thesis uses various examples of initiatives across the world. In fact, numerous works are collating initiatives such as the documentary 'Tomorrow' by M.Laurent and C.Dion (MM & Levy, 2015), the book 'Un Million de Révolutions Tranquilles' by B.Mannier (2016), the website 'transitionnetwork.org' (2020), or again the book of R.Hopkins (2014) about initiatives in regards to the ecological transition. Some of these initiatives will be described as illustrations of the potential benefits bring by 'LaFed'.

An introducing example would be 'Masks.Coronavirus.Brussels' initiated by E.Mossay. The goal of the initiative is to manufacture locally and provide anti-spray masks in order to help the fight against the spread of the virus. The initiative is based on P2P economy model as it is coordinated by a consortium of public/private entities, is open-source, and is replicable in other comparable metropolises. The initiative is answering to social criteria as it involved more than 1500 citizen-volunteers including disabled workers and to the environment criteria as it ensures that masks are washable and reusable. More interestingly, this scalable initiative appeared and grew at an exponential rate within an extreme short period of time. Therefore, the initiative not only answers to the social need, which is the sanitary urgency, but also respects the environment by proposing a good that is reusable.

A second example is the famous case of the city of Town Totnes. The objective of 'Transition Town Totnes' is simple: to do door to door within your street until agglomerating a group between six to ten members in order to organize seven meetings. Each gathering is dedicated to a precise theme (water, energy, transportation…) and each household receives a precise booklet introducing ideas and practical actions. According to R.Hopkins (2014), the 700 households that participate to this initiative have been decreasing by 1,3 Tons of CO_2 their emissions and saving 500€ per households.

A third interesting example is the case of '1000Bxl en Transition'. This initiative comes from the wish of a group of inhabitants from the center of Bruxelles, Belgium. Created in 2013, the association counts, in 2020, 30 active members. All the initiatives leaded by the association are meant to be local, accessible to everyone, and concrete, such as collective vegetable gardens or exchange of know-how. One initiative particularly interests me, the 'Creative Workshop' ('Atelier Créatif' in French) that has the objective of zero waste. To put this initiative into context, it is valuable to know that, according to a study pertaining only to

Finland, France, the Netherlands, Spain, and Sweden, around 80% of the waste was due to the demand for construction materials, metals, and fossil energy carriers (Wijkman, & Skånberg, 2017). So, how can we reduce demand for goods and waste? In conjunction with improvements at the start of the supply chain such as building more durable, qualitative goods, there is opportunity to reduce waste at the consumer level. Therefore, the basic idea of the workshop is to provide a second life to products. Beyond the profound local social impact that arises from such initiatives, it also brings a positive effect on the environment as it participates to the reuse of a good in its initial utility or for another goal.

A fourth example is the case of the first 'Community Land trust' created in Germany by an organic farmer, Christian Hiss, from Eichstetten, near Fribourg. After the refusal of a banking loan in 2006, he decided to create with its friends a corporate citizenship, the Regionalwert AG (RWAG), whose capital is opened to local citizens. In 2016, several hundreds of citizens owned a portion of RWAG that operates on eight hectares (Manier, 2016). In top of expanding organic lands, according to the structure of collective management, he created a genuine organic chain that encompasses vegetables production, a winery, a caterer that only use local products, three organic supermarkets, a delivery service, and other activities. Consequently, a local ecosystem has been emerging counting sixteen local enterprises and 200 workers (Manier, 2016). Each year, all the member of the RWAG receive a review not only describing the financial Snapchat but also the actions undertaken to reduce land degradation and the use of resources. Consequently, the establishment of the Community Land Trust has permitted to members of a locality to manage rationally commons. This example that seems to be further away from the idea of LaFed, shows well that a group from the civil society may help the administration of commons in an efficient way.

In fact, numerous other examples may be cited in respect to water management, agriculture and land degradation, local currency to develop local resilience, energy management, or again housing. They all show local initiatives that not only have social positive consequences but also profound local, positive impacts on the environment. In this vein, these local initiatives are partly answering to the environmental crisis. Indeed, the agglomeration of these separated initiatives are believed to be positive in regard to the environment. However, these initiatives are too much compartmentalized and marginalized. Consequently, the goal of 'LaFed' appears to be beyond the mission of 'Network in Transition' of helping to create local initiatives. In fact, 'LaFed' may federate this plethora of initiatives for the emergence of an ecosystem. An ecosystem that will share goods and services, create global commons, produce local values, manage local commons, and participate to the building of local resilience.

