Schumacher College

University of Plymouth

DISTRIBUTED NETWORKED BIOBASED ECONOMIES

A dissertation submitted for the degree of MSc in Holistic Science

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Contents

Abstract

> *"What is the meaning of democracy, freedom, human dignity, standard of living, self- realisation, fulfilment? Is it a matter of goods, or of people? Of course it is a matter of people. But people can be themselves only in small comprehensible groups. Therefore we must learn to think in terms of an articulated structure that can cope with a multiplicity of small-scale units."*
>
> E.F. Schumacher

Distribution is a strategy used in information systems architecture to increase fault-tolerance and overall resilience. Decentralising or distribution of energy generation improves the resilience of electricity supply compared to centralised big power stations with losses due to transmission lines. Distributed production can further increase the resilience of societal systems, while allowing cultural diversity and certain degree of self-determination. It could mitigate destructive patterns of large scale economies through concentrating on small to mid scale applications. Community ownership as well as local control and management of resources and natural assets establishes stronger communities, streamlines supply allocation along local needs and priorities while amplifying self-reliance and decreasing dependence on global markets and big business. Such structures could organically configure themselves based on bioregions. Electronic communication embracing open source principles through the Internet constitutes the base for equitable access to information and education worldwide, fosters collaborative, cooperative modes of working, interacting and sharing, and can be beneficial for any kind of project through the participative integration of potential contributors all over the planet. Costs of new developments can be driven down through sharing of information and experiences. Facing peak oil also means finding alternatives to oil products. Many such artefacts can be produced from biomass. Biorefineries are installations which convert biomass into usable products, like fuels, bioplastics, solvents or chemicals. The correspondent technologies are still in infancy; their development requires massive investments. Some are already available and suitable for small scale distributed economies, others might become over time. A distributed scenario encompassing technological advance requires appropriate materials; biorefineries could be instrumental in providing them through the conversion of biomass. The biggest challenge to this vision is the allotment of available biomass resources to different streams: food, clothing, energy, materials, arts and construction. Prioritisation along local conditions would generate regional differences and adaptations. Algae biomass holds amazing prospects. However, its implementation is all too uncertain today.

Chapter 1

Introduction

1.1 MSc in Holistic Science

This paper constitutes my thesis for the MSc degree in Holistic Science, awarded by the Schumacher College in Devon, in collaboration, supervision and accreditation of the University of Plymouth. Both institutions are located in the United Kingdom.

The MSc programme consists of studies of Goethean science, a phenomenological approach for scientific enquiry, and the philosophy of wholeness in nature. It imparts lectures on the science of complexity, chaos and Gaia theory (the study of the planet as a living organism) and their implications for the research of natural phenomena. With this academic foundation it prompts students to explore applications of this material in the realm of sustainability, education and ecology. Students also take part in three weeks short courses with external participants, this year dealing with topics like economics, sustainable design and development.

1.2 Background

Before joining the programme, I have been working as an electrical draftsman, musician and later as software engineer. Experiencing and observing today's threats arising from ecological, social and economical problems, I committed myself to contribute to a transition to a more sustainable human culture. Participating in the MSc has had tremendous impact on my world view and my perception of my role in the context of the web of life, especially through bestowing me with a positive attitude that a profound change of society and the way we interact with the planet and all its beings is indeed possible and feasible.

Finding a dissertation topic however has been a challenge for me, as I could not directly relate my previous professional experiences with the teachings received. In January though I participated in the short course "Can the Earth Survive Capitalism", where the notion of open source as a revolutionary way of sharing and collaborating information had been brought to discussion by a course participant. As an IT professional I was of course very well acquainted with the open source software community. I felt inspired to incorporate this element into my dissertation, but I could not determine an appropriate context yet.

Richard Douthwaite, who taught in the last week of the same course, introduced me to the notion of biobased economies (while also articulating his proposal of nested currencies), a growing field of research on renewable resources as substitutes for goods produced from crude oil. Although the latter was a completely unknown subject to me, I was thrilled and decided that I wanted to investigate about these issues.

It has been through another course lecturer, Ezio Manzini, instructor during the "Design for Sustainability" course in February, that I finally assembled the basic pieces for my work. He was speaking of "distributed systems" in the context of social innovation and interconnected communities. Distributed systems was a concept well known to me through my work with computer networks and complex IT systems in organisations. I became intrigued to analyse how distributed systems thinking could extend current initiatives like local food production and renewable energy generation while not ignoring the advances in technology achievements of modern society. In order to not remain in a complete theoretical exercise I saw the study of biobased economies as perfectly complementary for my work.

1.3 The Dissertation

In this thesis document, I try to amalgamate the idea of distribution with an open source model based on renewable resources. In a first part, a very short recapitulation of major challenges of today's society leads into a metaphor from complexity theory suggesting a way to understand the current drive for change. Afterwards, I introduce distributed systems from an IT perspective, followed by a discussion of real world networks, deriving from their characteristics some possible implications for a networked human culture. A chapter presenting the general vision of distributed, resilient networked communities precedes the second part, where I look at some of the technologies for the replacement of oil based production.

In this thesis I ventured addressing big questions, while attempting to not loose sight of the detail; I tried to remain faithful to my convictions while making an effort to not become vague and indulge in speculations; I dealt with many issues but strove to provide evidence. It has been a challenging project, but I am very happy with the outcome.

1.4 Methodology

The technologies and processes around biorefining are still in research and development; practically no book literature is available yet. Most of the information I gathered from online resources: web sites, forums, and electronic versions of journal articles, which then I synthesised, interpreted and put in context with distribution. A personal meeting with Mr. Bert Annevelink of the University of Wageningen, in Holland, has been a fruitful experience, as I got a grasp on the reality of biorefining. On his request, the meeting minutes of this conversation are attached in the appendix.

Although composing a document on aims and objectives has been helpful in clarifying my ideas, the core of my work evolved in the interaction with the different topics. This is in line with the academic and methodological content of teachings at the Schumacher College, which encourage to delve into the subject of study in a phenomenological attitude of immediate interaction, letting issues and questions emerge during the course of the investigation.

1.5 Acknowledgements

I would like to express profound gratitude to my supervisor, Rob Parkinson, from the University of Plymouth, for his invaluable contribution in streamlining my thinking and guiding me to find the real kernel of my interests. His very supportive spirit encouraged me to follow my instincts and distil my amorphous idea soup. I also express infinite appreciation for my main teachers at the Schumacher College, Stephan Harding and Brian Goodwin, who have set up an incomparable and unique academic curriculum which does not only nurture the intellect, but also the spirit and the heart. My time at Schumacher College has been an inestimable experience which changed the course of my life and utterly transformed my world view, the way I relate to the planet and all living beings and finally my own essence. It is thus all the same important that I include all my colleagues of the MSc class in my gratefulness; the life period we shared has been a beautiful and enriching exercise in communal life while taking care of each other helped us grow. Thanks also to all the staff at the College, not only for being instrumental in conferring to this place an unrepeatable aura, but also for inspiring conversations and healthy relationships. Of course I want to credit Richard Douthwaite and Ezio Manzini for sparking the ideas which lead to this dissertation topic. Appreciation is also due to Constantin Dunga, a short course participant, who put across the idea of open source during a session. Specific gratitude also to Sebastian Eslea Burch and his parents Joan and Nigel, who hosted me during the last month of the dissertation in Asturias, north of Spain, where I wrote large parts of my dissertation while helping in the mornings in their beautiful organic farm, giving me opportunity to balance the mental work with physical activity. Similarly, I spent a week in Wageningen, Holland, as a guest of Natalia Eernstman; this week allowed me to meet Mr. Bert Annevelink, from the University of Wageningen, leading in biorefinery research. The meeting has been exceedingly valuable as Mr. Annevelink has been my only direct contact with professionals of this technology. I thank my parents and my family for their endless love and support for everything I do in my life. Likewise, everybody I have had any type of relationship with - I believe that every contact contributed to shape the person I am today. And finally, I pay tribute and honour to all living beings, Gaia and the entire universe, without which I would not be, trying to return this infinite gift with love and compassion to all existence.

Chapter 2

Scenarios For The Future

> *"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."*
>
> Thomas Edison, 1931

2.1 Starting points

2.1.1 Peak Oil

Fossil fuels are at the base of our modern society [1]. They made the industrial revolution possible (thanks to coal), and accounted for the economic growth in the 20th century. Fossil fuels have been created by the earth's processes over millions of years. Their availability is clearly limited, as we take much more out of the earth's crust than nature is able to build up. It is obvious that this is a dynamic which cannot last indefinitely. There will be a moment when there will be simply not enough fossil fuels to drive our economies. This moment will come faster the more populations world wide are adopting a western life style of consumption and growth based economies fuelled by fossil resources. There is little dispute over the fact that there is a quantitative limit to these resources. There are fierce debates though about when peak oil will happen. The estimated reservoirs on the planet differ for every fossil resource. For oil, many studies suggest that peak production has been reached or will be reached soon (Figure 2.1 summarises different predictions in one graph).

2.1.2 Climate Change

Apart from the economical and "accounting" impacts, but more urgent and threatening, are ecological consequences associated with peak oil. The effects of burning fossil fuels for energy generation and transport on the climate have been intensively discussed, and thanks to independent scientific research with broad participation grounded on elaborate consensus methodology, it is widely accepted now that fossil fuels exhausts are influencing global climate through substantial CO_2 emissions [3] (see Figure 2.2).

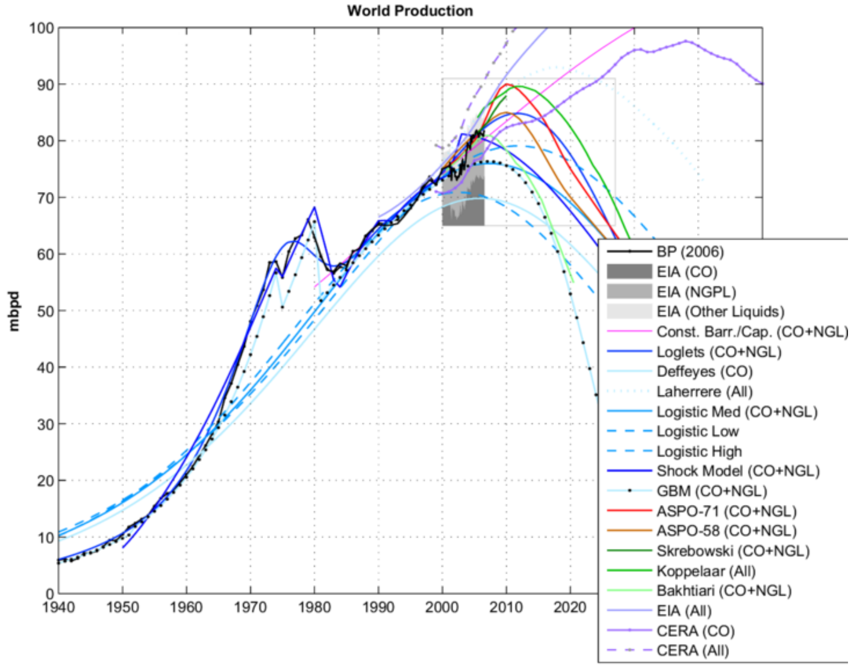

Figure 2.1: Summary of world oil and natural gas liquids (NGL) production forecasts. (Source: The Oil Drum [2])

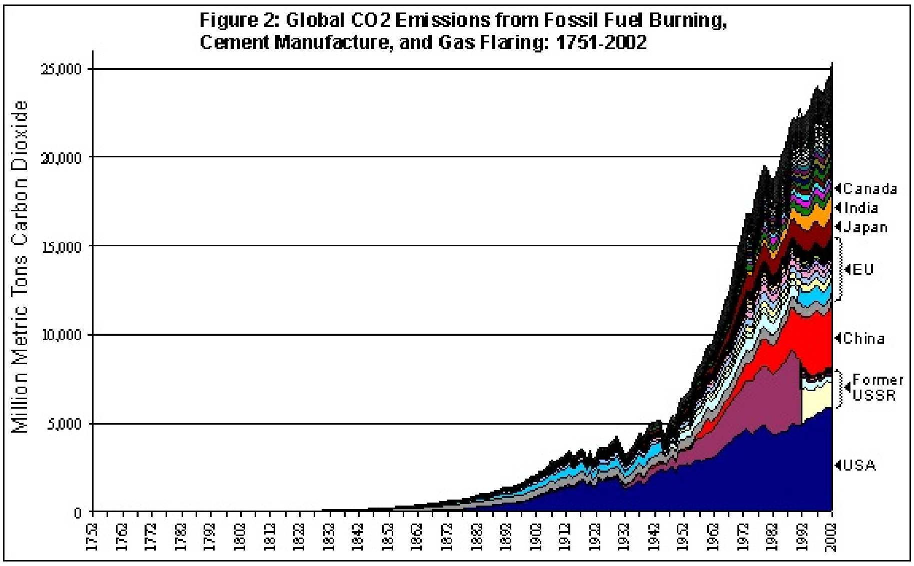

Figure 2.2: Global CO_2 emissions from fossil fuels burning (Source: U.S. Environmental Protection Agency [4])

2.1.3 Globalisation

Cheap energy from fossil fuels catapulted humanity into globalisation, which is basically rooted in free market ideology. This entails circulation of products to every corner of the planet, creating a new form of economical interaction. While some global players enormously profit from this type of economical activity, there is broad resistance to unbounded global free markets. Many thinkers, NGOs, and third world nations have pointed out how globalisation is detrimental to local economies, especially in poor and rural areas. Resources are drained to cities, while whole national economies are restructured for the service of global markets. Rural communities get disrupted, while at the same time capital and resources concentrate in cities. This phenomenon feeds back into the macro-economy by requiring even more resources, as cities generally imply a life style based on high levels of consumption. Globalisation affects also the social fabric of people as well as their psychology. The tendency to loose identification with the local place due to economic forces pushing towards homogenisation and uniformity of culture have been discussed in [5]. Individuals also have to cope with the lure of globalisation promising that well-being is coupled with more consumption. With faster modes of interaction and physical travel, not least through fossil fuel transport systems, but also through the new media of communication and the ever increasing pressure from business and work environments to be competitive and successful, the lives of people assume a faster pace often accompanied with stress symptoms and loss of social cohesion.

2.2 Where Do We Go?

In [6], Rob Hopkins illustrates the vast range of scenarios that have been devised about how our future could look like. The scenarios are organised in three major groups:

(i) Collapse of society as we know it

(ii) Adaptation through technology and economic growth

(iii) Evolution through a change of mindset

Assuming that we want to move forward as a human species and not fall back into pre-industrial modes of living, thus escaping a collapse scenario, we have to address the problems listed in the previous chapter. This means that:

1. We need to find alternatives for oil products
2. We need to limit our emissions and strive towards pollution-free modes of living
3. We need to bring about focus on more equity and well-being into economical activity
4. We need to recreate fragmented communities and strengthen social cohesion

It is appropriate to remark at this point that there is no way of predicting which of the scenarios will actually unfold. Unpredictability is a realm embraced by complexity theory. Thus, this theory could offer insights on how to approach current processes in society.

2.3 Self-Organisation and complex systems

So how do we achieve those aforementioned goals? It is interesting to note that people are trying out new forms of living and interacting all over the world. From ecovillage initiatives, to transition towns, to slow food movements, organic agriculture and permaculture institutes, co-operatives, the open source community, social innovation projects, and many more: these are all examples of how a vast part of the human population is self-organising in order to tackle the challenges posed by the modern world. Threatened to the very foundation of survival, individuals start projects and grassroots movements in order to experiment with new approaches and propose solutions for a more sustainable way of living on this planet.

Self-organisation is a characteristic of complex systems. Wherever self-organisation occurs, we encounter the phenomenon of emergent properties. These appear out of the interaction between the components of a system. This means, they can only manifest through interrelation of the components of a system. Therefore, we could deduce that through modern means of communication, travel and information the human species is building up new links between all the components, in this case the people, who according to complexity theory, would foster the emergence of new and unexpected phenomena.

The history of humanity displays a diversity of different social systems, empires and power structures. However, even the largest empires eventually reached physical boundaries. At the same time, although maintaining efficient communication links through couriers, carriages or fire signs, social structures tended to be confined to local areas like villages, castles and later cities (which only exploded in size and population since industrialisation; in the 18th century, London as the biggest city accounted for over a million inhabitants). While grouped in counties, principalities, duchies, republics, city states, kingdoms, empires and so on, human individuals were focused on local connections.

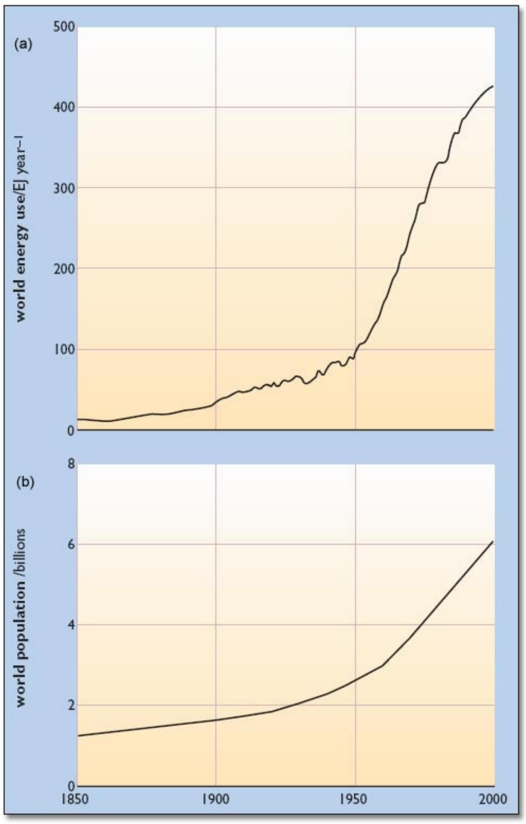

Figure 2.3: World energy consumption and population increase since 1850 (Source: OpenLearn LearningSpace [7])

As far as known history is concerned, we have never had a situation of global interconnectivity, which, empowered through modern communication technology, has raised the level of complexity to that of the current system. Over-connected systems however are more prone to collapse. According to complexity theory, systems work best at the “edge of chaos“, a state near the bifurcation from order to chaos. Can we as a human society tune ourselves into this dynamic state?

It is important though to not misuse the concept of complexity. There are many levels of complexity which could be applied to human societies: the number of agents, the number of connections, the complexity of social structures and social roles, the economic system, the increased impact on ecosystems, general structural as well as functional complexity, the technological aspects, and many more. Therefore, we can not analyse complex systems as an abstract entity, infer some basic principles and hope to be able to predict a future optimal social organisation and structure (this would anyway contradict the general postulate of complexity theory, that complex systems are unpredictable). What we can say though is that the increasing complexity of humanity requires increasing energy and resources supply. Figure 2.3 illustrates how population growth and energy consumption have augmented exponentially.

2.4 Dissipative Structures

In nature, most complex systems are dissipative structures. Such structures are defined as being far from thermodynamic equilibrium. This basically means that they are not closed systems, they are open: they share inputs and outputs with their context, their environment. These inputs and outputs generally take the form of energy and matter. All living systems are interpreted as dissipative structures. Humanity can be viewed as such a structure too. Dissipative structures, when continuously fed with more and more energy, generally will tend to reach a point of instability where they cannot maintain their structural integrity. They will adjust to the new levels of energy in order to deal with this higher energy state, exhibiting fluctuations or phase transitions. The most illustrative and simple example is the phase transition of water to steam when sufficient energy in form of heat is summoned. The point where fluctuations or phase transitions begin to occur are referred to as bifurcation points in the context of complexity theory.

Through our interference with the dynamics of the planet, the system as a whole attained a state of imbalance and fluctuation. Evidence for this imbalance in the planetary system is, on the ecological level, climate change, which, unstopped, has the potential to cause a mass extinction. The sensitive fluctuations of the global economic system are also indicators of augmented instability. According to Ilya Prigogine, the pioneer of dissipative phenomena study, for bifurcations to result, two requirements need to be met: systems need to be far from equilibrium and non-linear [8]. In the same paper, he attests non-linearity to society as every person’s action may influence actions of others. Therefore, non-linearity increases with the size of society. This effect is even magnified through modern information infrastructure, with its potential to multiply the number of connections. Connecting social phenomena with the sciences of complexity is gaining wide support [9].

What I am suggesting here is just a metaphor to understand why our system has become unstable. At this point, in the dissipative structure analogy, we would find ourselves at a bifurcation point: the constant rise in energy levels our society needs to function would result in changing the structure of the system, effectuating a transition from one state into another. It is interesting to observe that the Transition Town movement also uses the term “transition“ to describe its main rationale.

One result of the constant energy influx into the human system has been the self-organisation into a network society [1], which has been denominated as the "information age", on which Manuel Castell extensively elaborates [10]. He concludes that

> *"...dominant functions and processes in the information age are increasingly organised around networks. Networks constitute the new social morphology of our societies and the diffusion of networking logic substantially modifies the operation and outcomes in the processes of production, experience, power and culture."*

The network pattern gradually transforms all domains of social and economic life. Currently though, many structures do not yet reflect this network topology, and display centralised configurations. For example, electrical power is still mostly generated in centralised units [11]. The finance-centred economic order tends to foster the centralisation of capital, with the consequence of concentrating also resources and population into mega-cities.

There is no doubt that our present system offers many important achievements that we might want to keep, like communication tools, the Internet, travel and transport opportunities, computers for processing and storage of information, scientific machinery - you name it. At the same time, the problems with the current model have been documented extensively in literature and media. So the question really is, can we combine these achievements with a sustainable and harmonic way of living, which not only does not harm the environment, but also enhances our well-being and nurtures communities, rather than producing fragmented cultures [12]?

Through this excursion in complexity theory and dissipative structures, I intend to claim that it might be illusionary to think of an advanced complex society like ours with a low energy consumption. Nevertheless, it is not necessary to think of a regression into low-tech societies as a logical consequential collapse. The crucial point is that we would need to supply *enough* clean energy into the society to sustain it. As fossil fuel extraction will peak, the energy must be supplied by other resources. At the same time, I contend that adapting our structures could be crucial. As a whole society we are very fragile in the current system: a stock market crash in New York will have impact in Tokyo as well and in fact would affect the global economic system. Likewise, shortage of fossil fuel supplies would inhibit our current system from working and would inevitably push vast sections of society into serious crisis.

In the following chapters I will depict some possible strategies for sustainable living based on decentralised topologies. After introducing a general understanding of decentralised and distributed systems thinking, I will show some examples, like the Internet, renewable energy schemes and finally focus on physical resources for products development.

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[1] Nobody designed the network society, therefore it is a product of self-organisation

Chapter 3

Distributed Systems

> *“Resilience is about making communities more modular so that they can supply their core needs but they are all still linked into each other.“*
>
> Rob Hopkins

3.1 Information Technology

Distributed systems is a concept well understood in the IT world. It denominates computer networks which run as a single system, but are constituted by multiple computers. The computers are connected through a network, making the location of the single machines transparent: it doesn’t matter if they all are in the same room or residing on another continent. Another feature of distributed systems is the diversity of its components. Every participant node in such a system can run on different kinds of hardware, software and infrastructure. Whereas one node can be a supercomputer, another can be an ordinary PC; while one computer might run Windows, others can be Macintosh or Linux machines. What makes them working together is a set of agreements they adhere on, usually called a protocol.

The most famous example of such a system is the Internet. On the Internet, we can exchange information, media and other data through the use of a program called browser. In order to do this, all participants in the Internet must have a common means to understand each other - a common protocol. Anyone who has been on the Internet might have noticed the leading “http://“ on the browser’s address line. There is all the magic: by using the HTTP (HyperText Transfer Protocol), systems can exchange information over the Internet, independently of the hardware and the software used [1].

So why implement distributed systems in the first place? Some of the reasons are obvious:

- Connect geographically distant nodes together
- Exchange information between nodes

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[1] This is a simplified description of how the communication on the Internet works, but it is sufficient for the context of this paper

- Scale a system to be able to include more and more nodes

One of the most important motivations to build distributed systems is to increase *resilience* (IT professionals tend to prefer the term “fault-tolerance“ to resilience). Therefore, distributed systems in IT are mainly concerned with handling failures (for example, a node must be capable of dealing with an interruption of the communication to its counterpart). In fact, the Internet has originally been devised by the US military forces. They wanted to design a system that would be capable of working even if some of the nodes would be hit and destroyed by an attack. Originally called ARPANET [2] and consisting of just four computers, it spread all over the world now encompassing over half a billion computers with an estimated number of users of about one and a half billion worldwide as of March 2008 [13]. This certainly proves that the system scales very well!

The online Merriam-Webster Dictionary [14] defines resilience as

> *An ability to recover from or adjust easily to misfortune or change.*

The Internet has been designed exactly to be highly resilient. Its main architect, Paul Baran, in 1964 published a paper on U.S. telecommunication infrastructure which would survive a “first strike“ [15] . Baran was trying to conceive a perfect distributed network without any control centre of crucial importance.

It is evident how ingenious this approach really is. A heavily centralised system would be much more vulnerable to damage. Nevertheless, Baran could not foresee that his ideas would eventually lead to the spread of a global communications network. He tried to think of an *ideal* system: a perfect distributed system, where there are no hubs and concentrators at all. However, in nature, things tend to grow *organically*: they self-organise from the inside. Thus, the Internet eventually grew into a Small World configuration [16].

3.2 Small worlds

In [16], Mark Buchanan illustrates how networks are ubiquitous in the natural world. More interesting though is his analysis that many of these networks obey surprisingly self-similar rules. They follow a pattern called “Small World“, a term which has been coined by scientists Watt and Strogatz in 1998 [17]. Configurations following this pattern display an interplay of order and randomness. In order to mathematically model such networks, the scientists were using highly ordered networks, but then introduced some random connections. The Wikipedia entry defines that

> *“a small-world network is a type of mathematical graph [3] in which most nodes are not neighbours of one another, but most can be reached from every other by a small number of hops or steps.“* [18]

The parameters on which small-world networks are identified are

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[2] ARPA stands for Advanced Research Projects Agency of the U.S. Department of Defense

[3] The mathematical description for networks

1. The clustering coefficient
2. The mean-shortest path length

The higher the clustering coefficient, the more connections to its neighbours does a node have. The mean-shortest path length describes the average distance (how many steps) between two nodes. Small-world networks have high clustering coefficients with small mean-shortest paths. They are characterised by having some hubs with many connections while most of the nodes are not concentrators. Thanks to these hubs, mean-shortest path length decreases dramatically. It is into this configuration that the Internet eventually evolved.

