

GM Plants in Green Economies: A Risk of Necessity?

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Abstract

What this paper endeavors to achieve is an exploration into the issues behind and within the debate surrounding the inclusion of GM plants in a green economic framework. What is first described is the green economic framework, what it is, how it works, why it is desired. Following this is the subject of plant biotechnology, what it is and how it differs from conventional plant breeding, its potential, and how it is changing the economic system through geodistribution and resource maximization. Biorefineries are discussed in some detail to illustrate the combined bio and physiochemical potentials and processes of technology. Risk is defined, categorized, and compared. The management of risk is addressed and the democratization of risk is explored through citizen participation and informational transparency. Following this, the paper delves into perception and how it interacts with risk. Perceptions of biotechnology are managed, for better or worse, by proponents and opponents alike; this is explored through stakeholder identification, and through comparison of their motivations. Barriers to the emergence of green economic systems are identified and the objections put forth, the inclusions of GM plants within them are elucidated. Biofuels, as a crucial component of green economies are discussed in terms of their economic and environmental potentials, positive and negative. The paper finishes with rationale on why perceptions regarding GMOs should be openly and vigorously reconsidered. Placing GM plants back on the political agenda would call for rational debate and broader engagement with the issues posed by biotechnology, by industry, scientists, government and the global populace.

Key Phrases: Plant biotechnology, green economic framework, bio-based resources, risk and perception, genetic modification, GMO

Executive Summary

In exploring the questions of 'how important are GM plants to a green economy and why?' this research determines that they are, for better or worse, integral to such an economic system. This is a result of a mismatch in available technologies whereby privately funded biotechnology is outpacing the physiochemical advances necessary for a green economic frame to work. In exploring whether or not a green economic system can be realized without the inclusion of GM plants, the findings of this research indicate that, while it is indeed possible to realize a green economy without GM plants, sustained reliance on conventional plant breeding will delay the adoption and limit the capacity of an economy based upon fully renewable plant-based resources. The role of GM plants in the context of green economies is thus to facilitate the transition from petrochemical to biological feedstock, and to tangibly accelerate the global evolution of a bio-based resource system. GM plants also have important roles to play in short-range schemes such as those seeking to reduce anthropogenic CO₂ emissions through augmented phytosequestration. Yet, biotechnology must be approached with precaution and the risks inherent to it must be weighed very carefully to ensure that the potentials of genetic modification do not themselves pose unacceptable risks.

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Abbreviations

ENGOs	Environmental Non-Governmental Organisations
EPSO	European Plant Science Organisation
GEO	Genetically Engineered Organism
GM	Genetically Modified
GMC	Genetically Modified Crop
GMOs	Genetically Modified Organisms
GOs	Governmental Organisations
IIIIEE	International Institute of Industrial Environmental Economics
IUCN	International Union for the Conservation of Nature
LMO	Living Modified Organism
NGOs	Non-Governmental Organisations
OECD	Organisation for Economic Co-Operation and Development
PBR	Plant-Based Resource

Definitions

Anaerobic: Without oxygen.

Apomict: A plant that does not express recessive traits from generation to generation.

Autotrophic: Producing a complex array of organic compounds from inorganic molecules.

Biogeochemical: The biological, geological and chemical processes of the natural environment.

Catalysation: The process of using a catalyst, which is not consumed, to start a reaction.

Cellulosic Ethanol: A biofuel produced from the lignocellulose contained in non-edible plant mass such as stalks, wood, and grasses.

Cross-Licensing: A contractual agreement through which intellectual property rights are shared.

Depolymerisation: A process in which three-dimensional polymers are separated into monomers (atoms or small molecules such as glucose).

Gas-Expanded Liquids: A process using the pressure-tunable physio-chemical properties of liquefied gas as an organic solvent.

Germplasm: The genetic resources of an organism.

Hemicellulose: A heteropolymer structure with a weak, random structure. Unlike crystalline cellulose, it can be broken down enzymatically or with dilute acid.

Heterotrophic: A non-carbon fixing organism which utilises organic carbon for growth.

Hydroprocessing: Processing with water.

Hyperaccumulator: Organisms which remove above average amounts of contaminants from polluted mediums such as soil or water.

Latitudinal Diversity Gradient: An ecological pattern which shows the increase in species diversity at lower latitudes and a decrease at higher latitudes.

Methanation: A methane generating process resulting from the fermentation of biomass or thermo-chemical gasification.

Mixtrophic: An organism using different sources and combinations of energy and carbon.

Near Critical Water: Superheated, pressurised water which remains stable.

Noble Metals: Metals resistant to both oxidation and corrosion.

Phytoremediation: The use of plants to remove or mitigate pollutants from the environment.

Phytosequestration: The biological uptake and storage of atmospheric CO₂ by plants.

Plasticisation: A process increasing the malleability and fluidity of materials.

Self-Defoliate: The self-induced loss of leaves by plants.

Supercritical CO₂: Liquid carbon dioxide above critical pressure and temperature, suitable as an organic solvent.

Thermal Cracking: A process through which complex organics molecules are broken into simple molecules through the application of heat and pressure.