Indeed, first ‘LaFed’ is a platform of the sharing. A simple use of the platform will be to share goods and services, with an obligatory preference for the local. Consequently, according to the study of ADEME et al. (2016) previously introduced, this service provides a direct positive effect on the environment. Moreover, all the value captured through the sharing transactions will be reinjected within local communities according to the ‘generative model’. For example, imagine that the IT tools used by ‘LaFed’ permits to measure all sharing transactions that were proceeded in a region around a ‘LaFed house’. A certain percentage of the value of the transactions will be automatically redistributed to the ‘local house’ in order to undertake its initiatives. Secondly, ‘LaFed platform’ permits the creation of digital global commons, from knowledge to product designs. Concerning product designs, assuming the quality and durability of the designed good, they are participating to reduction of demand in material and reduction of waste from an individual. Such conclusions are defended by the report of the Club of Rome about ‘Circular Economy and Benefits for society (Wijkman, & Skånberg, 2017). Thirdly, in conjunction of the creation of digital, global commons, ‘LaFed’ permits production of local shared or market values. Imagine that a number of digital product design are freely accessible by ‘LaFed House’; using a 3D printing machine, a member of the ‘LaFed House’ may manufacture the real good. This production scheme already exists. For example, the start-up ‘Marklix’ is a web platform that connects manufacturers' brands and more generally any 3d file designer with consumers by producing 3d printing, on demand and locally, of spare parts. The immediate effects are the cost reduction for manufacturers (stocking costs and transportation costs of spare parts) as well as a greater reparation rate of goods. More generally, the world has been experiencing the emergence of Fab labs. For illustration, the network e-Nable conceives and distributes hand protheses at a cost a thousand times lower than classical products (Manier, 2016). Henceforth, the production of local shared or market value arise as an efficient way to produce goods at the lowest entropic cost.

In conclusion, the establishment of ‘LaFed’ would contribute positively to the environmental crisis explained in the first part. Again, the project ‘LaFed’ does not proposes a new technology, an innovative product, or unique service. The project innovates by constructing a complex and dynamic organization that will help the emergence of new technologies, innovative products, and customizable services. It exists a great number of initiatives that not only have positive social effects but great environmental impacts; however, these initiatives are still too much separated. 'LaFed', therefore, establishes itself as "a functional link between the exuberance of the crowd and the rigor of the norm, between horizontal chaos and vertical organization, between bottom-up and top-down" to restate the words of J.Blamont (2018-p260).

Conclusion

The objective of this thesis was to develop a theoretical structure of an organization that deals with environmental challenges and helps construct a more resilient and sustainable society. This section shall evoke the various arguments used to achieve this end, before discussing both the limitations of the analysis as well as of the impact of the organization itself.

Firstly, this thesis analyzed and described the environmental context and the major causes of the environmental crisis that is faced by society. Climate change and global land degradation are the two key elements constituting the environmental crisis. Both have a common denominator in human activities. On the one hand, agriculture, transportation, industry, or utilization of buildings, which are all based on an exo-skeleton (machines) running on fossils fuels, are emitting greenhouse gases. This increase in GHG emissions has contributed to the rise of GHG's concentration on land, in the atmosphere, and in the oceans. In the atmosphere, the direct consequence is an exacerbation of the greenhouse effect. As a consequence, Earth is accumulating thermal energy which has various effects such as the warming of the overall temperature, the warming of the oceans, the change of water cycles, etc. On the other hand, human activities, led mostly by population growth and economic development, are also degrading lands. Indeed, improper grazing land and cropland management, disturbance of forests, development of extractive industries, and finally the expansion of infrastructures are all direct causes of land degradation.
In fact, the analysis demonstrated that the development of human societies was possible due to an increased reliance on fossil fuels, from coal to petroleum-based products, which represented 81% of the primary energy used by humanity in 2018 (IEA, 2019). However, fossils fuels, that promotes food production through agriculture, more comfortable living conditions through industry and greater mobility through improved transportation may ultimately lead to long-term risks. Indeed, climate change coupled with land degradation are,

in turn, putting at risk Earth biodiversity, distorting ecosystems on which humans rely, degrading water resources, and impairing global food security.

Secondly, this thesis focused on a critical description of economics that have driven the rapid development of human societies over the previous centuries. Indeed, while the application of mainstream economics has been a useful tool enabling a great development of human societies on a short time scale, neo-classical economics is subject to a plethora of criticisms raised by various schools of thoughts, including biophysical economics.

Biophysical economics primarily raised doubts on the foundation of the model by questioning the notion of a perpetual motion machine, defended by the mechanical vision of the neoclassical school, and the paradigm of indefinite growth. Consequently, biophysical economics urges the application of the laws of thermodynamics and the integration of the biophysical matrix within the neoclassical model. In other words, biophysical economics defends the inclusion of the concept of energy and entropy within economics.

In this vein, this thesis focused on the concept of entropy that may play a crucial role in the development of economics theories. Entropy is a measure of order; looking at energy, it can also be viewed as the degree of degradation of energy. Applying entropy to open-systems such as human societies, this thesis demonstrated that these open-systems, defined as 'dissipative structures', were compensating their own entropic degradation by continuously assimilating negentropy within their system while rejecting greater amounts of high entropy in their environment. In other words, the assimilation of negentropy is linked on one side with the rapid development of human societies based on increasing reliance on fossil fuels; and, the rejection of higher entropy in the environment is linked on the other side with the increasing pollution rate that lead to climate change and land degradation. This conclusion raised the idea that humanity should move from a colonizing state (maximizing the flow of energy) to a climactic phase (minimizing flow-through of energy).