Buchanan explains that, through many social experiments and studies, it has been shown that our social networks are small-world networks. He also reports on other phenomena that follow this pattern: the growth of cities, the Internet and business firms; the neuronal network configuration in the human brain; human language structure; or the gene network interactions. Small-world networks it seems are ubiquitous in the real world.

But then, we could argue, if all these phenomena are organic and natural, where is the problem? What is wrong with city growth?

The problem resides in the unsustainable interaction with the context. Human society is not a closed system. It is a living entity, embedded in a context: the environment, the planet, and ultimately the universe. In the previous chapter we have seen that living entities are dissipative structures: they function far from equilibrium, by constantly adapting to circumstances of their environment, with influxes and outputs of energy and matter. In the above examples, the gene pool, although featuring a small-world network structure, is embedded in living cells, regulated by the biological system. The neuronal network in our brain, apart from being confined through physical dimensions of the skull, will not grow endlessly. The growth examples merely document how network systems tend to *structurally* organise themselves in the natural world.

3.2.1 Limits and Resilience

The city growth, and with it the economic growth, even if following a small-world network pattern, has been made possible thanks to massive centralisation and attraction of resources. In other words: This growth reflects a fundamental disregard and nonobservance of the notion of limits. Especially in the case of cities, there is (not least through globalisation) the implicit assumption that there is an incessant influx of resources. Clearly, most cities can not provide for their own needs, they plunge into a dependency from long distance imports. Obviously, if for any reason the supply of resources declines, a city will not be able to sustain itself. So limits are not only imposed by the physical amount of resources available, but also from the fact that through external factors like economical or environmental disasters a constant provision of goods might not be expectable.

Similarly, through globalisation and the advertisement machinery, even rural settlements with a western life style get flooded with products from far away. The current economic model mandates continuous economic growth in order to function. Economic growth is measured by the Gross Domestic Product (GDP) index, which basically measures how much goods and services are being produced. Therefore, a growing economy requires a growing GDP which translates to more goods and services produced. This only works if there are the markets for these products. Thus, businesses, through their power, media and advertisement, all along politicians constantly blare at us that consumption is essentially good and that we need always new and better products. Industrial mass production based on cheap resources (like plastics from oil) obliterate local crafts in non-urban villages and towns, making these also dependent on distant resources, draining the local economies of money and skilled people loosing their incomes.

In developing countries, the growth mantra restructured whole national economies to produce for export in order to attract foreign currency and boost their national GDP. While their economic indicators might have improved, their resilience in terms of basic food supply and local manufacturing has certainly declined, requiring food imports from other places. By following western ideals, they also import items produced elsewhere in order to satisfy an affluent elite, aggravating their dependancy.

Apart from the dramatic effects of pollution and inequality that this system evokes, it unveils an evident deficiency in terms of fault-tolerance or resilience. If for any reason the supply of resources ceases, the system collapses.

So far, challenging answers to the postulate of limits to growth have been based on technology as the factor improving efficiency allowing a perpetuation of the growth paradigm [4]. Such responses taste merely of a hopeful magic in the future. And notably, it is efficiency that reduces resilience in the first place. Economic efficiency is focused on limiting costs. An effective way of limiting costs is eliminating redundancy: agents in the system do only what they can do *best*. Furthermore, only profitable activities are pursued. Thus, in order to keep costs down and profits high, diversity and redundancy is annihilated by concentrating on few (economically) optimal processes. What follows is that the system lacks of responses to disturbances as there are no options to revert to. Ironically, right in the financial world this threat is recognised by the recommendation of "diversification of investments" in order to reduce possible losses if one item in the portfolio performs badly.

Approaching the issue from a resilience point of view, the vulnerability of the whole system to critical incidents is clearly exposed. The history of the earth impressively reminds us that unexpected events are always possible. Resilience theory in ecology research encourages to include external disturbance scenarios in any social-ecological resilience assessment [19].

By making us mutually economically dependent over long distances we are not able to cope in a crisis situation. The menace of Peak Oil should ring all our alarm bells. A long-term sustainable economy must observe the notion of resilience while being highly aware of limits. By sourcing for needs locally, limits are experienced and embraced in the human - ecosystem interaction directly. Local availability of resources can confer a sense of *enough*. As every place is different, local solutions and adaptations would crystallise, taking advantage of local abundance (like sun or wind) while economising on scarce resources.

In a distributed scenario, there is a high degree of redundancy, as many functions are performed in many areas. This also allows for a high degree in diversity of approaches, solutions, variations, adaptations and customisation of the way of doing things. Therefore, in crisis situations, societies can adapt and cope with changes much better.

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[4] As efficiency is defined as output divided by input, apart from the fact that there are also limits to efficiency, evidently if resources dwindle (input), efficiency must considerably improve to counterbalance the effect

In order for a social settlement to be resilient, it must be able to provide for its own needs. Certainly, this also lays bare the biggest disadvantage of this approach: If the crisis is not external (cutting supplies from without), but internal (affecting the local resources pool), the settlement's survival is threatened (which is also true for the current model though) .

But there are important factors who overweight this disadvantage.

1. **Conservation**

   If a human group is living off its local resources, it will tend to conserve its resource base rather than to exploit it. Caring efforts will likely be beneficial for the ecosystems; providing for biodiversity and sustainable extraction will enhance the ecosystems resilience and resistance to perturbation. Crisis situations are still possible, but will be reduced to natural events.

2. **Limitation of impact**

   As local or bioregional systems are self-reliant, even in catastrophic events the damage will tend to be confined to their proximity. With the current model, economical fluctuations in a corner of the world might have significant impact on very distant localities (which might not have contributed directly to the problem).

Localisation does not imply selfish isolated living though. To increase resilience, neighbouring communities can federate in order to build up emergency relief programs. Possible solutions could be the building up of monetary funds or shared emergency food storage, like the system employed by the Incas in South America[5]. In order to combine the advantages of the localisation strategy with cooperative and mutual support in emergency situations, it is therefore imperative to build up an information exchange and support network. Finally, it needs to be said that resilience thinking does not try to eliminate all possible threats - which in a highly unpredictable natural world is just impossible. Rather, it is a mindset which is focused on adaptability to change and recovery from disturbance.

3.2.2 Localisation, Distribution and Decentralisation

To illustrate the decentralisation strategy, it might be helpful to look at some definitions. From Merriam-Webster online:

Localize

1. to make local: orient locally
2. to assign to or keep within a definite locality

Distribute

1. (Apportion) to divide among several or many
2. (Scatter)

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[5] "It is estimated that at any given time in Incan history, there were three to seven years worth of food in the state warehouses". [20]

   - (a) to spread out so as to cover something
   - (b) to give out or deliver especially to members of a group <distribute newspapers> <distribute leaflets>
   - (c) to place or position so as to be properly apportioned over or throughout an area <200 pounds distributed on a 6-foot frame>
   - (d) to use (a term) so as to convey information about every member of the class named <the proposition "all men are mortal" distributes "man" but not "mortal">

3. (a) to divide or separate especially into kinds
   (b) to return the units of (as typeset matter) to storage
4. to use in or as an operation so as to be mathematically distributive

Decentralise

1. the dispersion or distribution of functions and powers; specifically: the delegation of power from a central authority to regional and local authorities
2. the redistribution of population and industry from urban centres to outlying areas

While all these descriptions are often used interchangeably in the context of resilient economies, some of these terms might convey different flavours. The term localisation for example is sometimes interpreted as ignoring the global. In this document, the context can induce slight differences in meaning: while "to localize" suggests regaining control at the local level, "to distribute" and "to decentralise" give an idea of spreading control from the global scale, while the latter to me confers the idea of a certain homogeneity ("decentralise the same") and independence. Generally though, I will use the term "distributed" as it is closest to my personal understanding of increased global resilience through:

- **Self-determination** and autonomy of local entities
- **Self-organisation** of entities from the "bird's eye perspective".
- **Self-reliance**
- **Redundancy** of processes
- **Diversity** of solutions
- **Small-world** characteristics with strong links within the local system and weak links to the outside
- **Interconnectedness** with other entities

Chapter 4

Resilient communities: a vision

> *"Ever bigger machines, entailing ever bigger concentrations of economic power and exerting ever greater violence against the environment, do not represent progress: they are a denial of wisdom. Wisdom demands a new orientation of science and technology towards the organic, the gentle, the non-violent, the elegant and beautiful."*
>
> E.F. Schumacher

4.1 The big picture

Basically, the concept follows a bioregional proposition. The strategy looks at maximising local resilience. Therefore, the general approach is to produce everything which is possible locally. Whenever an item cannot be produced locally, it will be produced at a higher level. In order to cope with ecosystem limits and resilience in all situations, a prioritisation of land usage is probably necessary. Accordingly, local food production is top priority, followed by shelter and health. Everything else (fuels, materials) comes after coverage of the basic needs. This section just lists some of the elements which could fit well into this vision, with no claims whatsoever to be exhaustive and comprehensive.

Bioregions are not completely independent. They follow a small-world structure, as this is the most organic pattern of self-organisation that nature offers. In fact, there is no need for a restructuring of the topology of human settlements. This would be illusionary, a man-made big scale redesign is quite unlikely. Rather, as every system has a history, which can not be ignored, the bioregional model would build on existing structures: villages, towns, and cities. The distributed economies approach advocates self-organisation of people in the first place, so there is no need for designing ideal topological maps of population clustering. However a bioregional pattern is a perfect match to it, as bioregions are not only ecological concepts, but are co-created through the cultural interaction of their inhabitants shaping customs, markets and celebrations.

Localising the production does not imply a return to agrarian societies, as we have already postulated. Therefore, it must be stressed that in this bioregional vision cities would not dis-appear. As cultural centres, melting points for ideas and people, as well as market place and innovation forges, cities are here to stay. However, building on resilience thinking, they need to stop being huge sinks of resources. Rather, they would highly cooperate with the surrounding rural areas, forming an important element of the bioregion. By adopting urban permaculture, green roofs and local energy production, they increase their own resilience and contribute to food security. Through Community Supported Agriculture (CSA) links to the rural areas are strengthened. Such solutions would offer platforms for alternative education for city children (and anyone who needs a break from urban life), offering hands on immersion in agriculture and land based living. Meanwhile farmers can build up connections to the city while sharing the risks of the coming harvest through the share holding of their agricultural business by members. More such social innovation projects transform the current city-rural divide into an atmosphere of co-operation and mutual benefit. Furthermore, cities would constitute the hubs of a small-world network, providing for links to other hubs - other cities and bioregions.

> *"An urban entity is the nucleus of its agricultural and village environs – not [as] an urban entity that stands opposed to them."*
>
> Murray Bookchin

At its roots, this approach consists of self-reliant communities, where needs are gradually fulfilled bottom-up. First priority is local food supply. Surpluses are traded, however in the first place to local urban centres, in order to increase the resilience of the whole bioregion. Energy is based on renewable systems, a crucial pillar of the distributed economy. They are best suited for decentralisation as they can provide energy for small scale at affordable costs, focusing on what is needed. Building materials are sourced locally, there is a long record of experience through the centuries in implementing this. It is only through economical analysis verdicts deeming traditional techniques and resources as "uneconomical" that many perfectly appropriate local solutions have been abandoned. E. F. Schumacher in his seminal work "Small Is Beautiful" pointed out that social entities (societies, groups, individuals) may stick to traditional, but "uneconomical" activities simply because there are other intrinsic values they connect with those activities [21]. Often, local materials are also the best choice for the local requirements concerning climatic traits of the area. Goods are also produced as much as possible locally.

A central element of a distributed scenario is the conversation about scale. E.F. Schumacher's work [21] is the reference on this issue. Small scale applications are generally cheaper for individual units than enormous big projects which in consequence require massive external funding. They then become affordable for communities and also the developing world. Moreover, often traditional technologies (or even new ones for that) are labelled "inefficient" and then dismissed as inappropriate. If a small scale device with low efficiency is covering the needs of a community, what is the benefit of increased efficiency (at maybe higher costs)?

Going local does also not need to mean isolation. Transport will be a very important issue. Fuels are maybe one of the most critical issues. Based basically on petrol today, they clearly need an alternative. Biofuels (biodiesel, bioethanol) have been heralded as the way out, but are facing resistance through the fuel vs. food debate. In a later chapter, I will analyse a very promising proposal: fuels from algae (see chapter 8.4). The much acclaimed hydrogen economy failed to deliver yet, mainly because it requires a big scale re-engineering of the transport system.

Diversity could become key in transport too. While rural areas could build on locally produced fuels from renewable resources, cities could feature integrated transport systems based on electrical energy or other forms of transport, while allowing substantial freedom of movement for pedestrians and bikers. Transport will also rediscover the advantage of water based travel where it is possible.

In brief, peak oil will not obliterate movements of people and goods. Rather, transport would incur in the true costs of motion: not cheap oil would determine the prices, but whatever the alternative will be. Assuming distributed generation of fuels, the latter would not benefit from massive price distorting governmental subsidies. Rather, they would be constituted of true costs of production, making transport more expensive and therefore also more sustainable as less trips would likely to be taking place. This may seem unjust, as less affluent people could afford less travelling. But this dilemma could be alleviated by community owned schemes: fuel cooperatively produced could be distributed to all members equally. Moreover, even at this scale permit schemes could be very helpful: instead of receiving the fuel directly, people could get permits. These could be sold to other individuals who need to move more than others, generating additional income for people who do not want to travel.

Localising all these elements would also invite for another step: embracing local and regional currencies. Money in the form of a local currency will be spent on the local economy. As an example, when we look at big supermarket chains operating on say a town, currency used to buy goods at the supermarket will be drained towards the headquarters, and is unlikely to be re-spent locally. Therefore, the local economy looses resources whenever money is drawn away to other places. Keeping the money local will enhance economic stability in the region. Having an own currency will also allow to adapt prices to the current market situation - much the way national banks do when they devaluate currencies in order to stabilise market forces. A possible scenario would be to have local currencies for local economies, then regional currencies at the scale of bioregions, and maybe a global currency for global trade and travel. Such a system has been described by Richard Douthwaite in [22].

Finally, the distributed scenario would foster the self-determination of people. As food, shelter, health and materials are provided locally, it just makes common sense that higher level political power would lose importance. Communities would decide how they live and how they want to organise themselves. Higher level structures would be used for coordination and inter-local, inter-regional affairs like transport and emergency cooperation. Electronic communications and the Internet provide interconnectivity, free circulation of ideas and global awareness. Open source guarantees access of information to every one and the spread of solutions all over the planet.

In the following sections, we will look a little bit more in detail at some of these issues. It is not the intent of this document to look at every aspect of human societies. Localisation of food production, which is of topmost importance in the context of distributed economies, is being proposed and discussed widely and there is vast amount of information available. Similarly, the political dimensions of self-determination will not be touched in this document, nor will be health, or currency. After reviewing briefly a practical implementation of the distribution principle which is partly in progress, the distribution of energy generation, we will turn to the focus of this work, local sourcing of products through renewable resources.

4.2 Distributed Energy Generation

For a society which combines resilience with modern technological advances, an appropriate energy generation is paramount. Prompted by global warming, the current energy provision system is challenged. Fossil fuels account for the majority of the energy supply worldwide: 80% from coal, oil and gas [23]. Voices for the adoption of nuclear energy as a substitute fail to recognise the biggest disadvantages of this energy form: they require substantial investments and subsidies; uranium mining is polluting and dangerous while its global reserves would not allow a global switch to nuclear energy; reactor decommissioning is costly; and finally, the radioactive waste problem is far from being resolved. Nuclear power is not a renewable source and would conjure new shortage problems.

The World Alliance for Decentralized Energy (WADE) published an article on its web site entitled “Security via Decentralized Energy“ [24]. This article analyses current power generation from a security point of view. In it, the authors located two major types of vulnerability: a) Supply vulnerability and b) Critical Infrastructure Vulnerability. Their conclusions:

> *“Strong arguments exist that suggest a system based on decentralized energy is much more resilient to dangers in any of the above forms.“*

They list the following arguments for the distributed energy case:

- Substantial economic savings via reduced capital requirements
- Increased fuel efficiency
- Significantly reduced pollution including fewer climate destabilising green house gases and health debilitating criteria air contaminants
- Smaller land use footprint
- Heightened power reliability
- Reduced infrastructure vulnerability
- Reduced fuel import dependence
- Most affordable to bring power to communities without modern grid.

Another fact is that 5 to 10% of energy generated is lost in “line losses“ on the way to the consumers.

Central generation is wholly dependent on the grid. Apart from line losses, transmission lines also pose vulnerability threats due to severe weather, sabotage, etc. Power distribution along a distributed strategy reduces the relative importance of any single power source - much like the Internet example, the system as a whole gains on resilience. Power is being generated where it is needed. This helps also reducing costs as there is no need to put up power lines! Communities could build up so-called micro-grids, where they generate their own power needs according to their choices and local characteristics: small-scale hydro schemes, wind energy, solar panels, CHP (combined heat power) and all the range of possible alternative energy sources. These micro-grids can be linked to the existing grid, providing for additional resilience of the overall system, and allowing for a market if this is desired: the micro-grid can sell energy to the grid and “download“ it if it needs so, nevertheless conserving its local focus and providing for the community’s energy needs, so basically always being able to work off-grid.

Community owned infrastructure can link social aspects with the technical. In the UK exists the legal construct of a “Community Interest Companies“ (CIC) [25]. CIC have been created

“...for those wishing to operate for the benefit of the community rather than for the benefit of the owners of the company.“ In order to keep community control over the local energy generation, CIC appear to be a very appropriate instrument. The Transition Town Totnes group [26] created TRESOC, the Totnes Renewable Energy SOCiety, with the ideal to provide local energy to Totnes and the surrounding area. Members buy one share of the company, but only a share per member is allowed, regardless of the amount of investment. Energy profits will be used to finance the infrastructure and its administration. After some years of operations, so the plan, when infrastructure is amortised, any profit can be reinvested in the community, with the members deciding what they want to do with that money.

Generating own power locally reduces independence from distant markets and events, reduces vulnerability and increases resilience. Furthermore it gives also much more political and management power back to the community. I look at a grid of distributed power generation through small-scale affordable units as a powerful tool to effectively break down big business control, the nasty side of globalisation and to obsolete the pleas for nuclear power stations.

The strongest critiques from conventional energy advocates stems from their claim that renewable energy can not provide the amount of energy required. The share of renewables on global energy generation is admittedly pretty small still. However, the major hindrances for a wide adoption do not come from technology. The Worldwatch Institute in its 2008 report states: “the main factors limiting the pace of change are the economic challenge of accelerating investment in new energy options and the political challenge of overcoming the institutional barriers to change.“ [27].

But maybe what we need is not just to replace all the energy produced with a new source. The Worldwatch report further informs that “...well over half of the energy harnessed is converted to waste heat rather than being used to meet energy needs.“ Another fact is that most of the consumers require small amounts of power. According to a presentation of Amory Lovins from the Rocky Mountains Institute, three quarters of U.S. households do not exceed 2.4 kW power requirements. Likewise, three quarters of U.S. commercial customers have average loads that do not exceed 10 kW [28]. As a comparison: average domestic solar panel systems can provide 1.5kW to 3 kW when operating in full sunlight.

The Internet requires electrical power to operate. It would just make sense to match its distributed configuration with the appropriate power generation, so that nodes are also self-sufficient in terms of power. This would certainly increase the resilience of the Internet - and accordingly increase the resilience of any community which is shifting to decentralized, self-owned and small scale power generation.

Climate change and roaring oil prices are putting pressure on the conventional energy generation principles. Renewable energy sources are the only known clean alternative solution. Such sources scale very well, and can be adopted from covering household needs (e.g. solar panels on roofs, a few kW) to impressive installations like the solar plants in the Californian Mojave desert, in the USA (354 MW capacity). Therefore, they are exceedingly well suited for decentralized power generation. Some countries, like Germany, Island or Denmark are already heavily investing in renewable energy.

4.3 Distributed Manufacturing / Bioregional production

> *"The networked environment makes possible a new modality of organising production: radically decentralised, collaborative, and non-proprietary; based on sharing resources and outputs among widely distributed, loosely connected individuals who co-operate with each other without relying on either market signals or managerial commands".*
>
> Yochai Benkler

4.3.1 Clothing, Building, Crafting

The biggest challenge to resilient, modern distributed societies is the question of where do we get our "stuff"' from. In other words, where do we get everything which is not food?

In terms of building materials and clothing, there is a long standing tradition that flourished up to the industrial revolution and later globalisation where needs where covered locally from what was locally available. Surely, commerce has always been taking place, and it has been very important for the trade of textiles since the first merchant routes were established. Trade in itself is not unsustainable; it is today's transport which makes things complicated, as well as the amount of goods transported, which do not follow a logic of needs, but one of consumption.

A big share of today's clothing is made from synthetic fibres. These are currently very inexpensive, not only because of cheap oil for transport and raw materials, but also due to exploitation of labour in developing countries. Peak oil will rise the price levels for such goods. Therefore, it might also look appropriate to think of local sourcing of materials for clothing. However, it is unlikely that we will not get any imports at all. Rather though, reality will allow for a reduced amount of transport and travelling, reflecting real costs of motion. Nevertheless, in terms of resilience, but also as a chance for local artisans, business people and artists, and therefore the regional economy, a revival of local production is pretty likely to occur. Home made garments, small scale manufacturing and shops could be prospering, giving fair share of competition to imported goods which would likely to be more expensive. The latter items could be seen as luxury goods, which are not essential needs, but nevertheless available to people who want them and can afford them.

This principle would apply even more for building materials and furniture. Sourcing and making them locally would suddenly become very attractive and economic. A re-instated wealth of local merchants and craftspeople could arise, recreating faded away networks of human interaction in towns and cities.

For this to become reality, a sustainable cultivation of materials for production would be essential. Therefore, fibre plants like hemp or flax would be crucial to grow, all along trees as resource for wood for furniture and buildings. Every local settlement would need to consult their traditions in order to rediscover ancient patterns of growing resources and harnessing local abundance. Enriched with modern knowledge, for example permaculture and agroforestry, local productivity can be substantially increased. Analogous can be said about any other kind of crafting: pottery, basketry, glass crafts, leather-work, all kinds of needle-work, stone and metal crafts, and so on. Only imagination and of course availability of materials limit the range of possibilities. Especially all products which today are made of plastics derived from inexpensive oil could incur into competition from traditional sources of production.

As for building, a very promising and convenient proposal comes from Compressed Earth Blocks (CEB), a natural and easy way to construct [29]. CEBs are formed by mechanically pressing soil into bricks. Therefore, building materials can be extracted right from where a house needs to be built from clay-sand subsoils which are nearly everywhere to be found. Mortar is superfluous, it is replaced by a mix of the same starting material with water. Machinery is required in form of the CEB press, which according to [30] can even demonstratively be produced locally. Building houses from local materials enjoys of course millennia of experience which we can tap into to produce ecologically sound and aesthetically beautiful dwellings. CEB, adobe, cob, straw bale constructions all along timber, bamboo, etc.: again here local resource availability, climatic and local customs shape the construction methods.

A final word on metals, which are vital for today's economies. Metal mining is polluting and resources are clearly non-renewable. Reserves are therefore finite and for some of them shortages could be encountered soon. Recycling will be pivotal to eliminate the concept of waste in any sector of society, but for metals it is even more important and as a side effect can be economically very efficient and attractive. Some mining is likely to continue, and some small local ores, maybe having being abandoned due to economical insufficiency, could be reopened. An interesting idea has been circulating in some online circles lately. Clays are soils rich in aluminium, which is very versatile and universally employable. An invention has been patented which extracts aluminium from these soils in an inexpensive way [31]. Although lacking of widespread scrutiny of this technique, it may provide for additional locally available metals in the near future.

4.3.2 Modern lives

Today's lives are impregnated by much more items than clothing and building materials. Again, we can assume that peak oil should have significant impact on price structures and resources trading. Nevertheless, a complete collapse of external material influx into local economies and bioregions is little probable. Even if no oil products at all would be manufactured respectively no motorised transport would take place, the most basic outlook must include trade happening through at least water and animal transport. This means that a fundamentalistic attitude to localisation is not adequate and not desirable. Resilience thinking must concentrate on the basic survival needs first, this is what necessarily needs to be provided for locally - in order to guarantee survival. Any other item produced locally will enhance resilience, strengthen the local and regional economy, and provide for jobs and income.

Modern societies have engendered a vast amount of items of undisputed utility and purpose. Attempting to compile a list is bound to incompleteness, but just a few examples: Computers, telecommunication devices, solar panels, electricity generators, high precision machinery, micro- and telescopes, washing machines, vacuum cleaners, tools, trains, planes, cars, etc. Can we produce all these things locally? What do we need, what do we want, what is desirable, what is superfluous?

Indeed, this is the biggest challenge to bioregionalism and localisation. Following the previously introduced prioritisation logic the first step is to provide for the basic survival needs. A modern society though, provided there is no complete or large scale collapse or even extinction-like event, will continue to rely on its technological achievements. Is there space for this in a bioregional distributed vision?

The main contention of this paper is that there is. In fact, every bioregion is likely to feature an urban centre. They could concentrate some resources in order to be able to provide goods which are not able (and/or don't make sense) to be produced locally. For big-scale items like trains, planes, etc. bioregions could federate together in order to provide the required resources. Ownership of such enterprises could be private, but alternative set ups would be imaginable, as some of those commodities are for the public good and therefore crucial for the well-being of the communities. Thus such companies could be managed or just supervised jointly by the bioregional entities, by appointing representatives, creating trusts, or generally adopting so called Fourth Sector models [32], which are basically For-Benefit organisations with social purpose: self-sustaining, socially, ethically and environmentally responsible companies.

Having said that, there is huge potential for local manufacturing of modern products. it is often forgotten that many high-technology appliances started in very modest environments. The first Apple Computer was put together in founder Steve Jobs' family garage 1975 [33]. The first semiconductor company, Shockley Semiconductor Laboratory (from which employees later founded the now famous microprocessor manufacturers Intel and AMD), has been established in a former fruit-packing shed in the Santa Clara Valley, California (later to be known as the Silicon Valley) [34]. William Henry Perkin 1856 produced his first aniline dyestuff out of coal tar in a small hut in the garden of his home in Cable Street, East London (discovery which later ignited the whole business of chemical industry) [35]. These are just a few examples. Many large-scale industrial processes have been started on a small scale. The reason to engage in economies of scale is to reduce costs [36]. There is widespread critique on the current business model which is only focusing on the monetary aspects of economical activity. Numerous thinkers worldwide are authoring information material on the dangers of current business and are proposing new economical philosophies. The tenor of these works converge around themes like ecological sustainability, social justice and human well-being. Going bioregional, as already mentioned, puts the handle on the economy back into people's hands and into the local area.

As any community or region could choose their own way of living their life and organising their social structure, the localised economies dynamics would take the wind off the sails from rapacious (neo-)capitalistic market colonialists. Therefore, every such human group would be able, besides to regulate their own affairs, to chose the level of technology they want to embrace. This may sound very theoretical and abstract, but in a global perspective we have to think of communities in a very diverse cultural world. Technological advance should not force every human being into a specific life style. We should also think of indigenous settlements, low-technology communities, or spiritually oriented congregations. Such societies would be free to pursue their own chosen life style. Of course, if they wish so, they can interact with the world by participating in the global telecommunication networks. They might actively interact with other societies and cultures by nurturing mutual learning and exchange programs, in which people would engage by deliberate choice. Civilisations would cease to be threatened by the unbridled expansive drive of western culture [5]. Even migration patterns would probably assume different connotations.

The analogy to IT distributed systems offers a helpful visualisation for this outlook. Every settlement, region or group can be looked at as a node in the network. It does not matter at the network level how the particular systems behind the node look like; that is, every social group defines its own life style (in IT jargon this would be labelled their "implementation"). In order to keep connections at the network level, an interface is set up. This interface acts as entry point into the community respectively into the network, depending of the direction of interaction. In fact, as we saw in the distributed system chapter, all participants in a network share a protocol, a common way of understanding. This can assume very diverse aspects and layers, like telecommunication systems, or rather political or humanitarian links like participation in regional and world councils, trusts or the like. The interface can be technical devices or persons investing ambassador functions. Arrangements of this type are being experimented in Andean cultures in Bolivia, where self-determined communities, called Ayllu [1] regulate their internal affairs in traditional manner, but appoint an interlocutor which acts as proxy to political and other institutions outside the Ayllu. What this metaphor does is underlining that self-determination can go very well along global awareness.

Facing shortages on oil dependent production, people will naturally concentrate on small scale production. Sourcing what is possible locally will organically align production with natural resources (linking to the discussion of limits and their experience). Products we use from petrol are ubiquitous. Fuels are the most known, and that all plastics are made of oil is also widespread knowledge (hence the term petrochemical industry). The list is endless: from CDs to toothbrushes, from backpacks to shoes, from cases to raincoats, bags, canvas covers, detergents, solvents, fibres, asphalt, lubricants, paraffin wax, tar, and many more. To extract all these materials, crude oil undergoes a process called refining, in which basically it is distilled into so-called fractions. This is the starting point for an immense industry of follow-up products.

Confronted with the threat of losing the grounds on which it is built, this industry is looking for alternatives to oil. The most promising alternative for them is the switch to biorefineries instead of oil refineries. Basically, these new refineries use organic renewable resources (plants, etc.) and break it down into other products. Biorefineries will be discussed in the next chapter. At this point it is just valid to note that there are alternatives showing up for small scale goods production which might enable us to combine high technology with small scale and modern life styles.

4.3.3 Making anything, anywhere

A development which can truly bring along a revolution for small scale production, (bio-)regionalism and modernity comes with the appearance of so-called fab labs. Wikipedia presents fab labs with the following words:

> *"The Fab Lab (fabrication laboratory) is a small scale workshop with the tools to make almost anything. This includes technology-enabled products generally perceived as limited to mass production."* *[37]*

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[1] from the local Aymara language

The fab lab program has been started at the Media Lab at MIT. One of the main driver for the research was the question of “how can a community be powered by technology at the grassroots level“. The magazine Nature published an article [38] with the title “Appropriate technology: Make anything, anywhere“.

The personal computer revolutionised information handling and brought about the information age. The first PCs were derided as toys by the at that time prevalent mainframe [2] computer industry. Modern manufacturing industry may incur in the same pit fall: fab labs are regarded as a playground for freaks at MIT.

The fab lab idea is simple: a printer today prints documents from a computer. With a fab lab, you should be able to print three-dimensional objects from a (digitalised) description. The vision includes the re-printing of fab labs by themselves - self-replication! With it, technology would be made accessible anywhere. One of the core targets of the MIT project is to roll out this technology in developing countries. Currently, there are 13 such fab labs installed around the world [3]. There are installations in India, Ghana, South Africa, Costa Rica, Iceland and Norway. They produce such things as wireless antennas for local computer networks (Iceland), transmitters which help herders locate their sheep (Norway), or sensors which measure the fat content in milk in order to get fair prices (India). The project is still in its infancy, but the potential is huge - it can distribute high technology to every corner of the world, providing things like computer chips or cell phones. Such fab labs can be customisable and flexible. They currently

> *“include a laser cutter that makes 2D and 3D structures, a sign cutter that plots in copper to make antennas and flex circuits, a high-resolution milling machine that makes circuit boards and precision parts, and a suite of electronic components and programming tools for low-cost, high-speed micro-controllers.“*

According to the fab lab centre at MIT [40] , 25’000 USD USD will allow to install such a fab lab anywhere. They promote the project as an “incubator for local micro-businesses“. The possibilities are virtually limitless. Especially if one of their visionary elements of the project will materialise: the digital descriptions of the items to be fabricated should follow the same format and should be freely exchanged between the different units. Therefore, designs could be circulated all over the world and items be replicated in any fab lab! Neil Gershenfeld, the major force behind this technology at MIT, expresses it in the following way: “In theory, an invention from one lab could be made by several others, essentially creating a global collection of local businesses“. This sentence sounds like crafted for this dissertation... This approach follows an open source principle of free information circulation and exchange. Which brings us to the next possible pillar of a future distributed economy: the open source movement.

4.4 Open Source

The term “open source“ has been coined in the software development industry. In a previous essay [41] I have already characterised the open source concept and its possible promotion into

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[2] Mainframes are big computing devices for high-end computation

[3] As of June 2008 [39]

other sectors of the economy beyond the software world. Taking advantage of information infrastructure, ideas and technologies can quickly and democratically be distributed and divulged across the globe, benefiting all layers of society, rich and poor populations alike. Especially in a distributed economy scenario, an open source exchange has the power to shift people into cooperative modes of working. What an immensely profounder well of creativity can be harnessed through tapping into worldwide available minds! Also, costs for new developments can be driven down. Instead of massive parallel investments of time and money into proprietary solutions, running collaborative projects can mean sharing costs and lowering individual costs too[4]. Should distributed economies, enhanced through appropriate technology infrastructure Ĺ-la fab labs and small scale products fabrication, become a reality, a much more equitable world could evolve, where vast populations could be participating in creating new ideas and enhancing technologies as well as products.

There is huge momentum currently perceivable on the ideas of open source outside the software realm. Many web sites on the Internet dedicate themselves to open source developments. They use sometimes differing terminologies, like Peer-to-Peer, collaborative design, or co-design. What is common to them is collaborative creation by different people. The range of open source projects is vast: from open source cars to cell phones, from a complete "Global Village Construction Set“ [5] to electronic hardware development. A list of projects with links can be found in the appendices. Clearly, there is ample motivation and potential for open source development of any item. The open source software movement has impressively demonstrated how powerful the approach can be, challenging multi-national big business firms through democratic and distributed processes - and initially nothing else than enthusiasm and committed time. The exceedingly successful products like Linux (operating system), Open Office (Office program suite), or Firefox (Internet browser) are standing proof of the validity, high quality and importance of collaborative distributed working models. It is just another tool to distribute power to the people, where nobody can monopolise and control information, unleashing a high degree of freedom for the masses, where it gets more and more difficult to dominate and suppress. It is a concept empowering grassroots genuine action. It has the power to contribute to break down capitalistic gigantism and monopoly [6].

A short notice on precaution seems nevertheless appropriate. Like with any other tool, be it a knife or a hammer, there are also potential risks. Just looking at electronic communication for example, threats of psychological Internet addiction are documented, or threats due to business dependence from the net, cyber terrorism, etc. It is in our hands to balance opposites and challenges with opportunities and strengths.

As I already mentioned, this overall vision is not a blueprint for everywhere and anyone. It is just a proposal. It is up to the communities to decide to which extent they want to engage. By first ensuring local self-reliance in basic needs, whatever crisis strikes (except of course devastating natural catastrophes which cannot be factored out altogether), survival is ensured.

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[4] Consider developing new solar cells as an example. Instead of say ten firms developing them in parallel, with each their own costs in research and development, transitioning to open source might lower expenses through sharing of information and experiences. Money would be earned from selling the solar cells

[5] A demonstration project for self-reliant land-based living in an advanced cultural background embracing modern technology at the village level

[6] Epitomised by the " There is no alternative! " [to market driven globalisation] declaration by Margaret Thatcher

4.5 Community and Social Innovation

No technological or designed solution alone will bring along sustainability, better lives, justice and equity. Only if technology is embraced by people, a change can be realised. One of the major problems of our modern societies is the fragmentation of culture and the loss of community. Despite unprecedented economic prosperity, people do not feel happier [42]. Isolation in cities is a well known phenomenon. Fragmentation of family lives is visible everywhere; people tend to live in single-person households: in the U.S., the percentage of one-person dwellings rose from less than 10% in 1950 to 26% in 2003 (29% in the UK, 40% in Norway) - the percentage in cities alone is nearly 40% - tendency rising [43]. While this might reflect personal choices, it certainly does not suggest that people want secluded life styles. Many of Manfred Max-Neef's classification of fundamental human needs have direct relation to social interaction [44]. Community is very important to human beings. Modern life styles have disrupted long preserved traditional communities. Distributed structures can bring this fabric back into existence. Creating a thriving local artisans, artists and retail network dramatically increases the amount of social connections, as people have more direct contact instead of anonymous shopping in supermarkets. Community owned schemes for power generation, biorefineries and other installations can strengthen social cohesion while conferring a sense of connectedness with the resources and the products, enhancing identification with the area and self-esteem as a community.

The problems of today's times require fast action. As indicated in the chapter on self-organisation, vast sections of the population are self-organising in order to tackle the challenge. They realise the solutions they want to see in their lives, instead of waiting for politicians or other external entities, shifting from a passive to an active attitude. This empowers, motivates and creates new forms of social organisation as prototypes of sustainable ways of living: the case for social innovation. From organic farmer markets, to community supported agriculture, to community gardens; time banks; resource sharing (cars, tools, etc.); nurseries at home; consumer and producer cooperatives: these are all examples [45] of what Ezio Manzini calls "creative communities" [46], spearheads of new and complex sustainable forms of organisations. The convergence of creative communities with the above mentioned technological proposals and the distribution of economies through distributed information, energy, production and creativity, has been termed by Ezio Manzini as the multi-local society, where local and global create unprecedented appearance in the form of strong local rootedness and experience paired with global interconnectivity and cultural interaction, at the same time open and localised. For the success of this vision it is in my opinion imperative to stress the autonomous nature of each "node" in the network. Participation must be voluntary, not forced. The "implementation" of the node must be transparent, which means that the local organises itself in the way it wants.

Finally, all suggestions offered in this paper are just tools in a toolbox proposed for usage by social groups. Creative communities are free to choose whatever suits their needs and best fits in their framework defined by economical criteria, resource availability and climatic, soil and environmental conditions. It is in this spirit that in the next chapter I will discuss some technologies to move from an oil addicted economy to a biobased one, which gets everything it needs from renewable sources and thus lives from what the planet yields, approaching us a little bit more to a harmonic way of living on our beautiful planet.

Chapter 5

Economies based on renewable resources

“Wealth consists not in having great possessions, but in having few wants.“

Epicurus, 270 BC

5.1 What do we want?

Regionalising and localising food production is something we can just start doing. There are thousands of years of human experience in agriculture. I already mentioned that traditional knowledge can be combined with current or relatively new philosophies of working with the land, like permaculture, agroforestry, biodynamic agriculture, perennial food production, etc.

Traditional skills on crafts and arts can also be revamped. Many new opportunities can be created through ingenious and inventive people. Recycling, when combined with handicrafts for example, can be an inspiring and fruitful activity.

The biggest challenge for a distributed economy scenario with modern connotations is the replacement of oil products, as this requires new approaches which have not existed before [1]. It requires combining new technologies with small scale production.

Before looking at possible scenarios of production, asking ourselves “what do we really want“ seems justified. In terms of survival, we don’t need any more “stuff“ than food and water, as well as shelter. Health and education are often also mentioned along with the most basic needs; they can be accomplished by non-technological methods, relying on passed-on knowledge. Are developed societies willing and capable of adjusting to such standards? Modernists, post-modernists and technology enthusiasts will want to maintain current technological levels. How does it look like in the sustainability movement? In conversations with personal contacts I have often perceived the tendency to renounce to any plastic fabric, adopting natural fibres and products instead, or a scepticism towards technology. Nevertheless it has been interesting to me

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[1] I would like to stress again the point that every community is free to implement their own way of living. This would create a huge diversity of different solutions, where people could decide to completely forego any oil related, synthetic or technological product

to observe that even very "green" individuals use computers, travel more or less extensively, use high-technology materials in their clothing (GoreTex raincoats, synthetic fleeces, shoes, etc.) or use cell phones. I have also been struck indeed by noticing that many permaculture and other land-based circles, truly committed to natural materials, use synthetic fibres in their premises for different purposes (for example for rain coating, polytunnels or ground covers in order to kill weeds). It seems to me that even for deeply alternative individuals and groups, some of the modern achievements are useful too. I have rarely encountered strong (while coherent and consequent) fundamentalism against any form of modern tooling.

The corollary for me then is that if we want to continue enjoying some of these things, we need to provide for alternatives.

5.2 Living from renewable resources

Fundamentalism is probably never a good idea, because it drastically narrows down flexibility and openness to possible remedies to wicked problems. But it is appealing as it makes issues appear much easier to deal with. As a matter of fact, accepting that we might want some of the goods that oil has made available to us, opens up a difficult debate on what we want and what we don't. To an organic farmer, using petrochemicals derived from crude oil as fertilisers will be unacceptable, while he might want to have a polytunnel in order to grow vegetables in winter - especially in colder climates. Cheap (but out-gassing and therefore unhealthy) plastic toys for kids could be avoidable, while good quality rain coat from synthetic fibres might be desirable.

It is impossible to address too many issues in this document. But I would like to express how three criteria offer some guidance on the mitigation of this dilemma:

1. **Price** Produce from fossil resources might start to become more expensive and therefore unaffordable due to scarcity. So products manufactured with alternative methods might become attractive. In practice, it might become just uneconomical to spray petrochemicals on soils, while operating with organic farming methods might become cheaper.

2. **Limits** As I have already elucidated on in section 3.2.1, working with limits makes them available to experience and thus more difficult to disregard. It streamlines usage of resources. Only as much timber as there are trees in a forest (managed sustainably) can be harvested. Cutting down all the trees will prevent the people from getting any timber at all. Limits can also boost creativity in the interplay with them. For example, roof top gardens to extend available food acreage is a creative solution to limited agricultural space.

3. **Education** Often mentioned in different contexts, this might be the most powerful but also the most vague of the criteria. One of the foremost lessons that global warming and the pollution problem is imparting to us as a species is that we need to learn how to live in harmony with the web of life on Gaia, our planet. I use the term Gaia here from a scientific point of view as elaborated and presented by James Lovelock, not as an abstract romanticised entity. Lovelock's work has enabled humanity to discover and encounter the intricate and complex interrelatedness of all living and non-living entities on planet Earth. In order for us humans to live on Gaia, we have to learn to integrate ourselves into this

> complex web in an organic way. Viewed from the perspective of complexity theory, any action we perform has repercussions which are impossible to predict, with effects finally rippling through to us. Latching ourselves into this web mandates care in not damaging and abusing of it, but does not prevent us from having a thriving economy. We have to learn not only how to be nourished from Gaia, but also how to nurture her, how to feed back our produce. In this thinking, the notion of waste does not even exist. Everything is food. Everything we do should be designed to be food for something else. Such a mindset sheds a different light on putting petrochemicals onto the soil. It holistically expands the context of our activities, it is thinking of all our relationships, our interactions. Currently we only concentrate on our human doings, limiting our view of economy by looking how *we* can benefit. Teaching the relationships to, our embedding within, and the interconnectedness with the web of life needs to become integral part of mainstream education, just like physics or biology. What kind of technologies and organisations will emerge from such quality of relating to Gaia?

If we still want modern items, without depleting finite resources, we need to revert to other sources. We need to strive for the ideal of a society which relies on renewable resources. Not only in terms of energy. But also in terms of materials. We could call this a biobased economy, or an economy relying on renewable resources.

For the rest of my dissertation, I will focus on the concept of the biobased economy, detailing its main components and implications, but putting it into context with the first part of the document, namely with the concept of distribution.

5.3 Biomass

5.3.1 Introducing biomass

The biobased economy sources every need from the biotic environment - from biomass. Biomass refers to any plant and animal matter. The term is mostly used in the context of producing energy and materials. Resources comprise aquatic and terrestrial crops, grass and wood plants, agricultural and forestry residues, as well as organic components of municipal and industrial wastes. Biomass is a renewable resource, if managed sustainably and environmentally friendly. Uses of biomass - from an energetic point of view - are:

- Biofuels: Liquid fuels for transportation
- Bioenergy: Generate heat and electricity from biomass
- Bioproducts: Convert biomass into usable products

Biomass is the oldest and most used energy form known to mankind. Humans have been burning wood since the discovery of fire. This practice, along with using woods for construction, shipbuilding and cooking, has decimated forests considerably, and some historians even attribute the collapse of whole societies to deforestation. In my opinion, this is the biggest challenge to the biobased economy. This aspect is rarely discussed, as many institutions are mostly concerned with specific implementations of technology, concentrating on wood-chip boilers, biofuels, or biorefineries. This is exemplified by Figure 5.1, which illustrates the biobased economy from the point of view of the biotechnology and chemical industry.

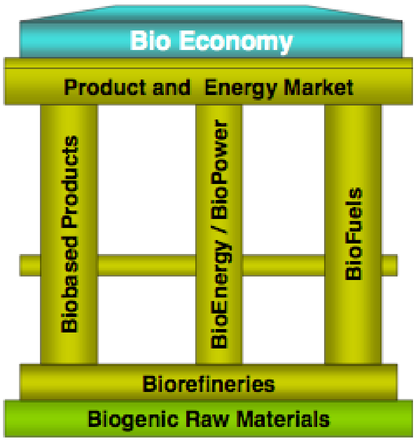


Figure 5.1: The 3 pillars of the biobased economy (Source: [47])

Many institutions proclaim the biobased era, heralding sustainable, clean practices based on renewable resources, which would solve our current environmental and finite resource problems. The reality is that we would need to allocate resources for a variety of products: food, construction and craft materials, insulation, fibres, textiles, animal feed, composting, fuels, chemicals, solvents, glues, etc. If left to market forces alone, I predict that biomass utilisation issues will exacerbate. As with fossil fuels, the current economic ideology would tend to externalise biomass resources in the balance sheets and therefore be prone to deplete them. Globalised multinationals need to be prevented of taking over biomass ownership and production.

The biobased era can only be a desirable and successful ideal if a more symbiotic relationship to our natural world is developed. More than just a rather esoteric statement, this practically means that the usage of biomass must be flanked by widespread and appropriate environmental education in all sectors, while sustainable environmental management practices must become the norm. Furthermore, in order to establish equitable access, it seems to me crucial that local ownership and management of assets should be the rule. This would greatly enhance and complement the distributed economy scenario described in the previous chapters. Local authorities, which could be organised in a variety of manners, like trusts, community owned structures or cooperatives, would manage resources according to local needs first. Therefore, they would have to balance exploitation with local requirements: a cold region may need to adjust for more heating power, while a very isolated community would maybe need to source more fuels. Depleting its assets would undermine a community's ability to survive, therefore generally we can presume a more careful management than through external management from distant multinational headquarters or even through state control. Studies should be undertaken which analyse the requirements, measure yields and evaluate sustainable procedures and suitable legal frameworks.

5.3.2 Composition

For biorefineries, mostly plant biomass is of importance. However, its composition in feedstocks is quite complex and divers, depending on the raw material. The main constituents of plants are carbohydrates. As the term suggests, these are compounds of mainly hydrates (water) and carbon. Carbohydrates in biomass are monosaccharides (the most simple sugar units, like glucose, fructose, galactose), disaccharides (two monosaccharides joined together; examples are sucrose, which is common sugar, and lactose), oligosaccharides (combinations of three to ten monosaccharides as in fructose chains for alternative sweeteners) and polysaccharides (complex molecules of many monosaccharides; cellulose and starch are the most prominent exponents of this group) [48]. Other basic building blocks are lignin, proteins, lipids (fats) along with vitamins, dyes, flavours and aromatic essences [49]. Each of these components has different chemical characteristics yielding different products, thus being suitable for different uses. An estimate of annual global biomass production amounts at 170 billion tons, of which approximately 75% are carbohydrates, 20% lignin and only 5% are other substances [50], therefore focusing on carbohydrates for technology development seems to be obvious. Biomass generally contains minor amounts of sucrose, lipids and starches. Most of its composition is termed lignocellulosic: cellulose, hemicellulose and lignin.

With estimated $3.24 \mathrm{x} 10^{11}$ m^3 global availability and $100 \mathrm{x} 10^9$ tons annual production, cellulose is the most abundant biological polymer in the world (about 33% of all plant matter in the world [51]). It features strong chemical bonds. Hemicelluloses are a variety of complex but shorter carbohydrate polymer chains compared to cellulose.

Lignin is found mostly in the woody parts of plants and in cell walls, conferring mechanical strength. Glucose, a monosaccharide accessible by microbial or chemical methods from starch, sugar, or cellulose, is pivotal as basic building block for a vast range of biotechnological and chemical products.

The fractionation of the raw materials into basic substances is primordial in order to obtain biobased products. Splitting the raw materials into fractions can be done by dedicated or combined mechanical, thermal, chemical or enzymatic procedures. This is the function of a biorefinery, to transform raw materials into final bioproducts.

5.4 Biorefineries

There is much research and development currently going on in the field of biorefining. As petroleum resources are dwindling, it is clear that the powerful oil business looks for alternatives. Biotechnology is a major academic, economic and industrial force, which is investing substantially in this domain, with the goal of developing new markets. Governments and institutions are financing advances in the area too, with the outlook to secure economic stability and continuity to their countries while addressing the challenges from global warming and sustainable development . Therefore, different definitions of biorefineries proliferate, depending on the stake-holders and the point of view. The appendix contains a list of different definitions.

Generally, biorefineries are facilities which convert biomass into other products: fuels, chemicals, materials and other uses, in principle much like an oil refinery does today. A biorefinery though does not denominate a specific technology, rather it is more of a concept, as feedstocks are manifold, and also as a variety of different processes have been engineered to finally result in a diversity of products. In fact, technologies are still quite young and not yet established.

Feed-stock is the term usually used for the raw materials for biorefineries - biomass. Every different raw material will yield different output, as plants differ considerably in their chemical composition. Hence, processes are an adaptation to these different conditions.

According to [52], biorefining technology can be classified in seven major groups:

- Conventional Biorefinery(CBR)
- Whole Crop Biorefinery(WCBR)
- Green Biorefinery (GBR)
- Lignocellulose Feedstock Biorefinery (LCFBR)
- Two-Platform Concept (TPCBR)
- Thermo Chemical Biorefinery (TCBR)
- Marine Biorefinery (MBR)

However, the same document asserts that a clear classification system is still lacking and is currently being developed. The system outlined above is based on raw material input (CBR,WCBR, LCFBR, MBR), technology type (TPCBR, TCBR), technology maturity (CBR or 1^{st} generation versus advanced or 2^{nd} generation biorefineries) and end products (Syngas and Sugar platform: TPCBR; Lignin platform: LCFBR).

5.4.1 Conventional Biorefineries(CBR)

Many existing processing facilities can be labelled conventional biorefineries. The conversion of beet roots and sugar cane to sugar, the processing of starch and vegetable oils, the pulp, paper, feed and food industries basically transform biomass to usable products. As for biofuels, technologies were concentrating so far on producing ethanol out of simple sugars from food crops. Such sugars are easy to extract and to convert (through a process called hydrolysis, see chapter 5.5). A niche activity for some time, it has recently attracted a lot of attention, as governments started pushing towards biofuels. They did so with certainly good intentions, but there is now wide rejection for biofuels from fuel crops, as they contribute to rising food prices, being the cause of the “fuel versus food“ debate. CBR are very well matured technologies and processes, although specifically focused on their specific end products (sugar, starch, etc.). The industry deems likely that such facilities will take an upgrading path in order to expand their product range [52]. In fact, they may constitute basic building blocks for advanced or second generation biorefineries, which are going to be described in the following.

5.4.2 Green Biorefinery (GBR)

This type of biorefinery is based on pressurisation of wet biomass like green grasses and crops (lucerne, clover). The pressing results in a fibre-rich press cake and a nutrient-rich press juice. The press cake contains cellulose and starch, as well as valuable dyes, pigments, crude drugs and other compounds. It can be used for feed pellets, as raw material for the production of chemicals, and for biofuels (conversion to syngas and hydrocarbons). The green juice contains proteins, free amino acids, organic acids, dyes, enzymes, hormones and other organic substances and can be processed into ethanol, lactic acid and its derivatives (e.g. biodegradable plastics), amino acids and proteins.

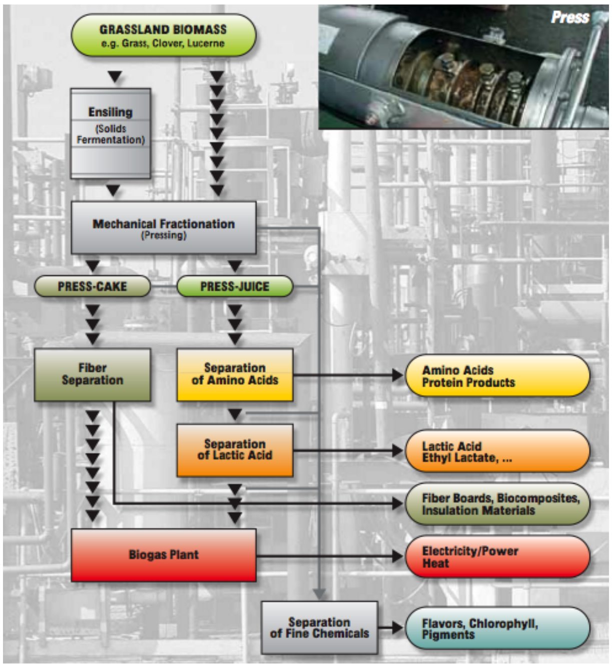


Figure 5.2: Overview of a Green Biorefinery (Source: [53])

As fresh biomass is used, issues on rapid processing or storage prior to processing need to be addressed. Cheap raw materials, good coupling with agricultural production and simple base technologies are main advantages of GBRs [52], making them attractive for small scale environments. They can process from a few tons of green crops per hour (farm scale process) to more than 100 tons per hour (industrial scale commercial process) [50].