In order to proceed to such a transition, various solutions are offered to Homo Sapiens. One can aggregate all solutions into two fundamental groups: technological and political. On the one hand, technological solutions encompass all solutions that increase energy efficiency of all energetic convertors, from light bulbs to power plants. Moreover, this category includes technologies that help the spread of renewable energy solving the issues of intermittency and dispatchability of renewable energy. For example, studies on storage energy solutions, research on smart grids and smart cities, or on biomethane are all valuable technological solutions to successfully implement an energetic transition and sustainable development. On the other hand, political-based solutions target the reduction and rationalization of demand pertaining to all human activities (agriculture, buildings, industry, transport). While a number of political-based solutions come from regulations imposed by governments, a great number of solutions originate from the bottom up — solutions emerging due to an active civil society. Concerning bottom up solutions, two fundamental trends are emerging: the expansion of the sharing economy and the development of the P2P economy.

The sharing or collaborative economy is defined as business models, where private individuals (service providers) offer their unused goods, services or resources, with or without compensation, to other private individuals or businesses (customer) via an online collaborative platform. The sharing economy is experiencing a rapid and strong development, although it has deviated from its initial vision of inclusiveness and sustainability. Indeed, all the dominant platforms are applying an 'extractive model', extracting values from exchanges made between individuals without reinvesting it within communities. Concerning the environmental benefits of the sharing economy, it could be considered a potential solution for the environmental crises as soon as factors of exchange modality and feedback effects are taken into account. On the other side, the P2P economy is an intersubjective dynamic characteristic of distributed networks, which is associated with the production of value (peer production) and the idea of peer governance. While P2P economy processes are highly spread into the nonmaterial world, it faces challenges into the material world, such as safeguarding collaboration and reducing appearance of free riding. In this vein, thinkers of the P2P economy defend commons-based peer production (CBPP) organization that produces non-material value globally and material value locally. This scheme is called 'cosmolocalism'. It involves local environmental benefits due to local initiatives. Aggregating these local initiatives is believed to be highly valuable to answering to the environmental crisis.

Finally this thesis described an imagined organization that provides a functional link between "the exuberance of the crowd and the rigor of the norm, between horizontal chaos and vertical organization, between bottom-up and top-down" (J.Blamont, 2018- p260). This organization is called 'The Federation of the Shared' (LaFed). LaFed is part of the realm of CBPP organizations, combining the creation of global commons and local commons or market-products/services based on peer-production. Having the mission of gathering the dispersed — 'sparsa colligo'—, LaFed aims to gather all dispersed local initiatives. As such, LaFed has three objectives of (1) offering a general platform in order to facilitate exchanges of goods and services as well as to help the production of shared value; (2) Enabling local communities to respond to local problems; and overall, (3) Helping the transition toward an entropic climactic phase and build up resilience of communities. In fact, applying a P2P economy system dynamic, LaFed is made of three dependent macro-structures that are (1) a for-profit association that safeguard collaboration within the ecosystems by establishing and ensuring the respect of rules and mechanisms; (2) an online platform that allows the share of goods and services between individuals and the production of shared value such as digital commons; (3) multiple independent local open-cooperatives, 'LaFed Houses', to create physical goods and services locally at low entropic costs so that answering to local problems while minimizing the impact on the environment.

Concerning the two primary objectives, LaFed is imagined to be an organization based on a 'generative model', in which the values derived from all sharing transactions made by individuals are partly reinjected in communities to help the emergence of resilient communities. The two first objectives may be realized due to implementation of IT tools and methods of governance based on collective intelligence and sociocracy. Applying these methods of governance will insure the establishment of peer-governance within the ecosystem of LaFed. Concerning the last objective of helping the transition toward an entropic climactic phase, LaFed may succeed it as the organization influence all members to change their way of interacting and consuming. In other words, the creation of LaFed might lead to increasing cultural-based solutions targeted reduction and rationalization of human activities (agriculture, buildings, industry, transport). Indeed, this organization may effect various sides of human societies dynamics as it pushes change within the transportation (e.g: increase car-sharing practices), within industrial activities (e.g: ensure local production), within consumption patterns (e.g: reducing consumption habits), and other fields that are direct factors of the environmental crisis. It is fundamental to say that LaFed does not position itself as the new way to live within the society, but as a new alternative way to live. An alternative way that prospers aside, and sometimes within, the market-based activities. An alternative way that consider the State not only as a ruler but also as a partner for answering the environmental crisis. An alternative way that see the digital revolution as an opportunity to not only enters within the 'time of access' but also within the time of 'commons'.

Limits of this thesis

While this thesis discusses the environmental crisis, summarizes the economic downturn, and opens on a possible creation of an institution to multiply the number reforming paths, it is essential to take a critical view. Research findings are presented in a more objective context, based on scientific analysis, before entering more and more within subjective matters.

Indeed, the first part of this thesis dedicated to the environmental and energetic context only summarizes the scientifically analysis. Content describing the climatic context is aligned with the work of the IPCC, content from land degradation is aligned with works done by the United Nations and the IPBES, and content concerning Energy is aligned with analysis of the IEA and other works of reference. In fact, scenarios from the work of the IPCC or the IEA are the sole element that need care. They should not be regarded as definite future outcomes but as potential future outcomes that depend on a set of factors. However, all of these scenarios provide valuable tools to draw policy and effective strategies to alleviate humanity from the environmental crisis.