5.4.3 Whole Crop Biorefinery (WCBR)

Whole Crop biorefineries operate on dry or wet milling of raw materials like cereals (rye, wheat, maize). The mechanical separation process results in a 20% grain portion which will be processed to starch or into binder, adhesives, and filler, while the remaining 80% of straw fraction is actually a lignocellulosic feedstock, which can be further processed in a LCFBR or specialised wheat straw biorefineries.

Dry milling is used on dry feedstock separation into grains and straw. Wet milling implies swelling of the grains and pressing of the grain germs, yielding high value oil (corn oil), while preserving high levels of cellulose, starch, oil and proteins. Both techniques employ well known basic technologies [50]. This kind of refinery is common in the USA. Obviously, the feed-stock used still competes with food crops. Together with my assumption that WCBRs might be related to extensive grain monocultures, their role in distributed economies thinking is rather dubious if food security and sustainable agriculture practices are not observed.

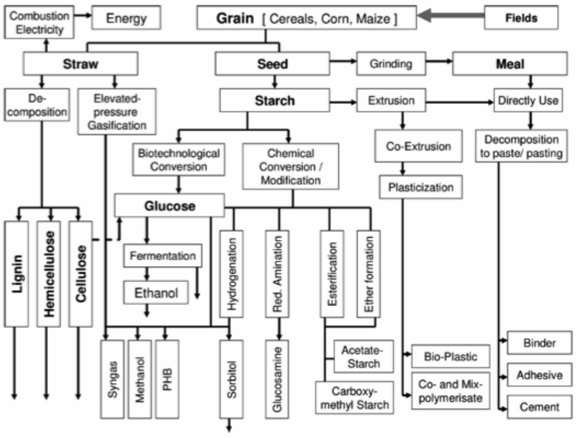


Figure 5.3: Potential products for WCBR (Source: [50])

5.4.4 Lignocellulose Feedstock Biorefinery (LCFBR)

LCFBRs are targeted at different types of raw materials: paper and sawmill effluents, organic industrial and municipal waste streams, manures, sewage, forestry and agricultural residues (e.g. straw), but also dedicated energy crops like willow, poplars, reed, miscanthus or switch-grass. The industry expects lignocellulosic-rich biomass to become the most important feed-stock of the future, because it is widely available at moderate cost and does not compete with food production [52].

A LCFBR fractionates the biomass into intermediate output streams for further processing. Such intermediary products are cellulose, hemicellulose and lignin. A particularly interesting product out of LCFBR is furfural, which is a base substance for Nylon (originally, Nylon was produced from furfural, but since the beginning of the 60s it has been replaced by cheaper petroleum compounds). LCFBRs further produce glucose (by hydrolysis of cellulose) and ethanol, which, apart from being a fuel additive, is a base compound for a vast variety of end products, like polyethylene (used in packaging such as bottles and tubs; it is not biodegradable though but recyclable) or polyvinyl acetate [50].

5.4.5 Two-Platform Concept Biorefinery (TPCBR)

This concept implies separating biomass into a sugar fraction, later processed through the sugar platform, and a ligno-celluosic fraction, thermo-chemically treated in the syngas platform.

1. The sugar platform This involves fermentation of sugars from biomass through biochemical processes. Ethanol is the main end product envisioned.

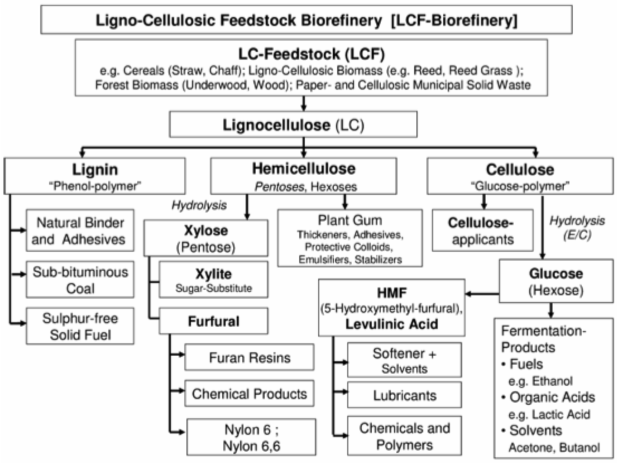


Figure 5.4: Potential products for LCFBR (Source: [50])

2. The syngas platform Entails thermal and thermo-chemical conversion of biomass, mainly through gasification (see section 5.8.2) and pyrolysis (see section 5.8.1). Syngas (in varying amounts) is the main resulting product. The processes are simple and low-tech [50].

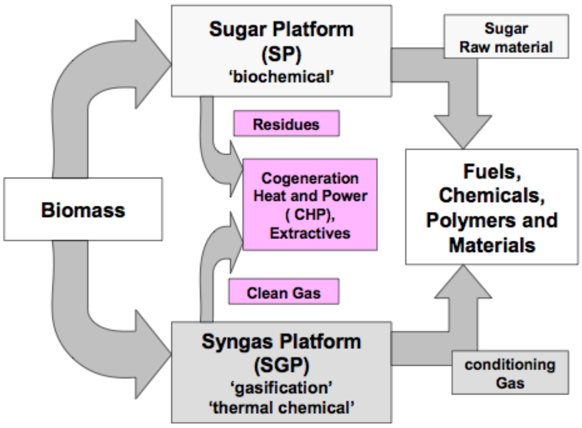


Figure 5.5: The Two Platform Concept Biorefinery (Source: [50])

Figure 6.6 in the chapter 6 “Made of biomass“ illustrates the vast range of potential products from the sugar and the syngas platform.

5.4.6 Thermo Chemical Biorefinery (TCBR)

In this approach, developed in the Netherlands (leading in biorefining technologies in Europe), several technologies are applied, which can be tailored to stake-holder needs. They basically are a combination of processes from the syngas platform with other methods.

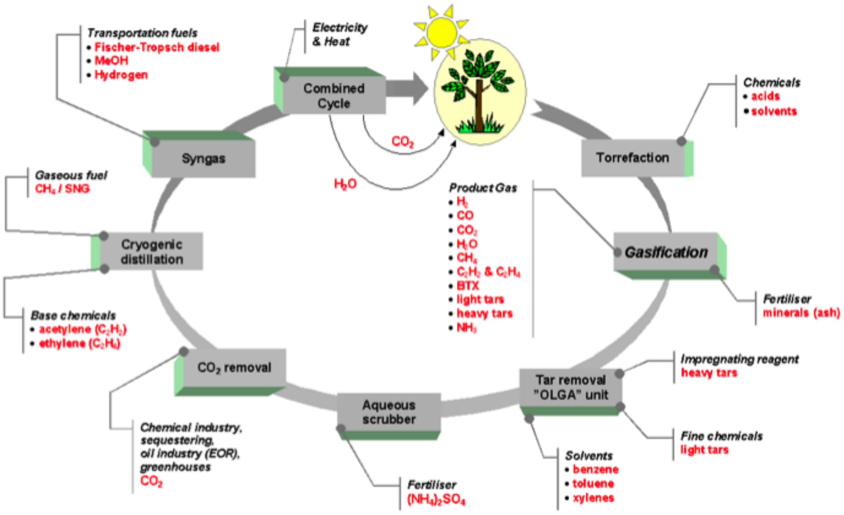


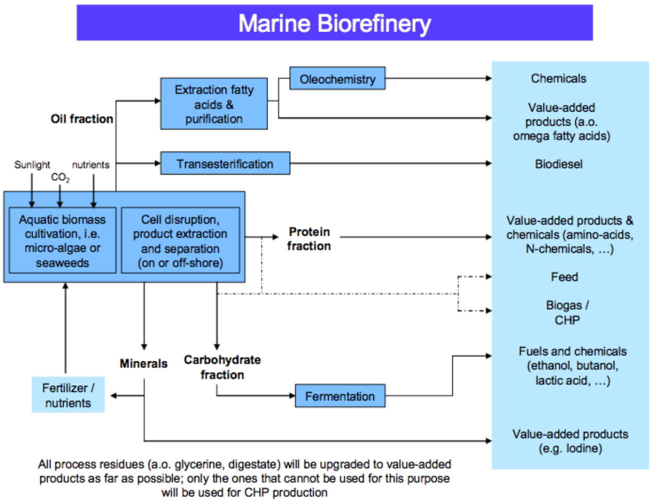
Figure 5.6: The Thermo Chemical Biorefinery (Source: [52])

A focus of this biorefinery type is to provide intermediate substitutes for fossil fuel based raw materials, which could be fed into existing capital intensive oil refining infrastructure [52]. This is not surprising if we recall that Shell is a Dutch company and therefore the oil refining business is very significant in the Netherlands.

5.4.7 Marine Biorefinery(MBR)

After initial concentration on mainly terrestrial biomass, aquatic sources like micro-algae (e.g. diatoms; green, golden, blue, brown algae) and macro-algae (seaweeds), which account for some 50% of global primary production, are attracting important attention. Their potential for carbon dioxide binding, higher yields than terrestrial crops and negligible competition with (human) food systems are the main reasons. They are especially being considered for biofuel production [50].

Micro-algae systems can be combined with waste water treatment facilities. They can be cultivated in open ponds or closed systems, so-called photobioreactors. Open pond configurations are cheaper and simple, but the maintenance of cultures is much more difficult, mostly because of contamination threats by external organisms (bacteria and micro-organisms). Photobioreactors can potentially give higher yields, while being much more expensive as a disadvantage. I look at algae into more detail in section 8.4.



All process residues (a.o. glycerine, digestate) will be upgraded to value-added products as far as possible; only the ones that cannot be used for this purpose will be used for CHP production

Figure 5.7: The Marine Biorefinery (Source: [52])

Seaweeds are harvested traditionally for food and feed production. Dedicated biorefineries do not exist yet, but are being considered, especially in combination with off-shore wind platforms.

5.4.8 Summary of biorefining concepts

This table summarises the concepts introduced in the last sections (taken from [50]). Note the last column. Most technologies are still in development!

One of the goals all biorefinery types strive for is to utilise the whole biomass matter, leaving zero waste but incorporating waste products from other societal activities in their processes. Of course, biorefineries require energy to operate, especially the ones featuring thermal conversion methods (pyrolysis, gasification). All the concepts presented (except existing conventional plants) are designed to provide for their own needs in terms of energy. Basically they adopt combined heat and power (CHP) strategies. They convert own process residues like bagasse to biogas through anaerobic digestion; biogas combustion generates heat and electricity. Pyrolysis and Gasification produce syngas, a flammable gas used to drive the processes. Finally, parts of the raw materials (especially ligneous matter) can be diverted for combustion. Electrical energy can be complemented through any kind of renewable sources (an interesting example is a pilot plant in Iceland, which takes advantage of geothermal energy) [47].

Biorefinery technology is still very young. In addition, the concepts portrayed are just that - an overall rough classification; an assessment for suitability for distributed economies is not straightforward as it depends on a lot of factors (e.g. feed-stock type and quantity available, processes employed, capital and know-how requirements, desired end products, local conditions, etc.). Conventional refineries often use simple, mature technologies which can be replicated at any scale. The most interesting models for small scale and regional application appear to be

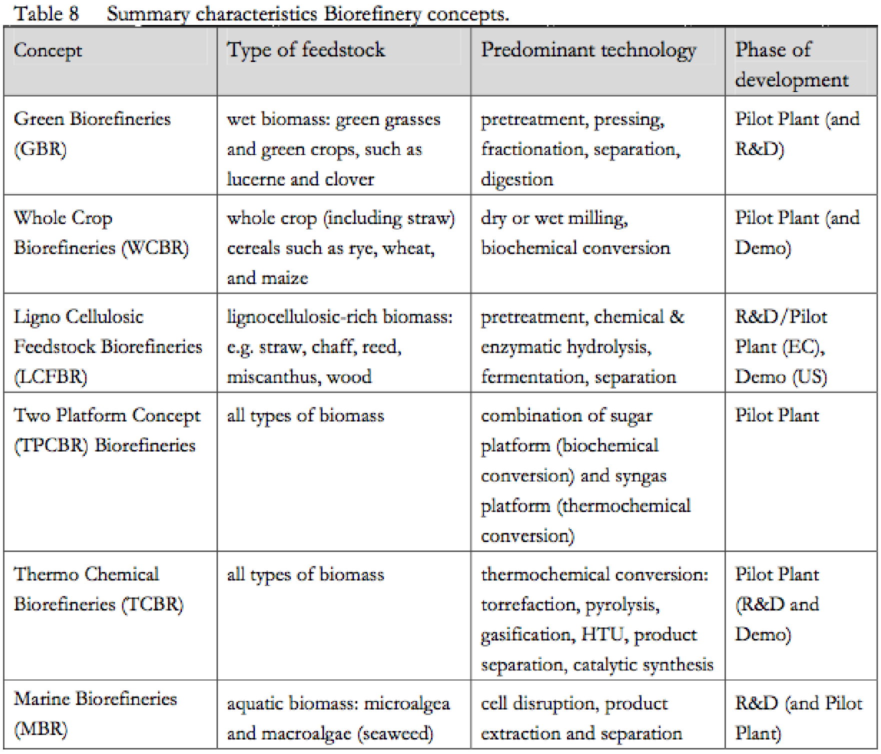


Table 8 Summary characteristics Biorefinery concepts.

Concept	Type of feedstock	Predominant technology	Phase of development
Green Biorefineries (GBR)	wet biomass: green grasses and green crops, such as lucerne and clover	pretreatment, pressing, fractionation, separation, digestion	Pilot Plant (and R&D)
Whole Crop Biorefineries (WCBR)	whole crop (including straw) cereals such as rye, wheat, and maize	dry or wet milling, biochemical conversion	Pilot Plant (and Demo)
Ligno Cellulosic Feedstock Biorefineries (LCFBR)	lignocellulosic-rich biomass: e.g. straw, chaff, reed, miscanthus, wood	pretreatment, chemical & enzymatic hydrolysis, fermentation, separation	R&D/Pilot Plant (EC), Demo (US)
Two Platform Concept (TPCBR) Biorefineries	all types of biomass	combination of sugar platform (biochemical conversion) and syngas platform (thermochemical conversion)	Pilot Plant
Thermo Chemical Biorefineries (TCBR)	all types of biomass	thermochemical conversion: torrefaction, pyrolysis, gasification, HTU, product separation, catalytic synthesis	Pilot Plant (R&D and Demo)
Marine Biorefineries (MBR)	aquatic biomass: microalgea and macroalgae (seaweed)	cell disruption, product extraction and separation	R&D (and Pilot Plant)

Figure 5.8: Summary of the characteristics of biorefinery concepts (Source: [50])

green biorefineries (which are not yet developed though) and thermal combustion based ones. Lignocellulosic conversion is an ideal candidate from a feed-stock point of view. However, at the moment it is aimed at economies of scale; it appears to be rather cost intensive, as it is linked to high-tech biotechnological research (using enzymes and micro-organisms to break down biomass), and involves genetic modification, an issue I discuss in chapter 5.10. Marine biorefineries are currently difficult to assess; seaweed based facilities are not existing yet, but should be comparable to other systems presented. Micro-algae based solutions experience a hype, but a breakthrough has not yet been reported. However, algae are potentially of topmost relevance. Please read chapter 8.4 for a more detailed analysis.

In the following chapter I give an overview of currently used basic processes for biomass treatment. The above mentioned biorefinery types all employ one or several of these basic processes. Please note that huge investment and research is currently being undertaken in order to develop completely new or new combinations of processes; some of this research aims at synthesising proprietary technologies which confer market advantages for the individual companies. Therefore, the list can only be understood as a broad overview of basic principles. The information is mainly synthesised from [54].

Processes for biorefineries can be organised in two major groups: hydrolytic mechanisms that extract monosaccharides from the lignocellulosic polysaccharides, and thermochemical processes that degrade the raw material.

5.5 Hydrolysis

In biomass, lignin and cellulose form strong bonds. On top of that, cellulose is highly crystalline, and direct hydrolysis degrades the hemicellulose portion and can inhibit subsequent fermentation. For these reasons, pre-treatment of the raw material is required. So while hemicelluloses can be hydrolysed relatively easily, the overall process is complicated. Cellulose itself is around 100 times more difficult to hydrolyse than starch. Pre-treatment is one of the most expensive stages for second-generation technologies (sometimes up to a third of the whole process), but it is essential, as it dramatically improves yields (e.g. from 20% to 90% in some processes).

5.5.1 Physical Pre-Treatment

Physical pre-treatment techniques comprise:

Size reduction Reduce raw material to small particle size, for greater surface area.

Steam explosion Biomass is put under high pressure steam at temperatures of 210°C to 290°C for several minutes before the steam is vented rapidly. The feed-stock undergoes explosive decompression and flash cooling and becomes better suitable for enzymatic hydrolysis. It is used more effectively on softwoods than on hardwoods. Applying a catalyst (dilute sulphuric acid) increases yields (from 45-65% to over 70%). The process is energy intensive.

Ammonia fibre explosion (AFEX) substitutes liquid ammonia for steam, resulting in high sugar yields, reducing the energy needs (no steam needed), but introduces ammonia costs and expenses for recycling - not only for cost reduction, but also to prevent contamination.

Carbon dioxide can also be used, as it is cheaper than both steam and ammonia based processing, but yields from subsequent hydrolysis are lower.

Liquid hot water Liquid water at 180°C to 230°C (under high pressure) is kept in contact with the biomass. Degradation of the raw material is minimised, and yields improved. This technique is still at the lab-scale.

5.5.2 Chemical Pre-Treatment

Chemical pre-treatments include:

Acid catalysed This is used mainly to hydrolyse hemicelluloses. Traditionally (dilute) sulphuric acid is used, but nitric and hydrochloric acids have also been used.

Alkaline catalysed Focused on solubilisation and removal of lignin. Cheap and easy recovered lime is preferably used.

Other chemical methods Many new methods employing chemicals are currently being developed by different companies. The goal is always to prepare the raw material for better hydrolysis later.

5.5.3 Dilute Acid Hydrolysis

Dilute acid hydrolysis technologies have been used since the late 19^{th} century, but were replaced by cheaper petrol based industries. Therefore, it is a well known process. Basically it is a two-step job: first, dilute acid is used at moderate temperature conditions (140°C to 160°C) to release pentoses (sugar class with 5 carbon atoms, obtained from hemicellulose), then the temperature is raised (200°C to 240°C) for cellulose hydrolysis of six carbon sugars.

5.5.4 Concentrated Acid Hydrolysis

After the liberation of hemicellulosic sugars in a pre-treatment stage, biomass is dried and put in contact with concentrated (sulphuric) acid. This allows an easy hydrolysis of cellulose. With concentrated acid, a variety of feed-stocks can be used, such as municipal wastes. The main disadvantage is the cost of the acid. Even minimising costs through recovery and separation of it from the end products make it more expensive than dilute acid methods.

5.6 Enzymatic Hydrolysis

In an enzymatic hydrolysis, often pre-treatment for hemicellulose hydrolysis is applied, in order to get a more digestible cellulose. Then enzymes are used to hydrolyse cellulose to glucose. This allows for milder process conditions (30°C to 70°C) and therefore lower sugar degradation as well as less energy needs. Enzymes (cellulases) are obtained from bacteria and fungi. Much research and investment is dedicated to develop specific enzymes, often including genetic engineering (see section 5.10).

5.7 Fermentation

The sugars, after hydrolysis, are predominantly broken down to alcohol (e.g. ethanol, methanol) through fermentation. Yeasts are used to accomplish this. Ethanol is then used for biofuels as well as a base product for more applications. There is much research going on in the field of fermentation yeasts, including genetically modified organisms that yield higher volumes, are cheaper, more efficient, or that can open up new pathways for fermentation into more products.

5.8 Thermochemical Processes

The oldest use of biomass is to burn it for heat and cooking. More recently, the same principle has been used for heat and electricity generation. Modern technologies can help in improving these combustion technologies. Generating electricity can be a welcomed side effect of some biorefining processes releasing heat. CHP (Co-generation Heat and Power) is already widely accepted as improving efficiency of resource usage in many industrial processes. However, other technologies (like solar, wind, etc.) might be better suited for the generation of electricity as a main goal. Thermochemical processes though can also be applied for bioproducts and biofuels.

5.8.1 Pyrolysis

Pyrolysis is the thermal treatment of a material in the absence of oxygen. In pyrolysis [2], a bio-oil is produced from biomass, along with gases (depending on process temperature varying amounts of hydrogen, carbon dioxide carbon monoxide, or syngas) and char, for which the term biochar is often used. Depending on the desired end-product (bio-oil, gases, biochar), adjustments on the process and the feed-stock are applied.

In fast (or flash) pyrolysis, feed-stock is ground to very fine particles, and then briefly (in the order of seconds) exposed to temperatures of 450°C to 700°C. High bio-oil yields, up to 70% of the feed-stock mass, is the result. The bio-oil can then be further processed into a variety of bioproducts.

At lower temperatures (300°C to 450°C), the biomass is of coarser size and processed for longer time, resulting in more biochar and less bio-oil. Biochar (essentially charcoal) is of value as fuel, but also as a fertiliser. A more thorough examination of biochar can be found in chapter 8.3.

Another side-product of pyrolysis are gases containing hydrogen, which can be used as fuel gas too.

5.8.2 Gasification

Gasification aims at converting gases from thermal treatment of biomass, termed syngas, into the desired product. The combustion occurs at higher temperature (>1000°C) than pyrolysis, with the addition of some oxygen, as gases must be very clean for the synthesis of fuels and chemicals. End products ensue after catalytic or biological reforming of the gases. See figure 6.6(b) for products for which syngas is a starting platform, including ethanol and methanol. For gasification, the raw material should be of low moisture content, otherwise substantial costs arise from drying. Syngas is also produced from fossil fuels (coal), so further processing technologies can be re-applied to bio-syngas, provided sufficient gas purity. Due to impurities, ash content etc., syngas from biomass is regarded as an economy of scale process for the high costs incurred through managing adverse conditions, requiring huge amounts of biomass with high transportation costs. To overcome this, it has been suggested to forward bio-oils from pyrolysis processes to gasification schemes. The local conversion of biomass into an intermediate state for advanced processing is a general strategy discussed in chapter 7.3.

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[2] Pyrolysis and Gasification are also used in incineration schemes for municipal solid waste - which does not consist only of organic material. As such waste contains toxins, plastics, and much more, these applications of pyrolysis and gasification have much more negative side effects in pollution and are not directly comparable with biomass treatment processes.

5.9 Summary of processes

While established processes from crop sugars (especially hydrolysis) are restricted in their potential product range and their yields, generally gasification offers more possibilities. However, hydrolysis processes are cost and energy intensive, especially due to pre-treatment. Technologies using acids are likely to involve pollution threats. Yield improvements are expected from enzymatic hydrolysis, a main building block for lignocellulosic biorefineries, but investment requirements and GMO implications suggest obstacles for distributed economies thinking. Gasification and pyrolysis imply combustion and therefore exhausts; they are carbon neutral technologies though as they burn renewable biomass which captured carbon during growth. Pyrolysis bio-oils are rated low-value end products by the industry, but technologies are mature and they can be adopted on the small scale; [54] states:

> *"Such facilities do not require the economies of scale of hydrolysis and gasification technologies, however, and they could offer value for local communities that wish to strive towards energetic and chemical self sufficiency with limited lignocellulosic resources."*

As a conclusion, it is probable that a multitude of processes will continue to exist, and employed dependent on the different feed-stocks available, as each of them offers specific advantages and disadvantages.

5.10 Remarks on genetic engineering

Is is no secret that the biotechnology industry is investing increasing amounts of resources in research for genetic altered organisms in the realm of biorefineries. There are two paths considered:

Feed-stock modification Plant material is genetically modified for higher yields and/or to better suit industrial processing lines.

Enzymatic modification New organisms are synthesised which can break down biomass raw material more efficiently and/or provide higher yields in the process.

It is not the intent of this document to analyse risks and potentials of GMO. However, some basic thoughts might be of relevance for this work:

Cost The more genetically engineered organisms enter the product chain, the more the technology itself tends to become expensive and therefore not suitable for small scale, and maybe not accessible for sections of society who do not have the expertise for such technologies (e.g. third world).

Intellectual property Genetically engineered organisms are very likely to be patented in order to offer competitive advantage for the companies who created them. Apart from restricting access to technology to market mechanisms, which can be exclusive and not equitable, this can lead into dependency and lock-in to particular companies.

Contamination risks Modifying crops bears the risk of contamination of the biosphere with non-natural organisms, with unpredictable results.

Ethical considerations Ethical implications of altering organisms arise too. For example, does scientific freedom imply “carte blanche“ to develop whatever is possible? Is it ethically acceptable that science can detach itself from further implementations of its accomplishments?

Whereas GMO in food production face fierce resistance from large sections of society, less opposition could be expected for fuels and chemicals, as organisms do not directly enter the food chain and health considerations lose weight. As soon as crude oil becomes really scarce and prices prohibitive, alternatives might encounter lower hurdles for acceptance. It is also likely that regulations and laws might be less restrictive for non-food applications. Industry might quietly take this path in order to cement their position and market influence and introduce genetic modification into common industry technologies, possibly weakening over time also rejection in the food sector. Fact is that biotechnology companies are already using GMOs in their research, as legislation is not restrictive in its application [55].

My personal point of view is that for most small scale applications, GMOs are not needed and should therefore not be considered, avoiding any potential risk involved. Also, investment costs can be kept lower for any GMO free technology, as well as know-how required for operation. Yield improvements and better efficiency are generally requirements arising from the drive to economies of scale; however, where production is focused on local conditions, other issues like self-sufficiency, coverage of needs and appropriateness of technologies gain on importance compared to efficiency.

5.11 Brief reflections from a holistic science student

It is indubitable that the industry, alongside political and academic institutions, will push forward the biorefinery proposition. The assumption is that petroleum will be around for quite a while even if declining, ensuring a smooth technology improvement over the years in order to be able to complement oil-based production. We will see if this speculation will hold up. We can though take for granted that as long as no radical change of civilisation takes place, or at least of the current economic and political model, biotechnology and chemistry will continue to play predominant roles.

Is there any foundation in ultimately rejecting biotechnology altogether? Or any technology? I believe such knowledge is part of our ontological experience, and hence becomes integral part of the whole of our collective consciousness. It cannot be eradicated as long as civilisation does not experience an absolute collapse.

Sustainability is becoming a term difficult to grasp. Every industry is creating principles of sustainable conduct and operation. We can read about sustainable development, sustainable chemistry, sustainable biotechnology, sustainable mining, etc. Even if used as a “green wash“, it reflects real concerns about our ways of production (but often also sincere endeavour). However, as long as permanent growth models abide, economic pressure severely threatens the attainability of the sustainability premise. At the least, non-pollution must become a primary commitment and indispensable prerequisite.

The classical divisions of science arose out of the reductionist hypothesis implying that deeper and exhaustive knowledge can be derived from dissecting phenomena into smaller parts or units, requiring specialisation, and infers repeatability and mechanical replication from scientific discovery. The holistic approach does not deny the value of reductionist outcome, but foregrounds the role of the context in which phenomena live and occur, highlighting relationships rather than focusing on independent objects.

In this mindset, there is much potential for the transition from highly specialised research into holistic scientific investigation, which goes beyond interdisciplinary cooperation by also embracing phenomenological and experiential inquiry methods.

In an idealistic hypothesis, biotechnological research would become an open source collaboration effort, driven by the aspiration to share knowledge and cultivate collective well-being, not by the demand for competitive advantage and by market coercion. As already mentioned, open source models can lower costs avoiding replication, making high technology accessible to everyone. They have the potential to even boost innovation by mutual enhancement and sparking of ideas through interaction. Furthermore, by putting technology in context, not only processes and organisms themselves, but also the embedding in their environment becomes paramount. Thus the benefit is not only evaluated in human terms, but for the whole living community concerned (acknowledging limitations imposed by a complex world in which human knowledge will probably never reach totality).

Until such a (possibly utopian) background is established, sciences like biotechnology and chemistry mandate considerate monitoring and critical discussion.

Chapter 6

Made of biomass

> *“Systems become healthier as they open to include greater variety. When diversity abounds in an environment of freedom, the result is strong and resilient systems.“*
>
> Margaret Wheatley

6.1 Biofuels

Biofuels are currently vividly discussed in public, politics and economics. Rising oil prices, the outlook of finite petroleum resources and greenhouse emissions from conventional fuels have instigated the search for alternatives for transportation. Initially received with much applause and enthusiasm as the panacea for mobility, a hangover feeling is now spreading.

Biofuels come in generally two types:

Bioethanol Bioethanol is the fermentation and distillation product of sugar and starch, from such diverse feed-stocks as sugar cane (especially in Brazil), sugar beet (Europe), wheat and maize (U.S.A.). It is currently mostly produced in conventional biorefineries. Ethanol needs to be blended into standard gasoline for usage. Up to 5% of ethanol in gasoline doesn’t require engine modifications, blends of 10% or 15% mandate small changes, while ethanol-rich fuels of 85% require adapted engines [56].

Biodiesel Biodiesel can be made from virtually any vegetable oil feed-stocks, which include rapeseed (Europe), sunflower, palm oil, algae, corn, soybean, jatropha, mustard, hemp, and flax, but also animal fats like lard, chicken fat, or tallow and finally waste vegetable oil, like used fry oil from restaurants. A process called transesterification applied to the oils results in the final product biodiesel, which in this form does not need modifications on (diesel) engines. Some “home brewers“ have reportedly used vegetable oil straight away, but this needs modification to engines, while being potentially damaging to them [57]. Biodiesel can also be blended with conventional biodiesel in any portion (a common ratio is 20%, termed B20; B100 is 100% biodiesel).

6.1.1 First generation feed-stocks

As we have seen, conventional biorefineries produce biofuels from the conversion of sugar, starch and oil crops (often termed first generation feed-stocks). For sucrose (like sugar from sugar cane) and starch (wheat, maize) crops it is relatively easy to separate (hydrolyse) the basic sugar units in water, after which they are fermented. Sugar hydrolyses freely in water, while for starch inexpensive enzymes operating in moderate reaction conditions can be used. Biodiesel from oil crops (soybean, rapeseed, palm oil, hemp, jatropha, sunflower) is also relatively easy to produce, and small scale production units proliferate over the globe. Transesterification of lipids (fats, oils, waxes, etc.) involves transforming the raw vegetable oil into esters in the presence of alcohol as a catalyst (resulting in methyl ester with methanol, and ethyl ester with ethanol).

However, these advantages face serious drawbacks. The energy balance of first generation biofuels is unfavourable, they contribute to rising food prices as they compete for valuable land, and some studies conclude that their cultivation aggravates global warming instead of mitigating it [54].

6.1.2 Second generation

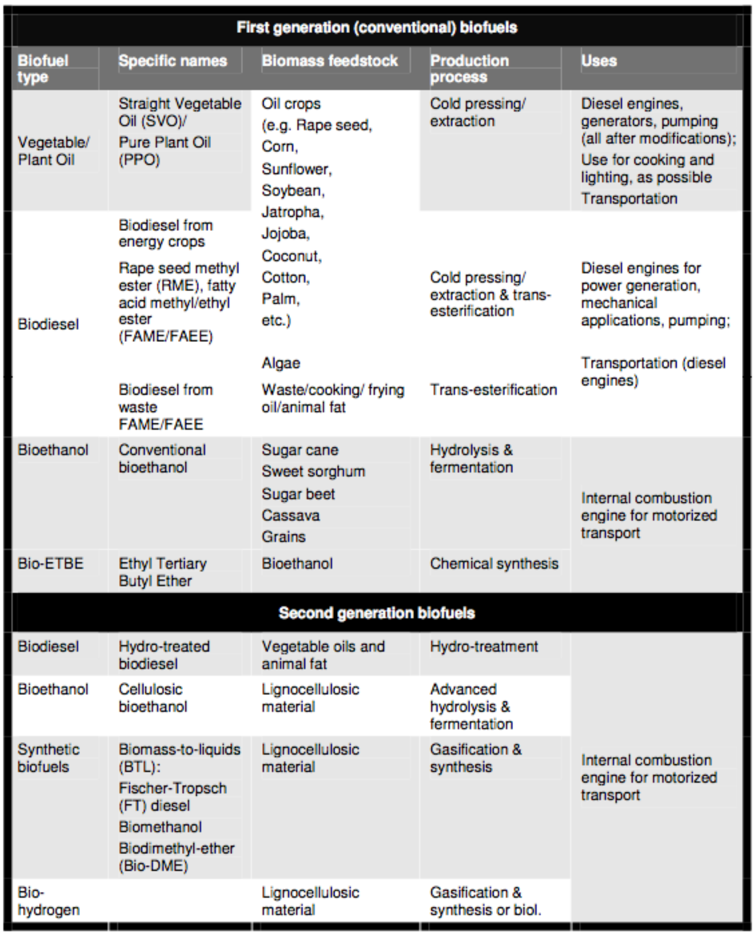
Second generation biofuels can be made from feed-stocks which do not compete with food production. Sources are residual biomass from forestry, agriculture, or municipal waste; almost any form of biomass is potentially a resource (lignocellulosic raw material). But second generation fuels include also dedicated energy crops (switch-grass, poplars, etc.), which then do compete for land and water resources. Second generation fuels are still in development and are not economically competitive with first generation fuels. The JRC report ([56]) estimates that even by 2020 second generation fuels will still be more expensive than first generation ones. Figure 6.1 gives an overview of the different types of biofuels.

6.1.3 The problems with biofuels

The problems related to biofuels are manifold. As already mentioned, planting crops for fuels converts valuable arable land for food production to fuel plantations, causing food prices to rise. If additional attention and investment is diverted to fuel crops, more and more land will probably be used for their cultivation, aggravating the food price increase. The issue is exacerbated if fuel earnings for farmers become higher (through better market prices, or favourable taxation) than income from food sales - not an unrealistic constellation.

Another drawback for biofuels is that deforestation could become much more acute than it is already, due to screening of forests for plantations. Converting wood land to fuel plantations definitively results in increased carbon dioxide emissions.

Furthermore, most fuel crops are grown on industrial scale in monocultures with high usage of pesticides, fertilisers and machinery. An overall net energy loss (apart from problems with over-exploitation of soils and no alleviation of greenhouse gas emissions) is suggested by a study which shows that it takes more fossil fuel energy input to produce the equivalent in (industrial) biofuels: a energy unit spent in fossil fuels will yield 0.778 unit of energy in maize ethanol, 0.688 in switch-grass ethanol, and 0.534 in soya bean diesel [59].



First generation (conventional) biofuels				
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**	**Uses**
Vegetable/ Plant Oil	Straight Vegetable Oil (SVO)/ Pure Plant Oil (PPO)	Oil crops (e.g. Rape seed, Corn, Sunflower, Soybean, Jatropha, Jojoba, Coconut, Cotton, Palm, etc.)	Cold pressing/ extraction	Diesel engines, generators, pumping (all after modifications); Use for cooking and lighting, as possible Transportation
Biodiesel	Biodiesel from energy crops Rape seed methyl ester (RME), fatty acid methyl/ethyl ester (FAME/FAEE)	Algae	Cold pressing/ extraction & trans-esterification	Diesel engines for power generation, mechanical applications, pumping; Transportation (diesel engines)
	Biodiesel from waste FAME/FAEE	Waste/cooking/ frying oil/animal fat	Trans-esterification	
Bioethanol	Conventional bioethanol	Sugar cane Sweet sorghum Sugar beet Cassava Grains	Hydrolysis & fermentation	Internal combustion engine for motorized transport
Bio-ETBE	Ethyl Tertiary Butyl Ether	Bioethanol	Chemical synthesis	
Second generation biofuels				
Biodiesel	Hydro-treated biodiesel	Vegetable oils and animal fat	Hydro-treatment	Internal combustion engine for motorized transport
Bioethanol	Cellulosic bioethanol	Lignocellulosic material	Advanced hydrolysis & fermentation	
Synthetic biofuels	Biomass-to-liquids (BTL): Fischer-Tropsch (FT) diesel Biomethanol Biodimethyl-ether (Bio-DME)	Lignocellulosic material	Gasification & synthesis	
Bio-hydrogen		Lignocellulosic material	Gasification & synthesis or biol.	

Figure 6.1: Overview of biofuels (Source: [58])

As often with analytical methods, results depend on the context, with sometimes contradicting messages. Another investigation [60] published attests net energy yields for biofuels, as illustrated in figure 6.2. In any case, it is clear that industrial biofuel production is dependent on high energy inputs.

Industrial production of biofuels might also be detrimental to water usage patterns for irrigation, as well as polluting water through fertilisers and pesticides ([61]), evoking conflicts. And finally, equitable access to land and self-sufficiency of small communities are threatened, if land is diverted from subsistence farming to biofuel plantations. Unsettling cases have been documented in India ([62]).

Second generation fuels might mitigate some of these problems (in terms of irrigation, pesticides and fertilisers), especially if non-food crops are used. They also contribute less to greenhouse gas emissions - assuming no required deforestation - than first generation fuels because of lower input requirements [56]. But these technologies are not competitive yet, as we have seen.

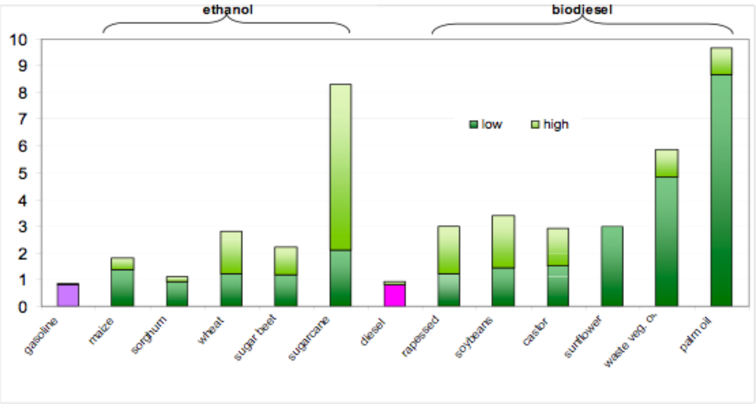


Figure 6.2: Net energy yields (Source: [60])

6.1.4 Sustainable biofuels?

So where to go with biofuels? I argue that most problems with biofuels arise from an industrial large scale context. For transport, distributed economies would need diversified solutions. Regions with abundant sunlight could strive towards electrical mobility, generating electricity with solar panels or any future solar technology. Likewise, wind can work much in the same way where it is abundant. Biomass could then just be another diversified, locally adaptable solution, not a technology aimed at substitution of all fossil fuels. As already stated in chapter 4.1, prioritisation of the usage of land would become important. Feed-stocks for biofuels would require to be aligned with other community and local needs. Besides, I am surely not the first claiming that some of today's transport is unnecessary; bicycles, water transport and other alternatives (animals!) can just be optimal options in many situations. A reduced availability of fuels streamlines their usage to more mindful patterns.

Small scale production of biofuels is likely to have a place in a future built on a distributed model. Established technologies, especially biodiesel techniques, are feasible, simple, and cheap. Algae might provide for an additional resource for sustainable fuel production on the small scale. I will describe such small scale processes later. Lignocellulosic feed-stocks and processing facilities could complement this view, but they need to mature in technology while becoming cheaper and accessible.

Humans have always been growing different kinds of biomass for different reasons. At no point resources were used solely for food! We used plant material for food, but also for animal feed, for construction purposes, clothing, artistic expressions, and to cook, be warm and to be burnt on fires. The scepticism against biofuels is absolutely justified as long as sustainability of feed-stocks, food security, forests, pristine natural environments and other primary land usage are threatened. Nevertheless, a diversified, decentralised management of resources can include biofuels too.

Biofuels might be just a transitional solution. They are mainly interesting because they do not need a complete re-engineering of our mobility systems. Necessity being the mother of invention, scarcity of fuels might prompt the emergence of new technologies. Electric cars, as well as hydrogen ones, are already widely available. The compressed air car is a soon to be launched alternative, which promises fuel usage at a fraction of current engines [63]. In fact, while material resources are certainly limited, there is still ample potential in transport for the harnessing of the most important energy resource - the sun. But until such utopian visions become reality, sustainable, small scale distributed biofuel production can fill some gaps.

6.1.5 Biohydrogen

Hydrogen is seen by many as the fuel for the future. It holds the promise of fossil fuel independence and a clean technology free of any greenhouse gas emission. The reality today is that its production, delivery, storage and conversion is too expensive (from a large scale coverage perspective). Furthermore, it is currently mostly derived from fossil fuels through highly energy intensive and environmentally prejudicial methods [64]. Hydrogen can be used in combustion processes or in a fuel cell to produce electricity.

Hydrogen from biomass is obtained through several techniques [65]. The thermo-chemical conversion processes pyrolysis and gasification both deliver hydrogen in their gaseous end products. The biological pathway operates at ambient temperature and is therefore expected to be less energy intensive. Biological processes are based on hydrogen producing enzymes which catalyse a chemical reaction.

Biophotolysis In (direct) biophotolysis, solar energy is directly converted to hydrogen from water via photosynthetic reactions; the enzyme used in this process [1] is extremely oxygen sensitive, thus requiring special problematic conditions. Indirect biophotolysis circumvents this by introducing intermediate reactions with CO_2

Photo-fermentation Photosynthetic bacteria produce hydrogen from water in presence of organic acids in nitrogen-deficient conditions[2]

Dark fermentation Anaerobic bacteria grown in the dark on carbohydrate rich substrate metabolise hydrogen.

Producing hydrogen from purely biological sources would be a sort of dream solution for energy requirements. Hydrogen as a clean fuel combined with renewable and pollution-free conversion techniques constitute an ideal match. From [64]: “...these techniques are well suited for decentralised energy production in small-scale installations in locations where biomass or wastes are available...“. They could therefore become important for distributed economies. The same source asserts: “However, development of such practical processes will require significant scientific and technological advances, and relatively long-term (> 10 years) basic and applied research and development“. It is however a development to be followed; specifically attractive is the fact that hydrogen can be produced by fermenting biomass waste - even from sludge or sewage. It is opportune to mention at this point that genetic engineering for optimised hydrogen

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[1] Fe-Hydrogenase

[2] Nitrogenase is the enzyme

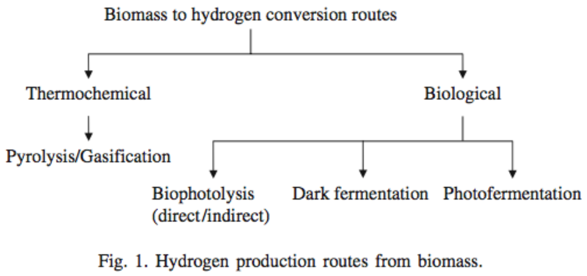

Figure 6.3: Biohydrogen production pathways (Source: [65])

metabolising bacteria cultures is a huge field of research; the same reflections as in chapter 5.10 apply here too.

As a by-product from pyrolysis though, bio-hydrogen is available today (see figure 6.4). A case study is documented in chapter 8.3.

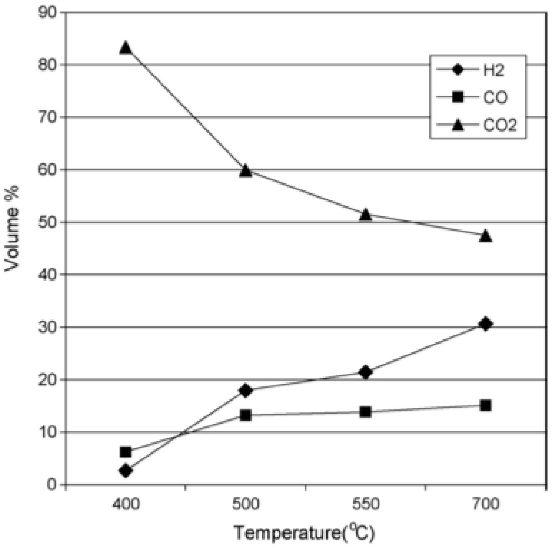

Figure 6.4: Hydrogen (as well as Carbon monoxide and dioxide) concentrations of the gaseous product of pyrolysis (in the example of olive-oil residues feed-stock) at different temperatures (Source: [66])

6.2 Bioenergy

Bioenergy is a term which in the current discussion about biomass gets confused in its signification. I use it to describe applications of biomass for heat and electricity generation, but of course using biofuels for transportation or combustion is also a form of bioenergy. The most known use of bioenergy is the burning of biomass for cooking and heating. In the modern context, the combustion of biomass is used to generate heat and electricity.

Very interesting in the context of bioenergy is the utilisation of any organic residual stream for biogas. Biogas results from digestion of organic materials in the absence of oxygen through microbial organisms (the process is often referred to as anaerobic digestion). It is very widely and successfully in operation in countries like India and China, where most of the organic waste (especially animal manure and human sewage) is collected in appropriate tanks or other facilities where the anaerobic digestion takes place. Biogas is then combusted for cooking, heating, and electricity generation. This is a very low-tech, cheap and mature technology which can be adopted anywhere, an important application of biogenic matter. Any process with organic effluents can avail itself of biogas for energy generation and self-sufficiency.

Biogas can also be used for the propulsion of motorised vehicles, as is already done in many places worldwide, like Kristianstad in Sweden, where all of the organic municipal waste and additional manure and residual material from surrounding farms is converted to biogas, employed for public transportation and taxis [67]. Engines running on natural gas can run on biogas without modifications and problems.

A form of bioenergy which is regarded as highly sustainable is the burning of wood chips and pellets instead of using fossil fuels, with the purpose of heating buildings and water. Dedicated wood for pellets can be grown in an environmentally friendly manner, while the burners operate on high efficiency to save raw materials. In combined heat and power (CHP) systems, the heat is also used to generate electricity. CHP systems improve the net energy balance of processes where combustion is taking place. In temperate and cold climates, where heating is required, biomass boilers, heating and CHP systems provide CO_2 neutral alternatives which build on local resources and are independent of fossil fuel imports. It remains to be seen however if wood production will be sufficient if the number of installed biomass systems increases (interestingly enough, these appear to not spark the food vs. fuel debate). Generally though, bioenergy applications described in this section are perfectly suitable for small scale and distributed economies.

6.3 Bioproducts

As already mentioned, products from biomass are countless: from paper to insulation materials, from textiles to decoration, from furniture to building materials, and so on. In this context, bioproducts refer to substitutes to current oil based products.

6.3.1 Bioplastics

According to a newspaper article in the guardian, a floating soup of plastic waste twice as big as the size of continental U.S.A. is floating in the ocean [68]. Plastics are ubiquitous in our modern world, without them many of our much cherished commodities are not conceivable.

Bioplastics are prominent exponents of bioproducts. The term is somewhat misleading; it denominates plastics made from biological sources and does not imply biodegradability. Successful applications of bioplastics exist in the packaging industry, where biodegradable materials, made primarily from corn starch, are used for food items.

Plastic fabrication should aim at full biodegradability, leaving no traces in the environment. However, many applications require durability: mechanical protection casing, poly-carbonates for greenhouses, or water-resistant coats to name but a few. Engineers are faced with the challenge to synthesise materials which respond to all these requirements while ensuring biodegradability. Where it will not be possible, alternatives should be considered. Sometimes synthetic polymers are chosen because they are cheaper; often organic materials are perfectly suitable for the application envisioned. The ideal that non-biodegradable materials can be fully recycled in a closed-loop system needs to be demonstrated; any fabric deteriorates over time. Biomimicry can be an inspiration: nature is able to craft amazing materials: hard and solid armours, flexible and versatile polymers (like cellulose), impermeable shells (e.g. coconuts) - all being biodegradable.

Bioplastics from corn starch or similar feed-stock are likely to be produced from fossil-fuel intensive large scale agriculture. The Wikipedia entry on bioplastics quotes Novamont, an Italian manufacturer. They state in their own environmental audit that producing one kilogram of its starch-based product uses 500g of petroleum and consumes almost 80% of the energy required to produce a traditional polyethylene polymer [69].

Bioplastic can be synthesised from polylactic acid (PLA), a commercial end-product from the sugar platform (see chapter 5.4.5 and figure 6.6(a)). NatureWorks LLC, manufacturer of PLA bioplastic, reports between 25 and 68% fossil fuel savings in their process compared to polyethylene [69]. However, PLA is currently also still made from corn starch or sugarcane, the growth of which is often linked to monocultures and therefore not fossil fuel free (besides competing with food!).

The reality with bioplastics for the moment is that their production is still fossil fuel dependent. Feed-stocks are centred on sugar and starch crops. Only if green and lignocellulosic biorefineries become viable is a sustainable production feasible. An interesting followup investigation would analyse how much sugars would be needed for small scale (biodegradable) bioplastic production with current known methods, where feed-stock would be provided from local and regional small scale farmers. Biorefineries break down biomass to products; the further processing into polymers is another branch of technologies which would need dedicated research on capital, know how and resource requirements in order to assess its suitability for distributed economies.

6.3.2 Biochemicals

As for chemicals, what specifically can be produced from biomass could easily be the subject of a separated dissertation assignment. The chemical industry itself however has long been sceptical towards the biobased economy. The hydrocarbons from fossil fuels have been a constant and homogeneous source of raw materials; processes are established. However, the industry is confronted with declining resources. Much of it is very polluting, but often we do not realise how dependent we are (paints, cleaning agents, solvents, personal care, design food, etc.). Linking chemistry with the bioeconomy (inevitable over time) puts pressure on resources and therefore shrinks the raw material pool - which can effectively optimise output to needs (not wants induced by marketing) if we also demand complete biodegradability from chemistry.

Figure 6.5 pictures that in principle petroleum products can be fully replaced by biomass raw materials[3].

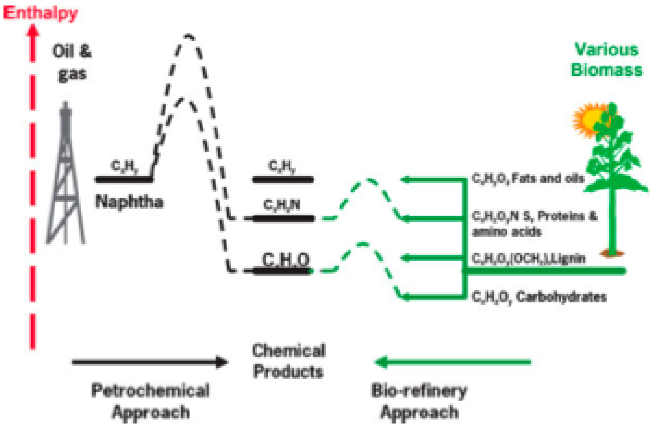

Figure 6.5: Using biomass for the chemical industry: replacing petroleum sources (naphtha) (Source: [70])

However, the time span to get there is long. In The Netherlands, biobased raw materials are expected to replace fossil fuels in the chemical industry by 25% in 2030 ([71]); the same assumption is made for the U.S.A. ([72] - starting from the premise that current levels of consumption need to be held up. Research for the chemical industry is massively funded.

In the following just a sample of possible pathways are highlighted. Figure 6.6 shows potential products from sugars and syngas.

Ethanol and Methanol are not only fuels, but a base platform for many other applications (see 6.7).

Glycerol, a by-product of biodiesel, can be used for soap production (especially interesting for small scale), but is also a base product for further processing into heavy chemicals [71]. In ligno-cellulosic biorefineries, levulinic acid is a major base platform chemical substance ([54]), which is used for polymers, lubricants or solvents, along with furfural as a base element for nylon and resins (see 5.4).