The second part on economics and economic trends may be more easily subjected to criticism as economics is one of the most complex systems that science tries to understand. Therefore, this thesis limits itself only to describe key features of neoclassical economics and biophysical economics. In other words, this thesis' objective is only to provide an overall approach of economics; I recommend to the reader further researchon mainstream economics and biophysical economics to deepen its knowledge. Moreover, concerning sharing economy and P2P economy, while the first has been deeply analyzed, the second has not been highly reviewed by the literature.As a result, findings were presented in a simplified manner in order to ensure clarity.. In regard to their effects, while their social effects have received greater attention, while not described in this thesis, their environmental effects are hard to analyze with robustness. Hence, the potential environmental impact of both trends should be the subject of further studies in developed countries and in developing countries.

Finally, the last part of this thesis is highly subjective as it describes an imagined organization. On the one hand, this thesis only describes the main lines of the organization's dynamics. It would be interesting to reframe the dynamics of 'LaFed' using collective intelligence methods. On the other hand, the potential of the environmental effects of 'Lafed' is only based on multiple local initiatives. While the potential effect on the environment is believed to be considerable, a close and scientific approach would be valuable to ensure the expression of such outcome. Moreover, while this thesis only describes the potential effects on the environment; it would be valuable to study the social context and the potential effects of such an organization on the social sphere.

A final word:

Despite the potential criticisms addressed above, this thesis has argued that the creation of LaFed would be a beneficial contribution towards dealing with the environmental crisis. Its strength lies in its bottom up - top down approach, which broadens the power of action away from solely technological breakthroughs or international, political decisions to a readily accessible institution.

Surprisingly, the creation of 'LaFed' may appear faster than could have been expected. Just as the recent initiative of 'Masks.Coronavirus.Brussels' to help the fight against the COVID-19 outbreak, by working with existent organisms, 'LaFed' could emerge in a relatively small amount of time. Indeed, the organism 'ouishare.com' that works at transforming the world through sharing, may help 'LaFed' in overseeing the operation of sharing. The organism 'P2P Foundation' and some of its projects such as the 'Distributed Design Market Platform' project, which acts as an exchange and networking hub for the European Maker Movement, may be a great leverage to rapidly design a tool to create goods and services at lower entropic cost. The organism transitionnetwork.org which collates initiatives led by communities worldwide may be a great source for a potential 'LaFed House'. All of these organizations provide to differing extents support or tools to help individuals answer their needs while safeguarding the environment. 'LaFed' may help the symbiose of these organizations in order to achieve more effectively each of their missions. Consequently, supposing the cooperation of existing organisms, 'LaFed' may emerge more rapidly than imagined in order to help the emergence of increasingly resilient communities and help the transition toward an entropic climactic phase.

In sum, 'LaFed' could contribute towards the fulfillment of social needs without exceeding the carrying capacity of the planet and damaging the vital cycles and needed balanced ecosystems that sustain human life.

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Appendix 1: Primary Energy Demand (IEA, 2019)

Table 1.1 ▹ **World primary energy demand by fuel and scenario** (Mtoe)

			Stated Policies		Sustainable Development		Current Policies	
	2000	2018	2030	2040	2030	2040	2030	2040
Coal	2 317	3 821	3 848	3 779	2 430	1 470	4 154	4 479
Oil	3 665	4 501	4 872	4 921	3 995	3 041	5 174	5 626
Natural gas	2 083	3 273	3 889	4 445	3 513	3 162	4 070	4 847
Nuclear	675	709	801	906	895	1 149	811	937
Renewables	659	1 391	2 287	3 127	2 776	4 381	2 138	2 741
Hydro	225	361	452	524	489	596	445	509
Modern bioenergy	374	737	1 058	1 282	1 179	1 554	1 013	1 190
Other	60	293	777	1 320	1 109	2 231	681	1 042
Solid biomass	638	620	613	546	140	75	613	546
Total	**10 037**	**14 314**	**16 311**	**17 723**	**13 750**	**13 279**	**16 960**	**19 177**
Fossil fuel share	*80%*	*81%*	*77%*	*74%*	*72%*	*58%*	*79%*	*78%*
CO_2 emissions (Gt)	**23.1**	**33.2**	**34.9**	**35.6**	**25.2**	**15.8**	**37.4**	**41.3**

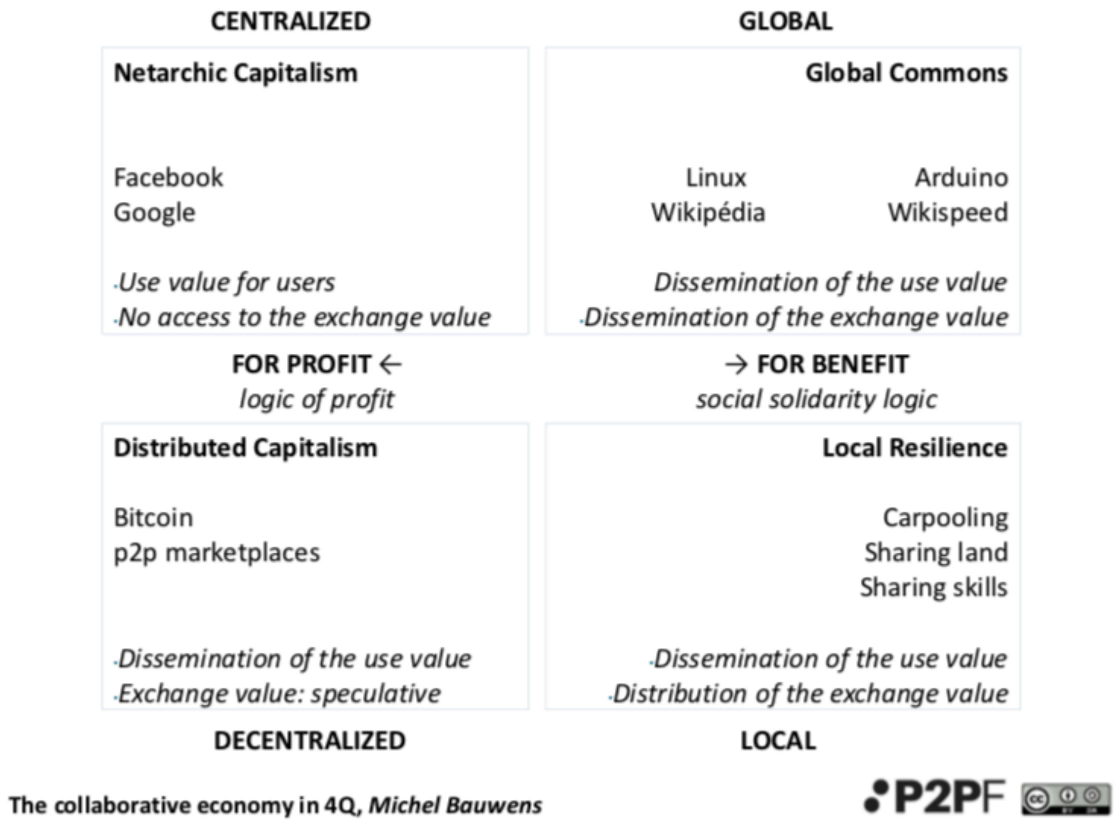
Notes: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes. Other includes wind, solar PV, geothermal, concentrating solar power and marine. Solid biomass includes its traditional use in three-stone fires and in improved cookstoves.

Table 1.2 ▹ **Total primary energy demand by region and scenario** (Mtoe)

			Stated Policies		Sustainable Development		Change 2018-2040	
	2000	2018	2030	2040	2030	2040	STEPS	SDS
North America	2 678	2 714	2 717	2 686	2 377	2 087	-28	-627
United States	2 271	2 230	2 214	2 142	1 942	1 687	-89	-544
Central & South America	449	660	780	913	669	702	253	42
Brazil	184	285	342	397	299	312	112	27
Europe	2 027	2 000	1 848	1 723	1 689	1 470	-277	-530
European Union	1 692	1 613	1 414	1 254	1 311	1 101	-359	-512
Africa	489	838	1 100	1 318	698	828	480	-10
South Africa	108	134	133	139	112	107	5	-27
Middle East	365	763	956	1 206	802	880	443	117
Eurasia	742	934	980	1 031	858	807	97	-127
Russia	621	751	767	786	680	635	35	-116
Asia Pacific	3 012	5 989	7 402	8 208	6 232	6 085	2 218	96
China	1 143	3 187	3 805	3 972	3 226	2 915	785	-271
India	441	916	1 427	1 841	1 143	1 294	925	378
Japan	518	434	387	353	349	300	-80	-134
Southeast Asia	384	701	941	1 114	797	858	413	157
International bunkers	274	416	528	639	425	420	223	4
Total	**10 037**	**14 314**	**16 311**	**17 723**	**13 750**	**13 279**	**3 409**	**-1 035**

Notes: Mtoe = million tonnes of oil equivalent; STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario. International bunkers include both marine and aviation fuels.