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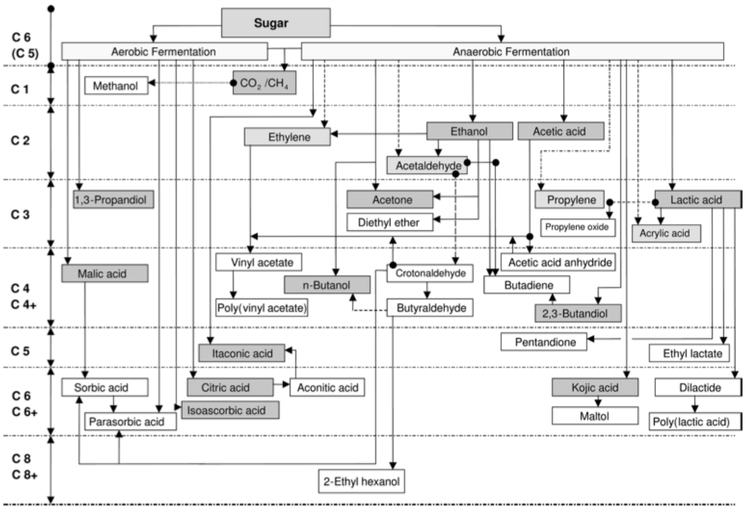
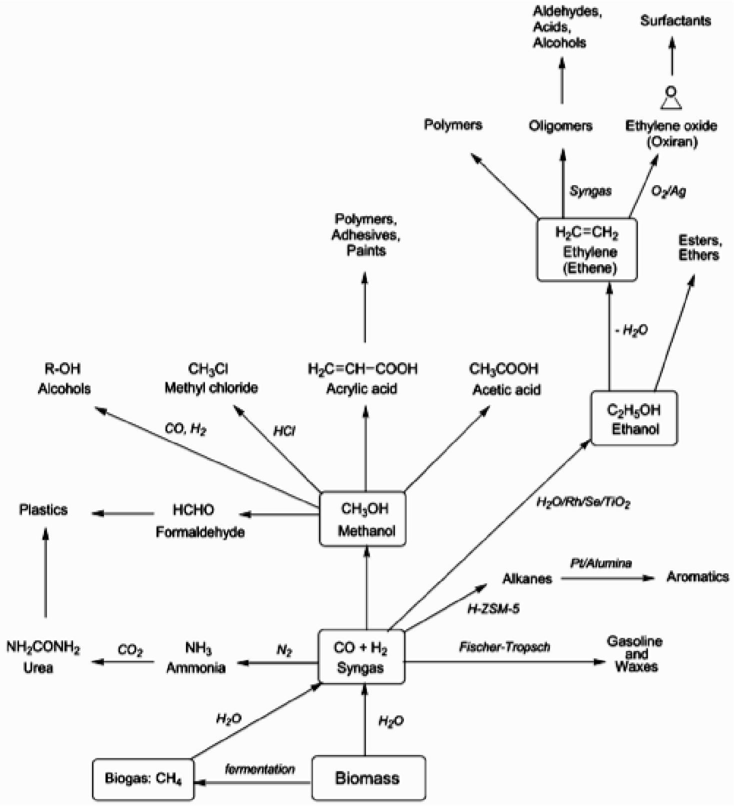
[3] Enthalpy in the picture stands for the amount of available energy



(a) Products of the sugar platform



(b) Products of the syngas platform

Figure 6.6: Product families for the syngas and the sugar platform (Source: [50])

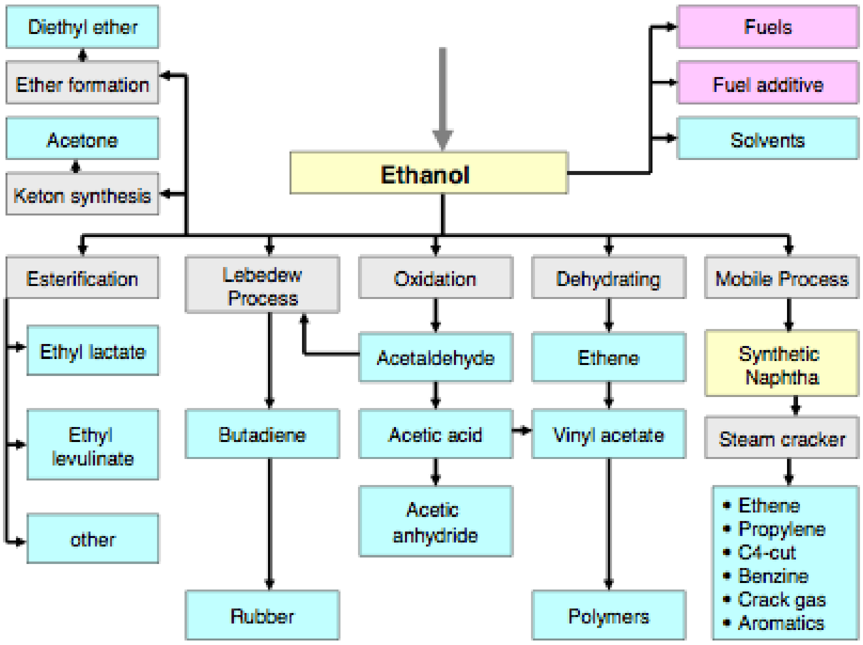


Figure 6.7: Ethanol as a platform chemical (Source: [47])

Chapter 7

Topology of biobased economies

> *“Man is not omnipotent. He, therefore, serves the world best by first serving his neighbour.“*
>
> Mahatma Gandhi

7.1 Is there enough biomass?

7.1.1 How to calculate?

Is there enough biomass to substitute fossil fuels? Current oil consumption amounts to 85’220’000 barrels daily - or 31’105’300’000 barrels yearly worldwide [73]. Knowing the energy density of oil, which is 48.6 MJ per kg for diesel or 54.2 MJ per kg for fuel oil [74], it is possible to calculate the total energy content of yearly oil consumption. We could then take any energy crops, be it corn, sugar cane, or miscanthus, and calculate, taking its respective energy density and average yields per hectare, the area required to replace consumption with biomass (see figure 7.1). However, what would this tell us? Certainly nothing about the sustainability of cultivation methods, nor about appropriateness to local conditions and regional differences or about who owns the land. Residual streams from animal processing, paper production, saw mills, etc. are often mentioned as alternative sources. We could collect data on quantities of world wide residues, and subtract this to the theoretically needed land for energy crops cultivation. This approach disregards claims of effluent materials for other applications. It is also not transparent concerning the sustainability of the correspondent animal, paper or wood processing respectively growth.

Can we ask how much food we really need? 1900 kcal daily is the WHO minimal human nutrition requirement for long term feeding[1] [76], while 2800 kcal are the current average nutritional intake worldwide [77]. We could try to come up with a calculation that crunches numbers on energy content of crops with respective yields per hectare and include the 2800 kcal to finally get a result on an average area requirement of land for food production, and see how much is left for non-food allocation. Or should we use 3400 kcal (industrial countries average),

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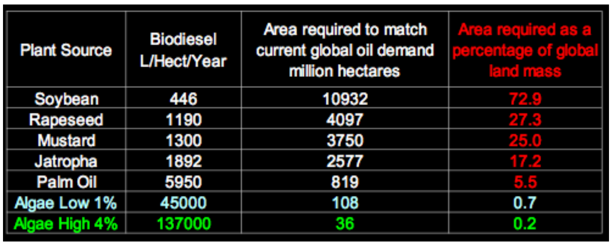
[1] in the context of disasters



Plant Source	Biodiesel L/Hect/Year	Area required to match current global oil demand million hectares	Area required as a percentage of global land mass
Soybean	446	10932	72.9
Rapeseed	1190	4097	27.3
Mustard	1300	3750	25.0
Jatropha	1892	2577	17.2
Palm Oil	5950	819	5.5
Algae Low 1%	45000	108	0.7
Algae High 4%	137000	36	0.2

Figure 7.1: Biodiesel yield per ha of some feedstock and required land (Source: [75])

or 1900 kcal? The average nutritional intake is an abstract entity which does not tell anything about the quality of the food, and relates to an imaginary average person.

What does a healthy diet consist of anyway? Vegetarians are certainly right pointing out that reducing meat consumption would free up more land for cultivation for human nutrition. Vegans would be even more drastic in their position. Fast food chains and affluence have made meat consumption affordable to more people, all the while obesity and other food related disturbances are a serious issue of developed societies. All these factors raise the level of complexity; finding an analytical way of calculating the minimum food acreage respectively the available space for other crops while accounting for feed-stock variety, regional differences and seasonal changes as well as for ethics and sustainability (which are very difficult already to define and even more so to quantify) is a monumental task.

There is consensus on the point that there is not enough biomass to provide for all current consumption - not even just for biofuels. Many studies have analysed the potential of nationally or worldwide available land for the biomass economy. However, exact analytical studies often start from assumptions which need to be put in context.

7.1.2 Some numbers

As an example, the U.S. Department of Energy (DoE) published a paper, where they come to the conclusion that 1.3 billion tons of dry biomass can be harvested annually in the U.S.A; 55 million acres (22.25 million hectares) would additionally be planted for perennial energy crops [72]. These calculations are based on current agricultural practices, which build on large scale monocultures and high fertilisation, pesticides and energy needs. Industrial monocultures deplete soils and threaten biodiversity, while pesticides and fertilisers introduce toxins into the environment. The study includes idle cropland and cropland pasture in the 55 million acres dedicated to energy crops; however, such a substantial area will have ecological and socio-economic repercussions. In any case, this theoretical harvest of 1.3 billion (dry) tons would be just enough to replace about a third of their petroleum based consumption with biomass sources, a goal the U.S. government set for 2030 (see figure 7.2).

A study in The Netherlands [71] comes to the conclusion that to only cover 30% of its energy supply from biobased raw materials, 3.5 million hectares would be required - while the surface of the Netherlands amounts to 3.3 million hectares. Although attesting huge potential to residual streams (waste from the food and drinks industry as well as from forestry, manure

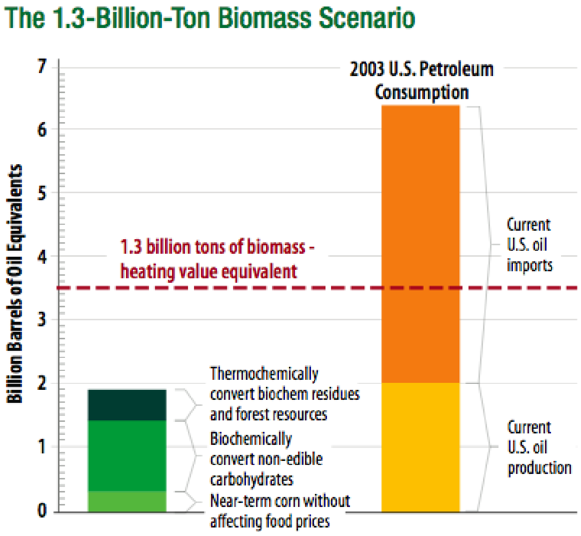


Figure 7.2: The 1.3 billion-ton scenario in the U.S.A. (Source: [78])

from agriculture, municipal organic waste, discarded frying oils, etc.), the study shows that self-sufficiency at current consumption levels is not possible.

Special attention should be placed on the term “waste“. In forests for example, dead or dying trees and plant matter is important: 20 to 25% of all woodland species depend on this “forest waste“. The study in Germany [79] finds that 5% of the biomass in German forests is rotting biomass, while in natural forests it would be around 40%. Utilising large amounts (if not all) residual forest material, implied in many studies, doesn’t account for this important element of forest health. Similar applies to compost. Many agricultural systems convert “residual“ material to compost, competing therefore with biorefinery claims for these materials; or, suitable substitutes must be provided. Most biorefining technologies produce a more or less concentrated fertiliser (biochar from pyrolysis for example, or press cakes). It would be more a social than technical challenge to introduce these.

Another work concludes that 125Mha of land (or the equivalent of 0.8% of the entire world’s land surface) is required to produce all functionalised bulk chemicals world-wide [70].

An article entitled “Renewable energy and food supply: is there enough land¿‘ states that today, 5 Gha of land are used for food production (including pastures for livestock for dairy and meat) [80]. It further comes to the conclusion that “...in the near future biomass is the most likely energy source, however, this source cannot fulfil all the energy needs“.

An IPCC paper, looking at the potential of biomass for carbon dioxide emissions reduction, calculates the energy contribution of biomass in 2050 around 200 to 400 EJ [2] per year, estimating the available area for biomass production at 1.313 Gha (around 8% of the world’s land surface) [81]. Currently, biomass provides 46EJ or 13.4% of global primary energy consumption (mainly

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[2] 1 EJ = $1x10^{18}$ Joules

in the form of wood and dung for combustion) [74]. As energy consumption is expected to increase almost threefold by 2050, biomass could account for roughly a third of total energy needs. [74] reduces expected contribution by 2025 to 2 to 22 EJ per year.

Such global approaches though make little sense in the context of decentralised economies, where local situations are imposing limits and conditions on what and how much can be grown. Although most studies try to incorporate sustainability issues in their analysis, most assumptions are still based on current agricultural and economical practices.

An important issue which is considered marginally at best, is the fact that biological resources follow the rhythms and whims of nature. Harvests can fail or significantly decline due to natural disasters, climatic extremes (possibly becoming more drastic through global warming) or pests, with seasonal differences affecting the continuity of supply, introducing additional factors and costs for storage. Potential biomass yields suggested by many studies should therefore be looked at with some critical eye.

But it seems clear that there will not be enough land for current consumption conditions. A regional example from Switzerland, examining a locally available crop for fuels, rapeseed. Its productivity ranges from 1100 to 1600 litres per hectare, while the whole agricultural land of the country could yield only around 397 million litres of biodiesel yearly, when the annual consumption amounts to 12'410 million litres [82]. Many academics put most efforts and hope for feed-stocks into lignocellulosic materials, like miscanthus or switchgrass, requiring second generation technologies and enzymatic hydrolysis together with optimised fermentation ([82], [83]). Miscanthus is a European crop which does not need neither irrigation nor fertilisation. Its productivity potential varies in Europe between 10 and 35 tonnes per hectare, typically being around 16.5 tonnes per hectare. Bioethanol yields span from 5368 litres (for the species Panicum Virgatum with minimal processing) to 35661 litres per hectare (Miscanthus Giganteum with optimised processing) - assuming maximal productivity [82]. Let's do the math: rapeseed's (lowest) productivity is 32.5 times inferior than the miscanthus's highest: 35661 / 1100 = 32.5. Therefore, at most favourable conditions, we would get for Switzerland 32.5 times 397 million litres = 12900 million litres, just 500 million litres above the current annual consumption. Unfortunately we just used up all the agricultural land for energy only crops...

Inevitably, we will need to reduce consumption to cope with all needs. Localising and regionalising promises massive savings in energy through reduction of transmission losses and transport distance. Intelligent allocation of resources, mindful interaction with the natural world and careful prioritisation and management of needs will need to be drivers for a sustainable distributed biobased economy.

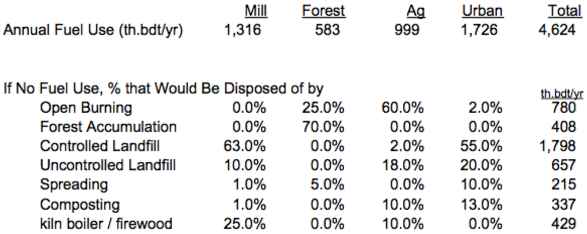
7.1.3 The right question?

> *"The original strength of Rome, like that of China, was that of a superior family-agriculture."*
>
> G.T. Wrench

Are we then maybe formulating the question inappropriately? Switching from high-industrialised agriculture, which requires huge amounts of fossil fuels, to small scale organic farming, reduces input needed into farming, and therefore the resources needed - another criteria for decentralisation. Sustainable farming, based on small scale holdings, reduces external dependence. Much has been debated about the efficiency of small scale (and ideally organic) farms versus industrialised methods. Many studies show that small scale farming can be at least as productive than large scale while being instrumental for a healthy agricultural sector [84] [85] [86]. Organic farms are systems which best ensure and preserve rich soils while fostering high biodiversity. Growing sustainable food is applicable similarly to growing sustainable energy crops.

Going further, we shouldn't forget about the potential of city farms, backyard and community gardens initiatives which are spreading all over the world [57]. Allotments and city gardens have always been part of the food production in urban settlements worldwide, and sometimes still are[3]. They can considerably contribute to food security, reducing pressure on agricultural land. In fact, this is one of the major pillars of the Transition Town movement, which promotes local food production, and empowers city inhabitants to implement urban solutions [6].

What about civilisation waste? In industrialised countries, around 30% of municipal solid waste is organic matter; in the Global South, this figure rises over 50% (some Indian cities reach 75%) [87]. Paper is found to be 25% respectively around 5%. Some few percent are wood, bones, and straw. The United Nations estimate worldwide annual waste production to be over 1 billion tons [88]. If we take the share of organic matter to be conservative 30% we get at least 300 million tons of organic matter which normally reaches landfills or incineration. This organic material can be used for composting, biogas - or any of the technologies portrayed in this document. Incineration is often the fate of organic residues from agriculture [89] (see figure 7.3).



	Mill	Forest	Ag	Urban	Total
Annual Fuel Use (th.bdt/yr)	1,316	583	999	1,726	4,624
If No Fuel Use, % that Would Be Disposed of by					th.bdt/yr
Open Burning	0.0%	25.0%	60.0%	2.0%	780
Forest Accumulation	0.0%	70.0%	0.0%	0.0%	408
Controlled Landfill	63.0%	0.0%	2.0%	55.0%	1,798
Uncontrolled Landfill	10.0%	0.0%	18.0%	20.0%	657
Spreading	1.0%	5.0%	0.0%	10.0%	215
Composting	1.0%	0.0%	10.0%	13.0%	337
kiln boiler / firewood	25.0%	0.0%	10.0%	0.0%	429

Figure 7.3: The fate of biomass residues at the example of California (2005) (Source: [90])

There are more developments with potential to mitigate limited availability of biomass resource materials. One is the ongoing research in algae based bio-oils and fuels. See section 8.4 for a closer look at the possibilities of algae cultivation.

A last fundamental point. I think the allegation that much of the energy we consume is simply wasted doesn't cause much distress and surprise. Such lavish utilisation of resources roots in the low cost of energy. Visiting Andean mountain communities or travelling in the Himalayan highlands of Nepal, but also meeting homeless people in our cities in winter, strikingly made me

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[3] Havana in Cuba is a good example; Cuba had to face a peak oil scenario when it became orphan from the former Soviet Union

experience how much value a little bit of wood can have if it is needed for heating and/or cooking. Therefore one of the major sources of energy is efficiency improvement as well as wary management of resources. A quote from Amory Lovins from the Rocky Mountain Institute:

> *"More efficient use is already America's biggest energy source – not oil, gas, coal, or nuclear power."*

7.2 Considerations on scale

For distributed economies, biomass small scale processing prevails to large scale units. Reduction of transport distances and costs as well as investments are the main reasons. Economies of scale certainly improve efficiency and yields; these gains are often lost to transport expenses. As a thumb rule, 10 to 15 tons of biomass per hectare yearly is the maximum harvest from (terrestrial) biomass [55] (which again, of course depends on the different climatic zones, types of biomass, soils, etc.). Research indicates that economies of scale require biorefineries capable of handling 5'000 to 10'000 tons biomass per day [91], therefore even mainstream industry is considering small to mid scale units.

90% of cost savings from increasing output of an ethanol plant from 10 million gallons to 100 million gallons is achieved by raising the output from 10 million to 40 million gallons. Only 10% of further savings arise by raising output to 100 million gallons [92]. Notably, these are costs per gallon unit of the final product. I contend that this is a biased economic factor, as bigger units always will tend to perform better under such an indicator. By contrast, investment costs for bigger installations will be considerably higher, requiring external financial support, introducing foreign ownership through capital and risk sharing and impeding local management of resources. When things are kept small, efficiency and costs per unit might be worse, but investment capital required tends to be lower, empowering communities for self-management of their assets.

Ownership of the units by farmers enables them to avail themselves of more shares of the whole value chain. Scale then not only applies to amount of raw materials, but also of investment capital. While at farm scale a unit can produce for self-sufficiency with some margins for sale, cooperatives of farmers can build bigger installations and share costs, while still taking advantage of high-value bioproducts. Cooperatives can even federate and form higher organisations where more ambitious projects can be realised. Of course, appropriate technical, financial (cooperative banking, credit unions, etc.) and maybe legal support should be provided for the successful implementation of such schemes. Such considerations are not pursued further in this document, but are of crucial importance.

Other ownership structures are possible, where urban and rural population cooperate, much along a community supported agriculture (CSA) scheme. Likewise, communities could participate in structures where they own shares on facilities which source raw materials from local farmers, municipal wastes and forestry residues, which in turn produce fuels, energy and other products from biomass. Depending on the capital raised different options for the implementation of technologies arise.

7.3 Topology

How could distributed biobased production be implemented?

First of all, I want to repeat that engaging in a kind of social engineering design will probably never work. What follows is a possibility, a potentiality, a rough sketch; approaching governments or institutions, pretending to have conceived a blueprint for sustainable societies and urging them to implement it would ignore the real basis on which these ideas are built upon: decentralisation is about people, about empowerment; acceptance is key.

Anyway, only few governments would probably be interested as some concepts might be challenging globalised businesses, multinationals, the economical mainstream and the political elite, although they begin to acknowledge that biomass harvesting will be economical only if decentralised, avoiding huge costs in transportation. However, their rationale for such thinking is a market efficiency one, not the sovereignty, self-determination or resilience of communities and (bio)regions [4].

Moreover, as I have highlighted several times in this paper, diversity, shaped by local conditions, is the rule in decentralisation, and what is appropriate in a place might be absolutely fatal on another. Therefore, the following outline is nothing else than a suggestion.

The basic assumption is that production is designated for local consumption in the first place. Surpluses can be shared with the wider bioregion. What can (and makes sense to) be produced locally will be produced locally.

In practice this could mean that energy generation would happen locally. Not only electrical, but also motive energy where possible. Means whatever the technology used, fuels could be produced more or less in situ. It makes no sense to build computers or to have a chemical facility on a farm; bigger scale requiring technology would be implemented in urban centres, alternatively through federation of cooperatives or other forms of communal and social enterprising.

For example, biodiesel is already widespread over the globe as a low-cost technology. It is relatively simple, and it can be produced at farm scale or by anyone in a garage (e.g. using waste oils). As the producer base is increasing, big business companies start to be worried, as their market shares could significantly be cut on the global scale [55]. Therefore, by adapting simple technology on small scale, a big impact can be achieved.

While biofuel and food production is relatively low-tech, lignocellulosic refining and high-value product development requires advanced technologies and bigger investment costs. However, multi-stage approaches can extend the reach of small scale production. Figure 7.4 shows a very rudimentary overview in a random European temperate climate area (electricity and heat generation not considered).

Small farms At farm level, whatever is produced benefits local needs and those of the community. Some surplus (pre-processed in the form of bio-oils or raw) of biomass is sent to the central processing unit at the nearest town or city (for example at market days along with food produce for the local organic market). Nutrients are retained and returned to the land from the effluents of production. A rough 70 to 80% of production remains for

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[4] Through ironic fate multinationals might be instrumental in instituting distributed (and maybe clean) production and decentralisation - if just for the sake of economic efficiency. In a complex world, this might enact unpredictable consequences more akin to alternative economic models - but these are just speculations...

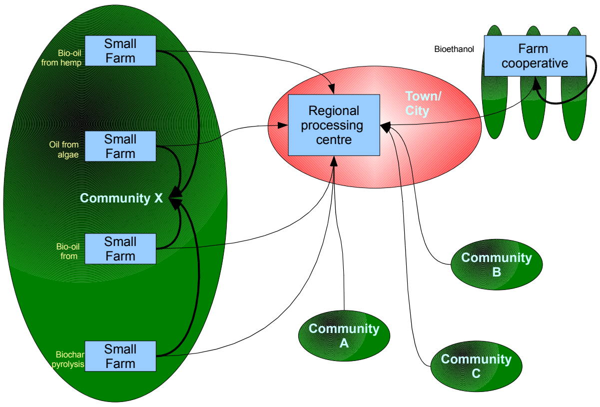

Figure 7.4: A possible scenario

local uses [55]. Any entrepreneurial farmer can establish own production of whatever is suitable (e.g. soaps from biodiesel preparation).

Farm cooperative Farm coops collect more biomass; they can employ more advanced technology in their biomass conversion, therefore other high-value products can be established - depending on amount and characteristics of feed-stocks different solutions are possible. Note that such constellations create high-technology jobs in rural environments, as such installations need to be maintained and operated. Cooperatives can federate to create larger organisations with higher availability of raw materials and therefore wider possibilities.

Town or city At urban centres, rural produce converges. They also provide raw materials from municipal organic waste; gastronomy; forestry, gardens and park maintenance; roof top gardens; city farms; algae cultivation. With higher economic power, advanced solutions are possible: from the bio-oils, solvents, chemicals and biodegradable plastics can be produced.

7.4 Chronology

Such a transition will not occur from today to tomorrow - nor will petrol imminently vanish completely. Technologies might improve, new ones be discovered, and existing ones become cheaper and wider accessible.

But some steps can be done today. More and more people are switching to home or locally made biodiesel [93]. It is a transition to start being independent from petrol with all its political, environmental and social implications.

However, processes which produce plastics and other items of modern times need to improve, adapt to circumstances (feed-stocks) and get cheaper; appropriate technology should be made available through open source information publication. This might require time; only necessity might speed up such developments. This is a challenge to the current unstable situation with rising oil prices and receding fossil resources. It is to be hoped that we have time enough to accomplish this transition. Having being a pessimist for many years, it is with great joy that I register how many people world wide are working for a better world in countless NGOs, organisations, farms, social groups, businesses and educational institutions to name a few. I turned to positivism, I believe that we can transform humanity into a species harmonising with its host, beautiful planet Earth. The outlook of catastrophe is not enticing; chaotic and violent reactions are likely to be the consequence. I prefer to visualise a hard, difficult but peaceful and successful transition.

The next chapter will look at some case studies which illustrate some processing of biomass into valuable products apt for small scale and distributed economies.

Chapter 8

Case Studies

It is not my intention to propose final solutions which fit anywhere, but to show that there is a diverse set of small to mid scale biobased technologies. The spreading of knowledge is the most enticing aspect of globalisation. By making information accessible to virtually anybody, communities and regions can collect data and chose the appropriate options.

8.1 Biodiesel

8.1.1 Home made biodiesel

Biodiesel is 100% biodegradable, degrading 98% in three weeks. Its combustion emits no net CO_2, as it releases the same amount of C that the plant took when it was growing. Further emission reductions compared to fossil fuel diesel are 40-60% of soot, 10-50% of carbon monoxide, with further reductions in a number of carcinogenic aromatic hydrocarbons [94].