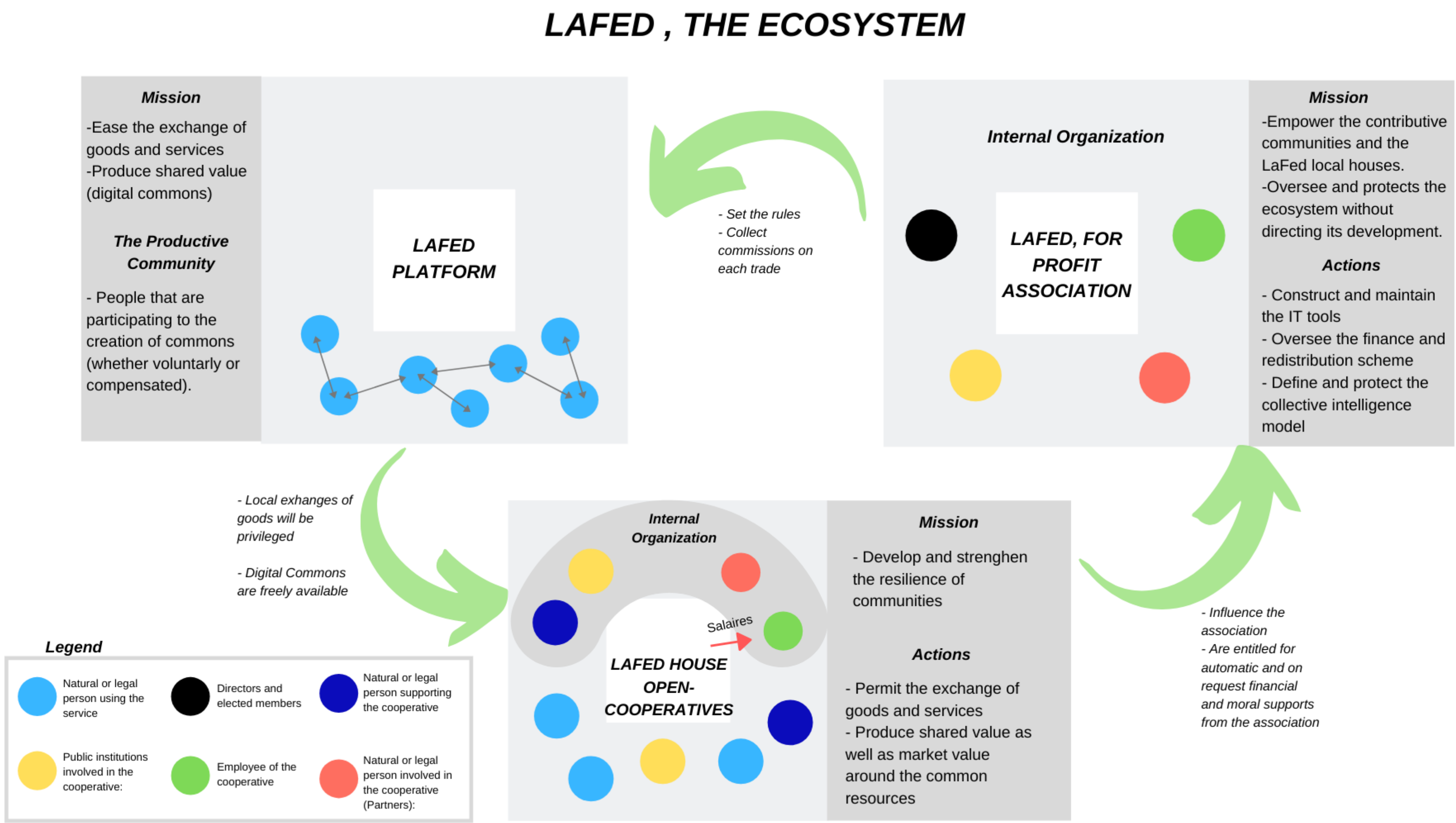
Appendix 2: The collaborative Economy



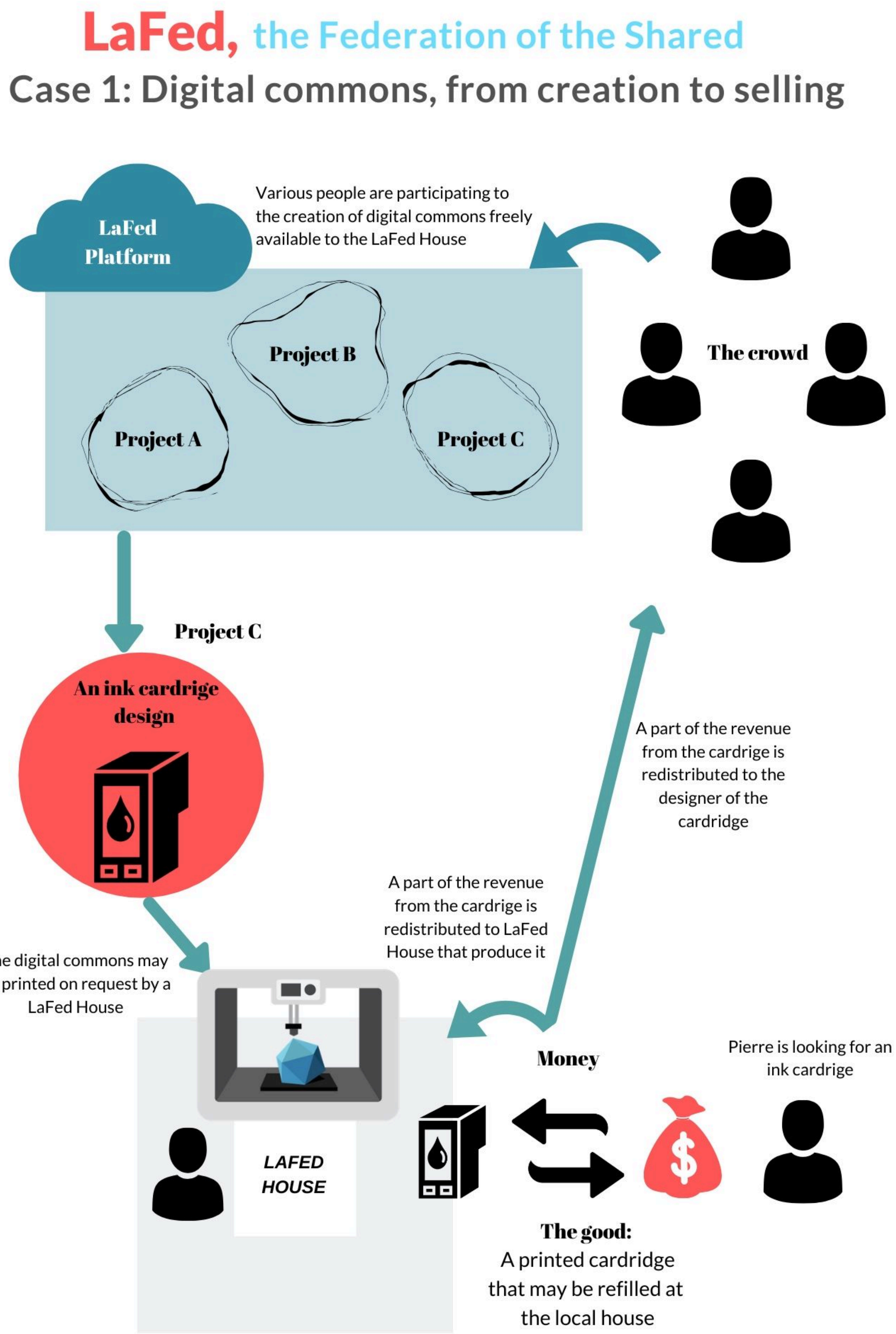
Generative models that are described in this thesis may be affiliated as ‘Global commons’ or ‘Local Resilience’ initiatives, according to the matrix developed by M.Bauwens.