Biodiesel has a long track of successful small scale production sites. Technologies and processes for biodiesel production are mature, well understood and simple. Web sites, mailing lists and wikis [1] dedicated to biodiesel manufacturing are plentiful (see appendix C). There are manuals available with detailed descriptions on how to make biodiesel at home. They usually suggest beginners to start with pure unused vegetable oil (canola, corn, soybean, etc.), but highlight waste vegetable oils or WVO in terms of recycling. [95] states that “biodiesel can be made at home using basic equipment such as a blender and a strainer“. The same source informs the potential home brewer that there is the choice of assembling an own factory from simple materials or of acquiring professionally made equipment from dedicated businesses - a considerable market. It is of course a matter of investments and personal dedication which solution is chosen. I redirect the interested reader to these sources for detailed instructions on how to make own biodiesel.

The procedure is basically the same for any vegetable oil, although WVO needs more care and experience, as it comes in very different purity and quality. Therefore, WVO needs filtration (removing of food particles and impurities) and separation from eventual water in the oil; next it

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[1] Wikis are web sites where everybody can add and edit content. They are virtual places for collaborative working, information and file exchange

needs titration, a process to identify the pH value of the oil, determining how much catalyst will be needed in the process . According to [57] , the costs for producing home made biodiesel from WVO amount to 0.5 to 1 USD per gallon [2]. The raw material (WVO) is often available for free from restaurants, but today it is not unusual that it will need to be purchased; however, prices are low (22p per litre in the UK is a quote from [95]. Additionally, biodiesel requires methanol (an alcohol present in many drinks and foods; as we have seen, it can also be produced from biomass, but currently it is mostly still derived from fossil resources) for the transesterification process (separation of glycerine from the oils). Lye[3] as catalyst enables the chemical reaction of biodiesel with methanol; these chemicals can be recuperated and recycled for many batches of biodiesel processing.

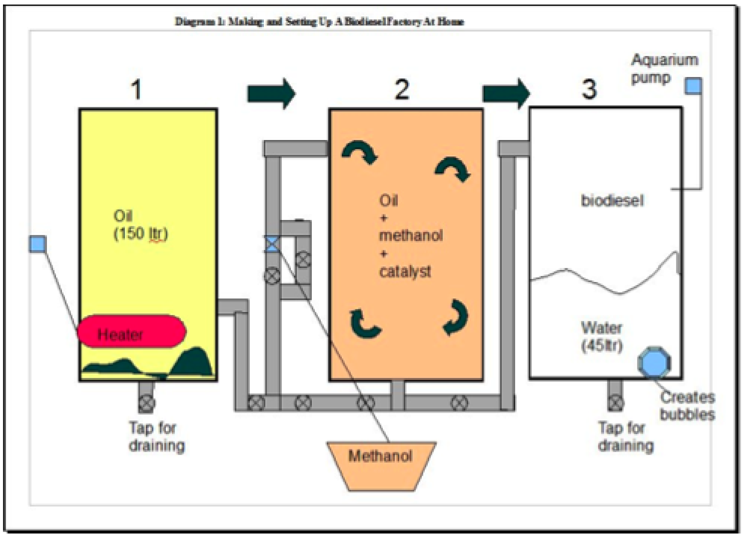

Figure 8.1: Example of a small scale biodiesel factory at home (Source: [95])

There is only one by-product from biodiesel fabrication: glycerol, which can be processed into soap.

10'000 tonnes of used cooking oil are produced every week in the UK alone, its usual disposal as animal swill has been prohibited by EU law [95]. Such feed-stock certainly is ideal for conversion into biodiesel. The [57] web site maintains that initially, from 10 litres used vegetable oil, 8-9 litres biodiesel is realistic, and that over time and experience the production rate can improve. The same source further declares that only 10% of WVO worldwide, equivalent to billion of litres, is being collected - the rest usually ends up in landfill.

Many plants are suitable for biodiesel production if pure vegetable oils and not used oils are targeted, and locally adapted varieties are obviously the better choice for environmental reasons. This means in consequence regional differences in yields. Figure 8.2 shows a list of yields and

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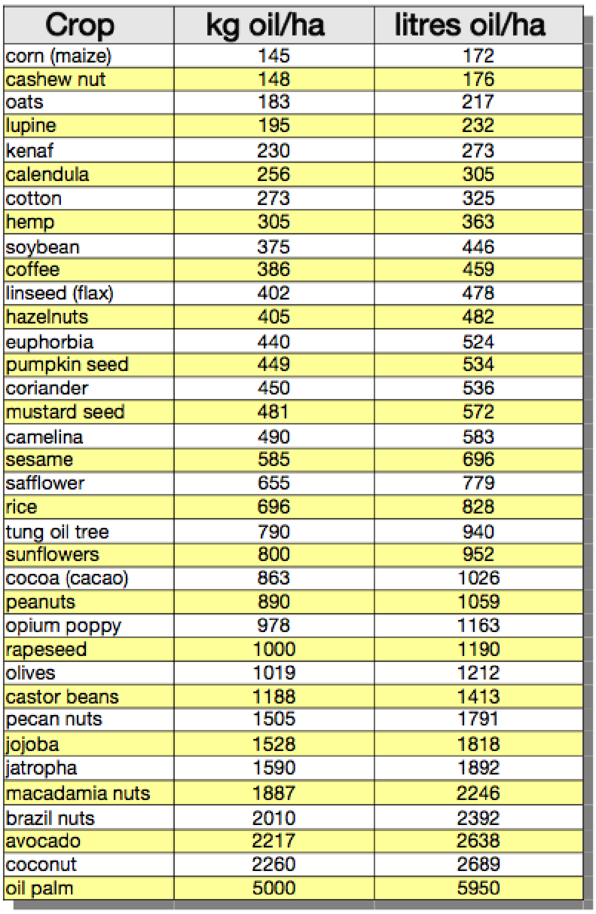
[2] 1 gallon = 3.7854118 litres

[3] Either potassium hydroxide KOH or sodium hydroxide NaOH

acreage for some selected crops.



Crop	kg oil/ha	litres oil/ha
corn (maize)	145	172
cashew nut	148	176
oats	183	217
lupine	195	232
kenaf	230	273
calendula	256	305
cotton	273	325
hemp	305	363
soybean	375	446
coffee	386	459
linseed (flax)	402	478
hazelnuts	405	482
euphorbia	440	524
pumpkin seed	449	534
coriander	450	536
mustard seed	481	572
camelina	490	583
sesame	585	696
safflower	655	779
rice	696	828
tung oil tree	790	940
sunflowers	800	952
cocoa (cacao)	863	1026
peanuts	890	1059
opium poppy	978	1163
rapeseed	1000	1190
olives	1019	1212
castor beans	1188	1413
pecan nuts	1505	1791
jojoba	1528	1818
jatropha	1590	1892
macadamia nuts	1887	2246
brazil nuts	2010	2392
avocado	2217	2638
coconut	2260	2689
oil palm	5000	5950

Figure 8.2: Oil yields from different crops (Adapted from: [57])

Energy is required for the blender during biodiesel production, easily proportioned through renewables. It is also recommended to heat up WVO to purify them, therefore requiring more energy. Immersion heaters can operate on electricity, while gas burners require another form of fuel; pellets or biogas would be most appropriate. Using fossil fuel (natural gas) would reduce the environmental benefits of biodiesel production and question much of its rationale.

8.1.2 Small scale production in Africa

MFC (Malifolkecenter) Nyetaa is an organisation in Mali with some pilot projects on biofuels from jatropha. These projects aim at providing sustainable development to poor rural areas in Mali. "Inclusion of local people in project design and implementation ensures these activities have community roots and local buy-in, and participate in revenue generation. Access to modern energy services improves living standards and conditions for small and medium enterprises“. [58]

MFC Nyetaa facilitated the plantation of 1000 ha of jatropha for biodiesel production, which is used to fuel a 300kW power plant through three 100kW modified generators, providing clean energy to 10’000 people for domestic use, small industries, businesses, schools, maternity clinic and community buildings. According to the project description, the funding amounts to 593’000 Euro. Users are required to pay for the electricity they consume, but get additional income by growing jatropha. Cultivation takes place on “...a mixture of unused and abandoned land, and people’s field. It does not compete with food supply,...“. The organisation claims that there is no irrigation needed for the plants, therefore water supply is not affected. [58] earlier in the document declares: “Jatropha grows well on marginal lands. It requires no more than 400-500 mm of rainfall per year and can withstand long drought periods. It can also grow in areas with less precipitation provided that humidity is sufficient“.

The Indian organisation Navdanya [62] has condemned industrial biofuels production based on jatropha as a false solution to climate change, as a threat to food security and specifically documented land grab by multinationals and authorities. It points out that often denominated “wastelands“ are communal lands of villagers, which traditionally use them for other purposes (e.g. grazing). Also, it attacks the claim that jatropha doesn’t need irrigation as a myth; referring to a report it states “Although jatropha can grow on wasteland with very little water and care the plant needs constant maintenance and inputs like fertilisers and irrigation to produce commercial scale yields. This is particularly vital in the first two to three years of the crop’s life cycle“. But they also conclude: “A decentralized, biodiversity based bioenergy policy can be a major route to rural development. Democratic decisions at the village level are the best process for determining the best mix of bioenergy for local needs“.

In the context of distributed biobased economies, this is exactly the envisioned approach. It remains to be proven if the Mali project performs along this line; however, it seems that the harvest is destined for the local population, and not drained to other sections of society like in the cases documented by Navdanya. The bottom line is that if the community has the ownership of the cultivation and the land, the decision power on what and how much to grow and finally to what the harvest is allocated (being therefore responsible for their food security as well), this example shows that small scale biodiesel production can be beneficial and sustainable for rural communities.

There are a number of such projects with jatropha; under the term multi-functional platform (MFP), there are many programs running in Africa (Tanzania, Ghana, Mozambique, Zambia) [58], or Latin America (Gota Verde in Honduras [96]). MFPs (see figure 8.3) are essentially small scale diesel engines, which, powered with jatropha oil in these cases, are used to drive a press (for pressing the jatropha oil itself or other oils), a generator to provide electricity, a mill (for grinding cereals), or a compressor (inflating tyres). The oil can also be used for transportation.

These MFPs require moderate investment costs (compare figure 8.4). The projects mentioned above are financed through external development agencies and organisations. Low-impact ecovillages and communities, especially in the West, can self-finance such infrastructure if cooperatively managed.

Figure 8.3: The MFP unit in Tanzania (Source: [58])

However, there are means other than diesel engines to generate electricity, which might be better suited for certain environments. Also, diesel engines of course are noise pollutants (and still a combustion device producing fumes, even if operating much cleaner by burning vegetable biodiesel instead of conventional - compare chapter 8.1.1), therefore an operation close to dwellings does have undesirable aspects.

8.2 Talukas in India

A lived example very closed to the concepts described in this dissertation comes from India. About 90 to 100 contiguous villages form an administrative block called *taluka*. On average, a taluka spans over 1000 to 1500 km^2 and encompasses 200'000 to 250'000 people. A town with about 50'000 inhabitants constitutes the capital. India has 3342 talukas. A study analysed their potential for the production of the "majority of its demand of food, fuel, fodder and fertiliser from the natural resources and agro-based material" [89] by looking at Phaltan, a taluka in the western Indian Maharastra region. In the study, a taluka is interpreted as a "closed biomass and rainwater basin". Such a definition is close to bioregional philosophy.

The inquiry included the following supply options:

1. Ethanol production from sweet sorghum and molasses produced by existing sugar factories
2. Pyrolysis oil production from agricultural residues
3. Electricity production from energy plantations and agricultural residues

The author concluded that these energies can replace the taluka's imports of petrol, LPG [4], diesel, kerosene and electricity, while providing employment to about 30'000 people. These conclusions are based on the following facts and assumptions:

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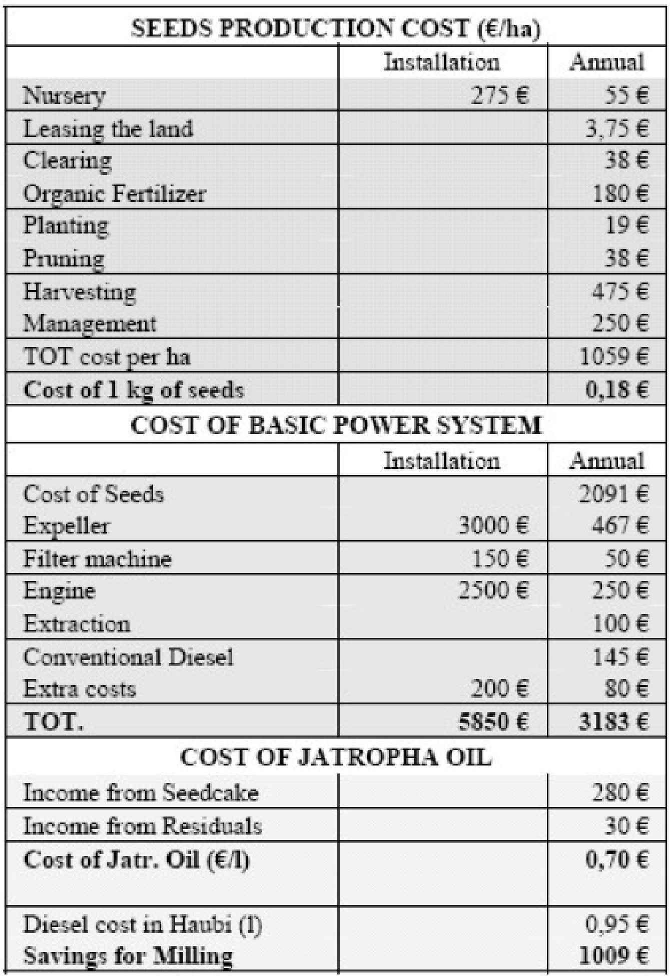
[4] Liquified Petroleum Gas



SEEDS PRODUCTION COST (€/ha)		
	Installation	Annual
Nursery	275 €	55 €
Leasing the land		3,75 €
Clearing		38 €
Organic Fertilizer		180 €
Planting		19 €
Pruning		38 €
Harvesting		475 €
Management		250 €
TOT cost per ha		1059 €
Cost of 1 kg of seeds		**0,18 €**
COST OF BASIC POWER SYSTEM		
	Installation	Annual
Cost of Seeds		2091 €
Expeller	3000 €	467 €
Filter machine	150 €	50 €
Engine	2500 €	250 €
Extraction		100 €
Conventional Diesel		145 €
Extra costs	200 €	80 €
TOT.	**5850 €**	**3183 €**
COST OF JATROPHA OIL		
Income from Seedcake		280 €
Income from Residuals		30 €
Cost of Jatr. Oil (€/l)		**0,70 €**
Diesel cost in Haubi (l)		0,95 €
Savings for Milling		**1009 €**

Figure 8.4: Production costs of a jatropha oil MFP in Tanzania (Source: [58])

1. The staple crop cultivated is sorghum. The author suggests to replace it with sweet sorghum, its agronomy being very similar between the two varieties; no additional land would be needed to be cultivated (cultivated area is at 75% of total area). Sweet sorghum provides for food, fodder and ethanol; the whole plant can be harnessed.

2. Of 340’000 tons of sweet sorghum stalks, 100’000 would be destined as fodder for cattle (enough to cover fodder requirement); grain harvests would be around 12’000 tons. The remaining 240’000 tons would yield 9.6 million litres of ethanol through a medium-sized bioethanol distillery. The effluents from the distillery are assumed to amount to 65’700 tons of bagasse, enough to produce 3.8 x 10^6 m^3 per year of biogas, able to generate 8.7 MW of electricity

3. The two existing sugar factories for sugar cane could produce 5.6 million litres of ethanol

from the molasses; biogas from the residual material would be used to run the distillery.

4. The toluka already produces 210’000 tons of agricultural residues every year, which are currently incinerated. The sweet sorghum portion of the 210’000 tons is 100’000 tons, of which 60’000 tons per year could be fed to the pyrolysis unit, its yields estimated at 45’000 tons of bio-oil (destined to be used as biodiesel), 6000 tons of charcoal and 9’000 of syngas, which would be used to run the plant.

5. The other 40’000 tons of sweet sorghum residues would be allocated for electricity generation from biogas, with potential for 46 million kWh electrical energy.

6. Further 39 million kWh electricity could be provided by the existing sugar factories; another 76 million kWh from the sweet sorghum distilleries.

While the petroleum products can be entirely replaced through biomass resources, electricity needs would not be met. A gap of 216 million kWh remains. The study proposes to put 16’000 ha under fast growing tree plantations for additional biomass harvests to fill the gap. 9000 ha would be needed from governmental forest area where the research claims the forest is “non-existent“; another 7000 ha would need a combination of wasteland and farmers’ land. The sustainability aspects of such measures are not transparent. However, the gap consisting of electrical energy, it could be argued that other and maybe better suited technologies like solar, wind or hydroelectric installations could be adopted instead of planting trees. Nevertheless, categorically rejecting to plant trees seems not the most sensible formula to me. Careful examination of local situations might very well open up possibilities for biomass planting for energy reasons, as such practices contribute to CO_2 abatement, improve air quality and increase biodiversity. Planting species for energy purposes is problematic if local ownership of the land is undermined or misused, the soil is being depleted, a net loss of biodiversity is the consequence or worse contributions for global warming result from changes in land usage.

Generally, the study shows that there is large potential for biomass based energy self-sufficiency at bioregion scale. Regional differences could be levelled out through different quotas of specific renewable options.

The author of the study through an email exchange with me asserted that his work has lead to the adoption of its basic principles in India through the Ministry of New and Renewable Energy (MNRE). Details on the current situation of the project could not be retrieved.

8.3 Biochar

Amazonian soil is known to be of poor quality; the lush tropical biomass assimilates most of the existing nutrients, the scant soil beneath it is called oxisol. Some of the soils in the same region however are of different characteristics: blackish soil that keeps nutrients and produces good crops, called *Terra Preta* or *Terra Preta do Indio*. It as a manmade soil, which indigenous pre-Columbian populations developed thousands of years ago. Their technique entails cutting down a portion of the rain-forest; instead of systematically burning down the area though (like today’s “slash and burn“ farmers in the Amazon), the cut trees are covered with straw, soil, turf, leafy vegetation or any other material that will choke the fire. The incomplete burning results in charcoal left behind. Mixing this charcoal with the soil creates Terra Preta, one of the most fertile soils known in the world [97].

(a) Oxisol of the Amazon (b) Terra Preta

Figure 8.5: Comparison between oxisol and terra preta from the same region (Source: [98])

The char produced has high porosity, and can absorb a multitude of nutrients while being host to a multitude of micro-organisms, improving the quality of the soil - especially in combination with sandy or clayey soils [99] [100] [101] .

A modern way of producing these effects is known as biochar. Biochar is obtained through pyrolysis (refer to section 5.8.1). It is the result of slow pyrolysis of organic material in absence of oxygen. From simple backyard kilns processing organic waste from gardens to advanced fluidised bed processing plants, this basic principle scales well over different application requirements and processing quantities. A continuum of sophistication is available, which varies specifically in efficiency depending upon the rate of utilisation of by-products [97]. A quote from the same source: "One can imagine the middle-scale device mentioned above[5] equipped with heat-exchanger and an assortment of gas filters for district heating a local village, at the same time providing a work-place for the production of chemicals, raw material for plastics,

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[5] Referring to farm scale equipment described previously in that document

using Fisher-Tropsch catalysis to convert carbon monoxide and hydrogen into biodiesel“.

In an article in *Nature* [100], a pilot plant is reported to process 10 to 25 kg of peanut hulls and pine pellets per hour. From 100 kg of biomass, it recovers 46 kg of carbon (half as char) and 5 kg of hydrogen - enough to fuel a hydrogen-fuel-cell car for 500 km.

The same article highlights one of the most remarkable characteristics of this process: even after the fuel has been burned, more carbon dioxide is removed from the atmosphere than is put back, promoting the technique as a prominent candidate for carbon sequestration. In fact, the char effectively captures the carbon from the biomass. If put back into the soil, a compelling method for long term storage of carbon is at our disposal, as the carbon is locked away for maybe hundreds of years, or even thousands [102]. Fuels made from bio-oils produced via biochar-pyrolysis thus become the only known carbon negative fuels. If carbon sequestration funds are implemented, this can result in additional income source for anyone producing biochar.

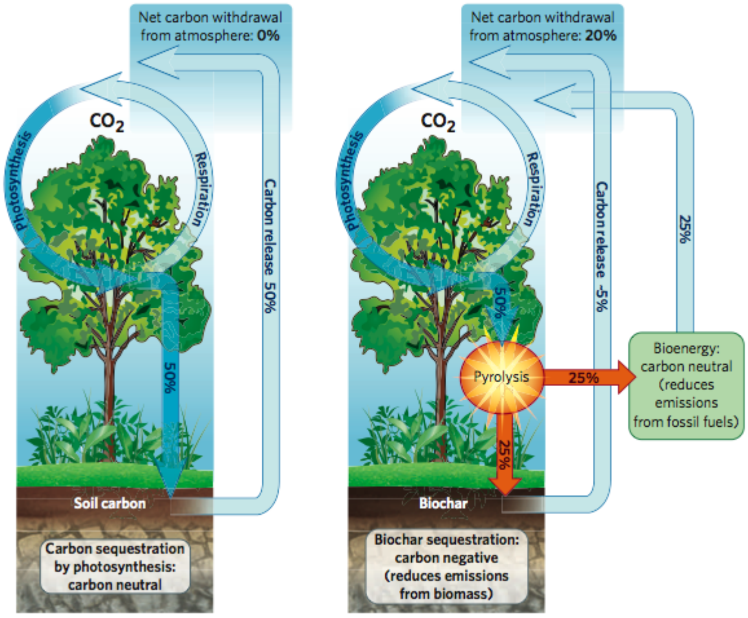


Figure 8.6: The principle of carbon sequestration with biochar (Source: [102])

8.4 Algae

8.4.1 The future?

Algae are praised as the remedy for the future. The reasons: they don’t need good agricultural land or forest clearing, and their cultivation does not directly compete with food production. In fact, the opposite is the case: algae like Spirulina are already being grown in different parts of the world (e.g. China, India, Hawaii) for the production of dietary supplements [103]. Furthermore, the yields of oil from algae are significantly higher than from any other oil crop (compare figure 7.1. Concepts have been developed combining algae cultures with sustainable, organic food and animal feed production, a combination of algae growing pond, greenhouse and fish rearing (e.g. [104]). They are also being targeted for wastewater treatment (which is the most realistic short term application according to [103]), as a potential provider of bio-hydrogen (see chapter 6.1.5) and even as a cure for CO_2 intensive industry: they are investigated to be grown near smoke stacks where they would feed on the carbon dioxide emitted (Carbon Capture and Storage strategies, CCS, implications of this approach are outside the scope of this paper).

Growing algae for biofuels and bio-oils is a different issue. Most sources agree on the fact that much research still needs to be done for the effective implementation of algae schemes. The majority of the published success stories are confined to lab environments or specific conditions.

Early research on biofuels from algae started in the 1950s, when first mass cultures were cultivated at the MIT [103]. From 1978 to 1996, the U.S. Department of Energy (DoE) ran the Aquatic Species Program (ASP), which focused on investigating biodiesel from algae grown in ponds [105]. Due to budget restrictions the ASP has been stopped in 1996. The program aimed to isolate strains of algae with desired characteristics: high productivity, high lipid (fats) content for high oil yield, competitiveness in outdoor culture, and fluctuations in temperature and salinity. No such strain could be found; it is assumed that conditions for high productivity and rapid growth respectively lipid accumulation may be mutually exclusive. Therefore the report closes with the recommendation for further research addressing these issues, while acknowledging that economic viability had not been proven. The ASP envisioned large scale algae cultures.

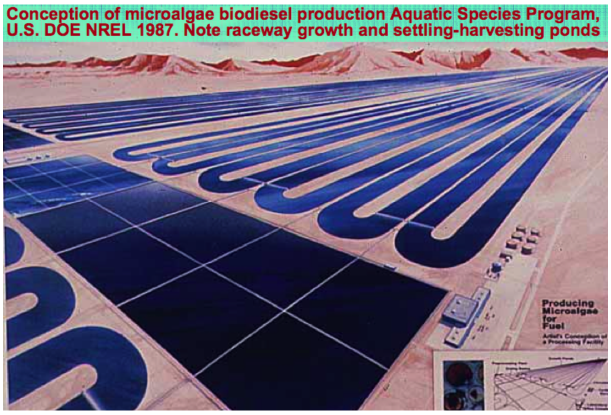


Figure 8.7: ASP vision of algae production (Source: [105])

8.4.2 About algae

By the way - petroleum is assumed to have been building up over millions of years from kerogen, a substance formed from algae and other degrading organic matter [106]. This means, what we are burning today as fossil fuels has also been built up by algae.

The general term algae comprises micro-algae, which are tiny single-celled organisms, and macro-algae (commonly known as seaweed), multi-cellular aquatic plants, which can grow to over 60 metres (giant kelps). Defining what algae are is a difficult task. There are 30'000 described species, not more than 10% of the estimated species number! By modern definitions algae are eukaryotes (cells containing a nucleus) and conduct photosynthesis. Browsing the Internet for classification information reveals a fundamental dynamic - things seem not to be fix. [103] introduces 11 divisions split up in 29 classes. [107] proposes 3 supergroups, while other sources show 8 groups [108] or 6 divisions [109]; others argue about different classifications depending on the amount of kingdoms (from 2 to 30) or divisions and classes. The most often repeated groups though are the brown algae (Chromista), the red algae and the green algae.

Algae provide the bulk of the oxygen in the air of our planet, consuming carbon dioxide in the process while providing their own food through photosynthesis. They are also the food base of many animals; the species coccolithophores and diatoms are furthermore instrumental in the Gaia theory [110]. Algae are thus of immense importance for the ecology of the planet - all living beings depend on them!

Algal organisms can live in the most various environments: from salty sea water to lakes, from mud to sand, from hot springs to snow, and from rocks to plants.

Proteins, carbohydrates, lipids, and nucleic acids are the basic components of algae - but of course, due to the incredible diversity of the species, in exceedingly varying proportions. Some species have high concentrations of lipids - that is what makes them interesting for biodiesel and bio-oil production. In fact, once separated, the oils can be processed in a similar manner like vegetable oils.

8.4.3 Cultivating Algae

Algae accumulate lipids when exposed to environmental stress - typically nutrient-deficient conditions, like nitrogen starvation. Therefore, lipid content varies according to conditions, one of the difficulties encountered so far in research. So the basic question when starting an algae cultivation is obviously “with which strain do I work¿‘. As we have seen, the ASP, after 17 years of investigation, could not come up with a concluding answer to the question - which epitomises the magnitude of the challenge. They did however conjecture that diatoms, a silica-walled type of phytoplankton, and green algae might be the most promising candidates.

Algae can be grown either in open ponds or in closed structures called photobioreactors. To live, algae need sunlight, carbon dioxide and water. Rearing them in open ponds is the cheapest and most simple strategy. Notwithstanding, there are severe implications which need to be addressed. In open environments, it is difficult to keep undesired species from contaminating the culture. Such species, which are likely to be of little interest in terms of lipid content, could take over the pond ousting the desired strain. Furthermore, conditions (light, temperature, CO_2) are more difficult to control, and location might dictate the growing season length. The Ecogenics approach [104] improves this situation, as a confined greenhouse inhibits external species from colonising and introduces much more controlled and constant conditions. Commercial ponds are called racetracks, they feature paddle wheels to keep the water moving and the algae suspended.

Photobioreactors are mainly made of glass or plastic tubes, tanks, plastic sleeves or bags. They are mainly used in high-technology research, as they increase the cost and the complexity of the system. Their rationales are less contamination and water use, better light exposure and generally optimised controlled conditions.

8.4.4 Biodiesel from Algae

[112] seems to be the most active open information site currently on the web on the issue of algae oil. Under Algae Oil Extraction we can read: "In terms of the concept, the idea is quite simple: Extract the algae from its growth medium (using an appropriate separation process), and use the wet algae to extract the oil. (Note: The algae need not be dried before oil extraction)“. It maintains that oil extraction is the most costly of the steps, determining the future sustainability of algal oil production.

They suggest three well-known methods for oil extraction, which are being already applied for extraction from oilseeds.

Expeller / Press Plain mechanical pressing of the algae; simple and fairly effective: 70 to 75% of the oil can be recuperated with this method

Hexane solvent This is a chemical approach, often the carcinogenic compound benzene is used, but ether or hexane work as more economical alternatives. Despite the yields of 95% if combined with mechanical pressing, this seems not an appropriate environmentally sound option.

Supercritical Fluid Extraction Almost 100% of the oils can be secured. CO_2 is liquefied under pressure and heat and acts then as the solvent. Requires special equipment for containment and pressure.

Other less known methods used are enzymatic, osmotic shock and ultrasonic extraction.

After algal oil has been extracted, it can be transformed into biodiesel through transesterification - much in the same way as with other vegetable oils. However, [112] alleges that the process is normally done with ethanol (instead of methanol) and sodium ethanolate (a result of the reaction between ethanol and sodium) as catalyst. To isolate the biodiesel, ether and salt water are added, mixed well and afterwards left alone; the biodiesel/ester mix will settle on the bottom. Biodiesel is then separated from the ether by a vaporiser under a high vacuum: the ether vaporises, biodiesel ready for use is the result. An alternative is to employ centrifuges: they can be useful in algae separation from their medium or to segregate biodiesel after transesterification.

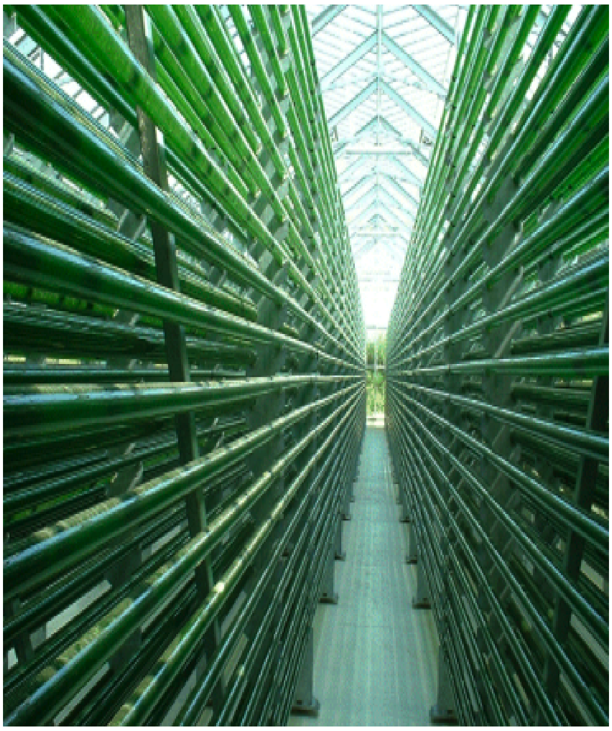
As algae are biomass, effluent material from the oil extraction can be processed like any other organic material discussed in this thesis (biogas, pyrolysis, fertilisers, animal feed, etc.).

Finally, other uses for the oils other than fuels is possible too. Thus, the potential is huge.

8.4.5 Are we there?

On forums like [112] or [93], there are entries in forums of people claiming to have produced oil from algae. However, none of these sources can be verified. There have been also assertions made from commercial enterprises that successful biofuel production from algae oil had been achieved. Notwithstanding, the reality is that nobody seems to have a stable production going.

(a) Commercial open ponds



(b) Commercial photobioreactors

Figure 8.8: Examples of open ponds and photobioreactors (Source: [103], [111])

But with all the attention that the topic of energy from algae has got, and the money spent in research, it can be assumed that some sort of breakthrough is not too far away. News about corresponding announcements from companies all over the world abound. Although being speculative now, it seems algae will be able to provide fossil free fuels in the short to mid term. As they don't compete with food resources, are potentially able to be cultivated in very diverse environments, and with a much higher yield per hectare, algae in fact have the potential to make fossil fuels history; they are the only alternative to petroleum that indeed can replace the entire current consumption without requiring arable land, planting of fuel crops, deforestation or land grab - in theory.

On the other hand, with algae we are dealing with life - it is not something we can just extract from the crust and use; we have to rear and care for it. Moreover, life inherently is unpredictable. Like with any crop, harvesting algae might be subject to fluctuations, uncertainty and failure. Therefore, maximising resilience regains weight in the discussion, even if in a few decades all of the oil products could be replaced by algae oil. Thus, decentralising at smaller scales instead of gigantic cultures (which could be compared to monocultures in land based agriculture) threatened by diseases, contamination, atmospheric and climatic events (or massive extinction in closed environments) and other natural menaces would certainly increase the degree of resilience. It might even be easier to grow algae in smaller magnitudes than to keep conditions appropriate for huge cultures.

Genetic engineering will want to play a significant role with algae too. There are many papers (see NREL web site, [113]) documenting the potential for modified organisms.

I realistically assume that non-algae based biomass will still be complementarily important (especially for oil production), as growing algae might not be suitable everywhere, respecting giving conditions.

> *"The advantage of biofuels and other renewable energy sources is that they will be so scarce and expensive that we will need to use them very frugally instead of wasting them wantonly as we do now with fossil fuels, and would with nuclear energy."*
>
> John Benemann [6]

8.5 Biogas and composting

Biogas is a technique which is very established and well understood. A big portion of India's (rural) economy is based on biogas; it is also gaining importance in our countries for organic residues. Composting is even more widespread, namely in organic agriculture settings all over the globe, but also in urban environments for the useful disposal of organic household and garden leftovers.

As documentation and articles on both solutions is profuse, they are not further detailed in this chapter. However, I want to stress that they are integral part of biobased economy concepts, and often will be the most suited application in many situations.

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[6] Principal Investigator and main author of the U.S. DOE Aquatic Species Program (ASP)

Chapter 9

Conclusions

Distribution (or decentralisation) is a key element to increase resilience. Distributed energy is best implemented with renewable systems, and is therefore environmentally friendly. These systems scale very well and can therefore be used from household to industry level. If we equip our houses and dwellings with local power, who needs nuclear stations anymore? Furthermore, it makes communities independent from national policies, market fluctuations and power cartels and gives the authority over energy back into communities, improving self-sufficiency, autonomy and consequentially helping to instantiate real democracy, as the individual's say is of greater influence in community matters. The level of autonomy and self-determination is increased with any more item which is distributed: production, political decision making, financial and resource management. The notion of distribution subtly entails that communities are free to decide on their own life style, customs and structures. A very decisive aspect is that it does not denote isolation; communities form coherent wholes within their bioregion. Rural settlements, small villages, towns and cities are interdependent: local and city markets are vital for economic interchange, while people share language, traditions and culture, reinstating sense of place and belonging to the natural surroundings. Like everything in nature, boundaries are neither rigid nor impenetrable, but responsive and permeable.

This thesis also highlights the importance of electronic communication, therefore networked economies. Specifically, the free circulation and voluntary sharing of information has enormous potential to creatively shape our daily lives. It provides for connectivity, but also promises unrestricted access to information and therefore to education. Open source animates people all over the world to participate in collaborative work, study, production and exchange, and is a powerful tool affording equal conditions to everybody with potential to raise living conditions for the disadvantaged by publishing technologies, educative material, etc. For me globalisation bears an alternative opportunity: globalise information, not products!

A sustainable society does not deplete resources but nurtures and tends to the natural world, preserving it for future generations. Therefore it has to source its needs from renewable supplies, not only for energy, but also for production. Hence biobased economies: societies based on biomass - on life.

I feel this is the biggest challenge to the principal propositions in this paper. That is why I decided to go a little bit deeper on this issue - even if (or just because) I have no expertise whatsoever in the field. Information on how to decentralise energy generation with renewables is abundant; initiatives which promote localisation of food production are plentiful, as well as voices advocating to resuscitate and revive ancient and traditional knowledge in local arts, handicrafts and manufacturing. Reality is, modern life is very reliant on oil and petrochemical artefacts. My personal opinion is that many achievements of the current age are worth conserving; I do not think that a pure agrarian society is what we would like to have. How do we get there?

That is what this thesis tried to outline in a few points. It showed that technologies exist which can substitute many of the petroleum based products. Most of these technologies are in development or in pilot phase at best though, and information is scarce, often restricted by businesses because of intellectual property concerns. I have showed that a complete substitution of petroleum products by biomass is highly unlikely, if not impossible. A diminution of consumption is the best way to approach us to a sustainable society based on renewable resources; however, such a society might require regional structure and moderate scale.

The most challenging hurdle to be overcome by this proposition is the settling of competition for resources. As I stated several times, in an environment of limited raw materials, real needs would dictate what should be produced, not an artificially created market.

Currently, only biofuels can be produced at the local level. Technologies for biodegradable bioplastics seem not to be ripe for small scale yet. The chemical industry has a long record of innovation and operation at the small scale, but it would be the biorefineries that would provide the raw materials. Biorefineries therefore need to evolve; but for the distributed hypothesis outlined here, they need to do so in an open source spirit embedded in sustainable principles, coupled with simplicity for replication and suitability for the small scale.

The global players in the energy, biotechnology and chemical industry will push the biobased economy along their agenda, which follows the current economic logic. Most information about biorefining technologies depicted in this thesis has been published by mainstream business and academics. I have tried to distil this information for suitability to the context of distributed regional economies. One motivation for doing this is the observation of contemporary governments instigating wars to secure (fossil) resources; I do not see why this should be different if the resource is biomass and not oil.

Many question marks remain though. This thesis could not finally show if numbers count up for community ownership of biobased schemes. How much biomass respectively how much bio-oil is needed to set up such schemes? How many units per area do we need, what area is needed to provide biodegradable plastics? Also, as the technologies and many processes are still in its infancy, it is not clear how much investment costs arise. Furthermore, social and organisational issues need to be addressed. There is ample space for a deepening PhD study: numbers differ per feed-stock, local conditions, processes, etc. On the other hand, this is also exactly one of the pillars of the view offered here: produced is not what is technically possible, but what is desirable and realistically doable. If biomass is really going to become that important, usage will put severe competition on resources: limits will influence the allotment of the raw materials. Probably prioritisation will have to streamline resources allocation. Oil and biomass from algae are too uncertain at the moment to include in the balance, but are for sure one of the most promising propositions.

Chapter 10

Epilogue

Climate change and global warming are popular topics nowadays, an accepted reality for large sections of the scientific community. Peak oil is slowly entering into people's mindsets, as oil prices begin to rise. Millions of individuals begin to contemplate sustainable life options. They self-organise in communities, ecovillages, NGOs or engage in projects and institutions which tackle issues from global justice to fair trade, renewable energy to organic food, alternative health systems to civic rights, and many more.

This thesis joins the voices who call for a sustainable society which does not deplete natural resources. It is a positivistic appeal and tries to stimulate creative minds to further elaborate and refine the basic concepts suggested herein, while it offers a base for discussion and an invitation for debate. It is not in my intention to stipulate a model to be followed, even less to claim to have found fundamental principles or transcendental truths. The goal of this work is to present a potential. It is meant to inspire people and to offer new points of view.

Current structures of energy generation and economic activity have become unapt for our times. They are based on assumptions of endless, free resources and rooted in human-centric reasoning, adopting ideals which overemphasise materialistic values. As a result, wealth is concentrating in the hands of few, while ecosystems, soils, air, water, animals as well as the poor and weak are getting over-exploited. Western civilisation expanded its economic success through colonial appropriation of foreign resources, often ignoring and abusing of indigenous populations. The following industrialisation flourished thanks to a continuous influx of resources and the introduction of fossil energy. National states were still protecting their internal economies though; while the gross domestic product rose exponentially, external competition was systematically taxed.

The progression to global markets towards the end of the 20^{th} began to undermine national regulations, and the insatiable hunger of our economy became rampant and unrestrained. The hegemony and compelling power of the principal actors on these planetary business now subverts democratic decision making. Many individuals conform as they feel their impact to be negligible and futile.

Unnoticed by mainstream media, a movement crystallised in response; amorphous, self-organised and decentralised, challenging the status quo from many different angles. One which particularly inspired me is the Transition Town movement. This thoroughly positive reaction empowers people to act, achieving to energise and creating a healthy and powerful psychological impetus.

It is much in this spirit that my thesis proposes distributed networked biobased economies. In fact, the fundamental tenet is that an elegant tool to break the overwhelming domination by globalised markets and economic gigantism is to make them obsolete. In our communities and cities we depend on the electrical grid, which provides energy - generated by huge complexes burning fossil fuels or by horrendously expensive nuclear power stations (with their implications of contamination and waste disposal) . We depend on products shipped, flown in, or transported in lorries from any conceivable corner of the planet - all the while we feverishly produce more and more stuff (not least to be exported), incited by politicians and business leaders sermonising on perpetual growth.

Many questions still are left for distributed economies: who builds trains, air planes, or solar cells (assuming they will still be fabricated)? Are bioregions sufficient for such things? Ideas circulate on the Internet, one of which imagines that some larger urban hubs, along the small world principle, would exist (roughly one or a few per continent), which would deliver such services. Other uncertainties arise about security or laws. However, it is obviously outside the scope of a paper limited with a deadline and a word count to address all these issues. Even more important, there is no way to design everything ahead - in other words to predict the future. Solutions will emerge, adaptations will arise over time, and things will take their course.

Much of the information in this thesis is rather technical; personally I am convinced that technology is only one element out of many which characterise the metamorphosis to a sustainable society. We will need to relate to our natural environment with respect and love, and not just treat it as a supplier of resources - it is a living entity! This is for me an essential element of the Gaia theory. It bestows upon us a contemporary account which reconciles mythology with pure, solid and earnest modern scientific endeavour. It prepares the ground for caring relationships with the other-than-human, on which we can grow and perceive signs of meaning from our surroundings. Distributed economies (which ultimately are about people) is about rediscovering connections to our immediate surroundings, developing sense of place, sense of relatedness, to local landscapes, plants, animals and people. Where we might feel much more part of the complex web of life, embedding ourselves in harmonious giving and taking. By receiving what we need from living matter engages us in conversations with nature; instead of imposing our designs on the landscape, we might learn to read the signs of nature, and tend our cultivations in sustainable organic methods which root in patterns that strive to perpetuate and nourish. Symbiotic linkages would be the ideal; the Earth cares for us, and we care for the Earth, for the plants and animals which make our life possible. That is why I personally also cherish the idea of cultivating algae, beings which are at the very beginning of life on Earth, which gave us petroleum, and which might allow us to build a thriving society. Perhaps we should offer them beautiful living environments, marrying art with the landscape and technology, finally transforming our habitats in beautiful and inspiring places.

The transition proposed in this paper is a peaceful one, driven by people and communities who want to evade the yoke from current economic models and regain control over their life, their surroundings and their resources. A transition towards a dialectic mode of understanding nature, where direct experience of the land and its limits dictates the rhythms and patterns of living; towards a symbiotic relationship with the landscape.

I don’t know if the Buddhist way of the middle, as proposed herein through appropriate scale and technology, is feasible in the context of advanced societies, but It could be a way to reach the "edge of chaos" as introduced in the chapter on complex systems (2.3). In my opinion, it is worth trying.

Appendix A

Biorefineries

Definitions

Here is a list of definitions of biorefineries. Note the affinity of expression to the stakeholder's point of view (Source [52]).

- A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and value-added chemicals from biomass. The biorefinery concept is analogous to todayÕs petroleum refinery, which produces multiple fuels and products from petroleum (NREL, 2007).
- A biorefinery is a cluster of bio-based industries producing chemicals, fuels, power, products, and materials
- A biorefinery is an overall concept of a promising plant where biomass feed stocks are converted and extracted into a spectrum of valuable products (DOE, 2007).
- Biorefinery is the separation of biomass into distinct components which can be individually brought to the market either directly after separation, or after further (biological, thermo chemical/chemical) treatment(s) (Elbersen et al., 2003).
- Biorefining is the transfer of the efficiency and logic of fossil-based chemistry and substantial converting industry as well as the production of energy onto the biomass industry (Kamm et al., 2006).
- Biorefineries are integrated bio-based industries, using a variety of technologies to produce chemicals, biofuels, food and feed ingredients, biomaterials (including fibres) and power from biomass raw materials (EU Biorefinery Euroview, 2007).
- Addition of pure plant oil into traditional oil refineries (Shell, 2007).
- Biorefinery is efficient use of the entire potential of raw materials and by-streams of the forest-based sector towards a broad range of high added-value products (by co-operation in between chains) (Biorefinery Taskforce FTP, 2007).

- A biorefinery is an integrated cluster of bio-industries, using a variety of different technologies to produce chemicals, biofuels, food ingredients, and power from biomass raw materials (Europabio, 2007).
- Biorefinery is the sustainable processing of biomass into a spectrum of marketable products and energy (IEA Bioenergy task 42 on Biorefineries)

Appendix B

Open Source Projects - beyond software

In the following a list of running non-software open source projects. As such the various projects do not necessarily have to be directly related with the dissertation; they are merely listed as examples of open source collaborative working. The bulk of the links is from Wikipedia at `http://en.wikipedia.org/wiki/Open_source_hardware`.

Name	URL
RepRap A self-replicating 3D printer	`http://reprap.org/`
Open Source Ecology	`http://www.openfarmtech.org/index.php?title=Main_Page`
Business models for open source hardware design	`http://pages.nyu.edu/~gmp216/papers/bmfosh-1.0.html`
An open source cell phone	`http://wiki.openmoko.org/wiki/Main_Page`
A low cost EEG device and free software to go with it	`http://openeeg.sourceforge.net/`
Open source Solar Heat Pump Electrical Generation System	`http://www.shpegs.org/`
The Foundation for P2P Alternatives - P2P Foundation	`http://www.p2pfoundation.net/Main_Page`
OScar an attempt to design an entire car	`http://en.wikipedia.org/wiki/OScar_(open_source_car)`
A Prosthetics designed with open source principles.	`http://www.openprosthetics.org/`
OpenStomp guitar effects processor	`http://www.howleraudio.com/index.html`
Aurora USB mixer	`http://www.auroramixer.com`
Build-It-Solar Renewable energy	`http://www.builditsolar.com`

Appendix C

Web links

Biodiesel production

Name	URL
Piedmont Biofuels Coop	`http://biofuels.coop`
Biodiesel.org	`http://biodiesel.org`
Go Biodiesel	`http://www.gobiodiesel.org`
BDPedia.com	`http://www.bdpedia.com`
BioDieselNow	`http://www.biodieselnow.com`
Biodiesel Fuel Online	`http://www.biodieselfuelonline.com`
Sustainable Biodiesel Alliance	`http://www.sustainablebiodieselalliance.com`
Biodiesel Community	`http://www.biodieselcommunity.org`
BioLyle's Biodiesel Workshop	`http://biolyle.com`

Biodiesel from Algae

Name	URL
Peswiki	`http://peswiki.com/index.php/Directory:Biodiesel_from_Algae_Oil`
BioenergyWiki	`http://www.bioenergywiki.net/index.php/Algae`
Ecogenics	`http://www.ecogenicsresearchcenter.org`
Oilgae.com	`http://www.oilgae.com`
Algafarm.com	`http://www.algafarm.com`
BioDieselNow	`http://www.biodieselnow.com/forums/13.aspx`

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Meeting Minutes

Where:	University of Wageningen, Bornesteeg 59, 6708 Wageningen
Who:	Mr. Bert Annevelink, University of Wageningen
When:	Friday, 25th July 2008. 10am to 12am
Topic:	Biorefineries

Meeting purpose

I am writing a MSc dissertation on distributed networked biobased economies. I am interested in how economies could transition towards using renewable resources as a substitute for oil products. My dissertation outline (version 4) describes my work. I am focusing on regional and small to mid scale installations. This are meeting minutes of a meeting with Mr. Bert Annevelink, from the University of Wageningen, who kindly offered to assist me in my research and to answer some questions. A list of questions had been sent in advance.

Introduction

What are biorefineries? Introduction according to definition in the “Status of Biorefinery 2007” document: A process where biomass is sustainably converted into a spectrum of marketable products.

In the long term, the goal is to have complementary production of food and non-food biomass. The integrated biorefinery concept combines food, timber, paper, chemicals, etc. into a coherent programme.

Fossil resources based products could be replaced by biomass. However, the totally renewable energy society is not a reality, as things like metals and silicate for chips, etc. would probably still need to be extracted from the planet, although recycling can get us far on this too.

Scale

A realistic view of the future would imply a mix of big and small scale applications. Raw materials that cannot be grown locally (e.g. For special uses), and products that cannot be produced locally could require centralized big scale installations.

A thumb rule is that per hectare, a yield of 10 to 15 tons of biomass can be harvested. Maybe this is not enough for having all production at local scale.

A 2 to 3 steps process is maybe appropriate: fuels and food production could be local, whereas some part of the feed-stock could be forwarded to more centralised plants which would focus on chemicals and more high value products (plastics, etc.). To reduce transport costs, etc. the processing is possibly very regional, but this doesn't mean that consumption would be only regional too. Export to other areas is very likely. An interesting model for small scale could be approx. 80% of the production to be destined to biofuels and bioenergy, while 20% could be diverted to (centralised) chemicals facilities, as generally can be said: bioenergy/biofuels is a low-tech, while chemicals and biobased products is high-tech.

Big scale offers improvements of yields and efficiency and fosters innovation. Therefore big and small scale could complement each other, depending on the situation. Low cost small scale installations would also require some financial, management and legal (e.g. Ownership regulations) support, it is not only a technological issue.

Owner of biomass (farmers) in small scale applications have more chance of to get something out of the whole value chain. A part of the feedstock can be sold for further processing, while substantial parts of it can be used for self-sufficiency and to feed back to the land (fertilizers). Co-operatives are a very effective institution where farmers can federate in order to form ownership structures of biorefinery installations. In the Netherlands, co-operatives are very common, so this could be very interesting for farmers. Depending on the size of the coop, and accordingly on the amount and type of feedstock, different scales can be implemented (e.g. Biofules only for a few farm coop, or a mid-scale chemicals and bioproducts refinery for a large coop).

An example of small scale is Prof. Sanders Cassave system, where cassave is pressed, resulting in a juice (which with its nutrients can be reused as fertilizer) and a cake for further processing. I'll get information from Mr. Annevelink by email on this system.

The sustainability mandate could result in a certain percentage of the feedstock to just be left without processing/harvesting, while near-field processing could also return some nutrients directly onto the fields.

What is small-scale? Biodiesel as such is a small-scale technology, but the widespread adoption of it is worrying big businesses like Shell, BP, etc. Most food processing in the Netherlands is organized in cooperatives.

Thermochemical treatments requires a lot of biomass (1 mio biomass per year).

GMO

It is possible to operate biorefinery technologies without genetically modified organisms (GMO). But it is likely that the industry will use GM in order to maximise yields and improve efficiency. More problematic is the GM of feed-stocks. However, for microbial organisms in closed reactors which process biomass GMOs are very likely to be used, as they already are and this usage is permitted by laws.

Technologies

Processing sugar beet with mobile units as a possibility: traditionally, industry tried to produce as much sugar as possible. Now, a diverse strategy is more desirable, e.g. 60% for sugars, the rest for fuels, chemicals --> this means focusing on several products.

This could result in a major redesign of the production chain, with a combination of technologies. The Integrated Products project (IP, biosynergy) is a pilot for this approach.

Production could already be regarded as distributed, but the information systems and the management could influence on how the produce is really distributed to.

Most technologies are still in research, pilot or lab phase.

The chain management of the biorefineries is a major point which will attract some attention in the future. Who is the director of the chain? How to distribute the value? How to manage the whole chain? Today for example, there are no links between the agro- and the chemical industry, which buys its feed-stocks directly.

Algae are another 2nd generation technology, not a 3rd. There should always be a 1st generation technology used with a 2nd, in order to take advantage of established knowledge and processes. Biodiesel and bioethanol processing are very different. 2nd generation are also much more environmentally friendly than 1st generation, which suffer from the fuel vs. food problem.

1st and 2nd generation should only be used for biofuels.

For biorefineries, the term Phase I,II and III should be used, as there are different implications.

Algae are at a very early stage. They do not have land use competition generally. However, some installations are possible where ponds could be constructed. Or, installations on heightened structures are also a possibility. Algae systems incur in energy costs for the pumping of water to a central processing unit. Mostly, algae are aquatic crops, where they could suffer from contamination and disease problems, much like salmon cultures.

Algae could be harvested for biomass destined to several product streams. Currently, they are already used for food purposes (e.g substitution of dairy proteins in foods with algae proteins).

The biobased economy therefore is very focused on local circumstance. However, converting all fuels to biomass is impossible.

The time frame for the switch to a biobased products platform is 30 to 50 years, but many changes will occur already in the coming year.s

Bioenergy

Bioenergy had to deal with a lot of the questions that biofuels do today: sustainable production of biomass, sustainability, amounts of feed-stock, etc. The lessons learnt should feed into the biorefinery discussion (e.g. Policies should be more stable). In the concept of biorefineries, combined heat and power (CHP) can still be very interesting. Gas prices are coupled with oil prices, so they will rise too. However, replacing the well established (natural) gas system in the Netherlands with for example pellets based systems is very difficult and will take time.

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