In fact, this matrix “attempt to provide a birds-eye-view of the initiatives that utilize P2P social dynamics and technologies by introducing four quadrants. Each quadrant stands for a specific scenario in which a dominant force determines the de- sign of the particular networks to facilitate specific outcomes. The forces at play want to protect their interests through the control of technological platforms, which encourage specific behaviours but discourage others.
(…) The vertical axis presents a polarity where the top (up) indicates the central- ized control of the digital production infrastructure and the bottom (down) for the distributed control of it. The horizontal axis relates on one side (left) to an orientation towards profit maximization versus on the other side (right) an orientation towards the commons. In addition, at the top are the infrastruc- tures with global orientations, and at the bottom initiatives with more local or ‘distributed’ orientations. So, the left side can be called ‘extractive‘ because it impoverishes the natural and community resources it uses. The right side is the ‘for-benefit’ side that aims to create common good value either at the local level or the global level. This latter side we also call ‘generative‘8 as it seeks to add value to communities and commons, both social and environmental” (Bauwens, Kostakis, & Pazaitis, 2019 — pp.35-36)

Appendix 3: LaFed, The Ecosystem

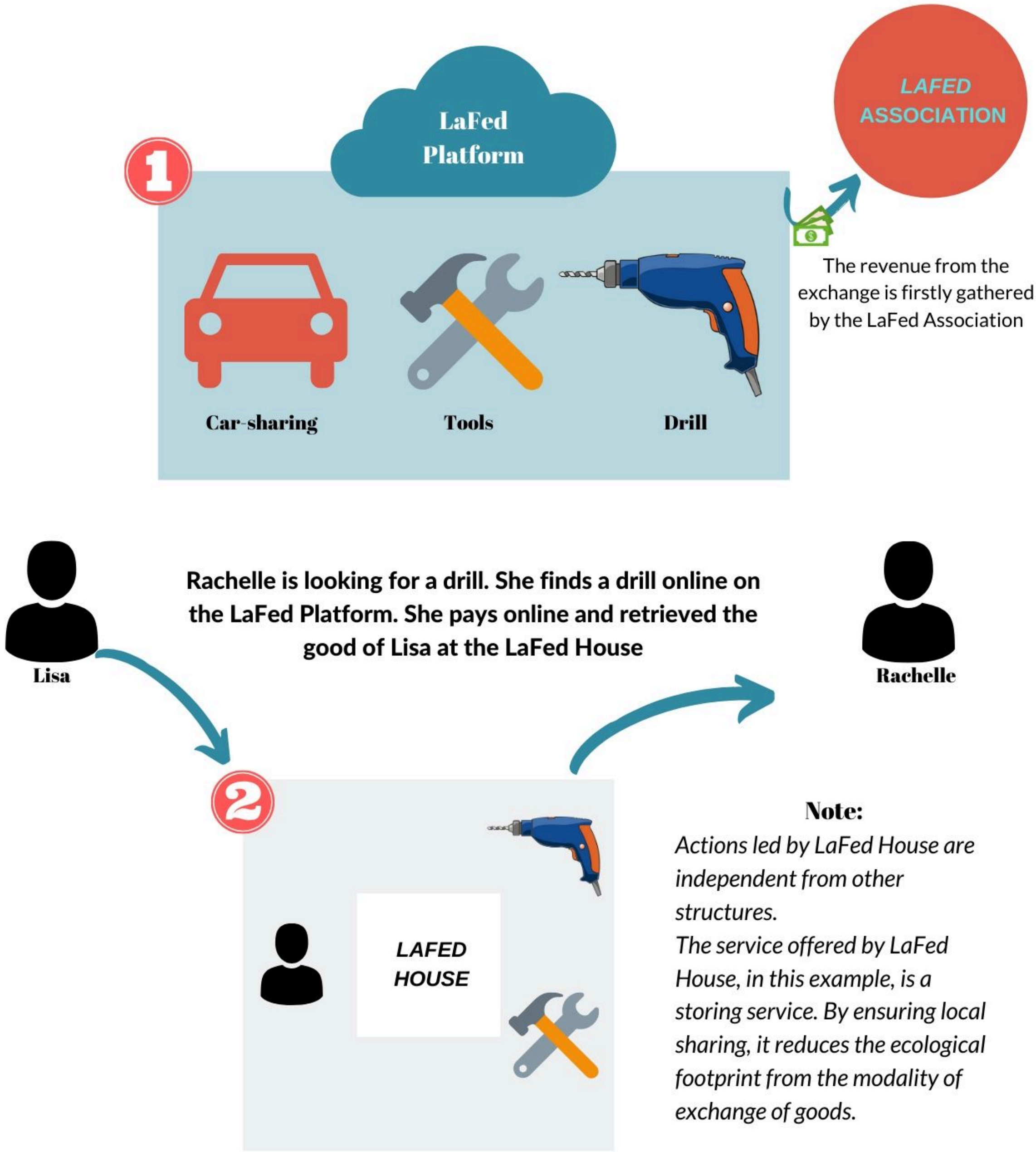


Appendix 4: LaFed: Illustrative Cases



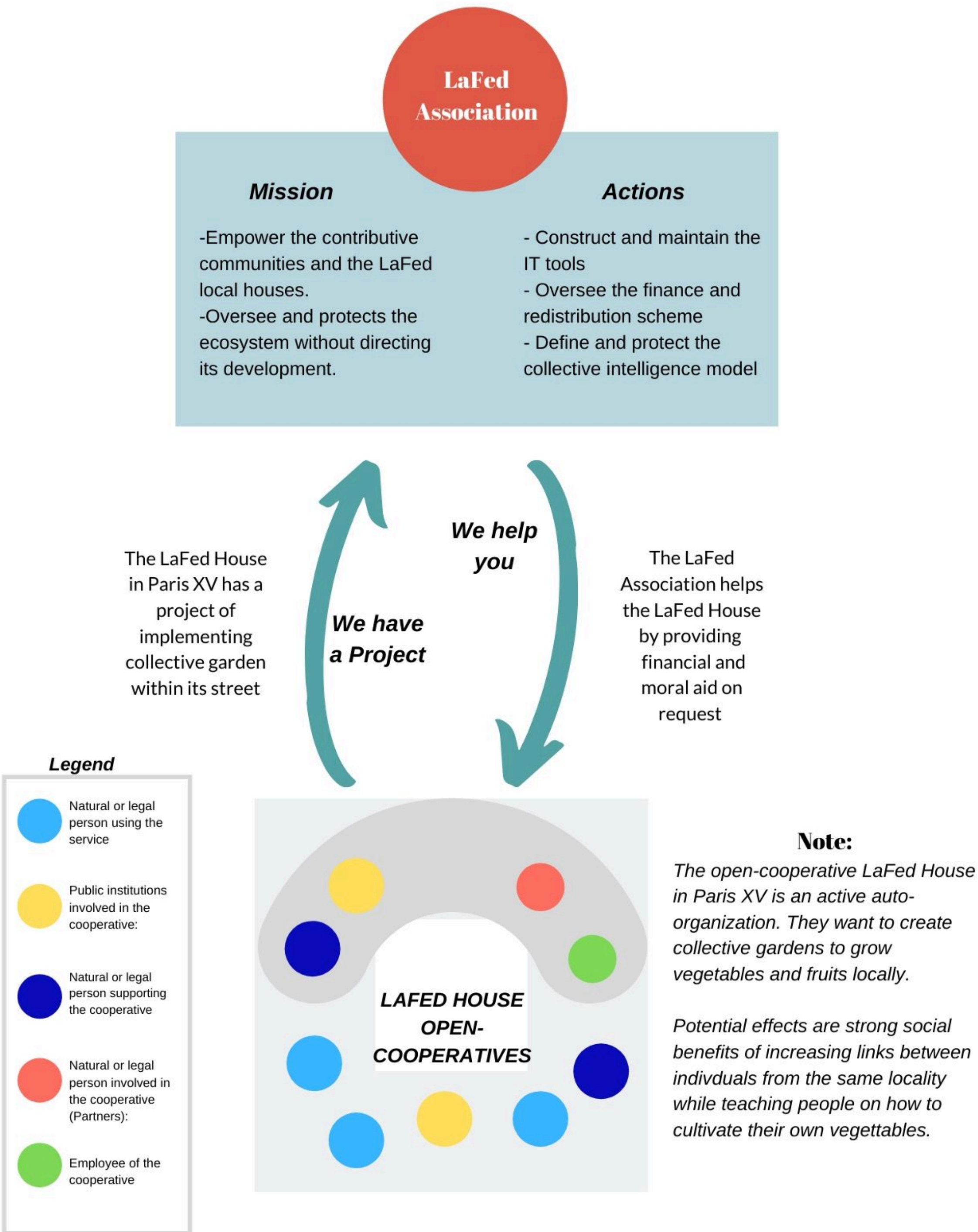
LaFed, the Federation of the Shared

Case 2: LaFed House Actions



LaFed, the Federation of the Shared

Case 3: LaFed House Initiatives



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