Transesterification: An enzymatically catalysed reaction in which the organic group of an ester is exchanged with that of an alcohol.

Wet-Fractionation: The separation of proteins and starches through soaking and or acidic treatment.

1 Introduction

Decisions towards the widespread uptake of GM plants within green economies pose difficult questions. Evaluating risks and perceptions of risk are difficult issues in themselves and likely will require the tandem effort of arduous consideration and a reworking of the frameworks used to evaluate risk. The pressures of resource depletion, contamination, and scarcity coupled with climate change legislation, growth in population, resource demand intensity, and economic crisis are forcing real time decisions. While there is a broad consensus that the transition to green economic systems which are built upon the biological platform of genes rather than hydrocarbons is both desirable and inevitable, the question is not if but rather when and how this transition will take place. The implications and thus the considerations are complicated and intertwined. Yet it appears that the complexity of decisions cannot halt the change and progression of which GM plants are part. Whether they are necessary for the transition to an economic system based on renewables is a matter of great concern from many disciplines and directions and warrants careful consideration.

Concerns with the genetic modification of plants (and other living organisms) are in no shortage and cross a multitude of disciplines. Social scientists worry about the effects of agricultural intensification and corporatisation of farming on agricultural communities and rural populations (Eaglesham et al., 2003). Biologists are concerned with the effects of ingestion of GM plants on various species and how changing the composition of plants will change the food webs, dominant species and ecosystems of the areas where GM plants are deployed (Kirschenmann, 2003). Entomologists are disturbed by insecticide resistant species and their detrimental effects on the vitality and populations of target and non-target species such as the Monarch butterfly (Bartsch, 2009 and Llaguno, 2001 & Snow et al., 2003). There is enormous concern about the increased selective pressure put on insects and the capacity of herbicides and pesticides to speed the normal biological adaptation of both pests and weeds (Bigler et al., 2008 & Young, 2004). Insect resistant species embodying the bacterial toxin bacillus thuringiensis (Bt) carry a whole host of concerns which may provide the most damning evidence yet against the safety of GM plants (Llaguno, 2001).

The transition to a green economic system can be facilitated through the genetic engineering of plants which can alter both chemical composition and morphology. Compensating for process and material engineering technology not yet developed but necessary for the biorefineries upon which a green economy depends, bioengineering focuses on what technology can do to plants. Transitioning to biologically based feedstock without genetic alteration currently necessitates energy, petrochemical and water intensive processes which stands in direct opposition to the goal of a green transition to renewable sources with minimal processing inputs. Goals in the transition to a green economic system are intelligent and efficient use of renewable resources with decreased environmental impacts, distributed localised procurement, and processing of these resources.

Because of the current technological disparity between what we are using to process fossil derived inputs and what we need to process biologically derived inputs, there have been some missteps in the development and deployment of plant biotechnology; this has resulted in the erecting of barriers to the adoption and use of GM plants and thus the transition to a green economic system. Funding structures of research, private development of biotechnology, and high economic stakes have led to behaviours negatively impacting perception. Innovations, risks and information regarding these and the results of lab and field trials have not been disclosed to the public, nor has the underlying science. Profit oriented research in bioengineering has led to some questionable avenues of research and a race to the market.

The promotion and adoption of biotechnology has become a corporate game of who can manipulate regulatory agencies and industry to make the most money (Helmreich, 2008). Understandably, there is great concern surrounding this, as the products have the capacity to affect the survival of humanity and change the plant, microbial, insect, avian, reptilian, and mammalian life of the planet, alter biogeochemical cycles and the climate. To date, this technological race has not been guided by or centred upon development to facilitate a green transition; reorienting the goals and drivers remains an area of tremendous mutual potential for private industry and the environment.

Green fuels are being developed to reduce transportation oriented carbon footprints and have the, as yet unrealized *potential*, to reduce fossil fuel emissions by 40-50% using corn-based ethanol and by 60-70% using wood-based methanol (Jaworski, 2001). With further research and development, this could make a tangible contribution to meeting CO₂ reductions targets. This is discussed further in the section titled “Biofuels”. The economic, political, and environmental potentials of GM plants under a knowledge-based green economy represent a very tantalising set of opportunities (Jaworski, 2001).

The opposition to the inclusion of genetically modified plants within the green economic context is tied to perception, uncertainty, economics, and risk. Perception is socially based and politically manipulated through the inclusion and exclusion of information and through scientific uncertainty, thus, it has both socio-cognitive and socio-political dimensions. In this context, the genetic modification of plants can be positive in that plants form the basis for life on earth and have the capacity to provide for the changing needs of a growing population and to mitigate the negative effects of that same population on resource availability, carbon cycling, and the climate. Plants are central to a green economic system, and biotechnology is inextricably linked to the cultivation and breeding of plants in the 21st century.

By effectively managing the perceptual and scientific risks associated with GM plants, interested stakeholders can further the adaptive capacity of plant biotechnology to transition away from an economic system with a petrochemical basis to a biologically based one. Renewable in the short and medium term, bio-based inputs are essential for responsible resource use. Risk, normally associated with its negative manifestation as harm, has a positive side. In a positive incantation, managed risk translates into the responsible development and utilisation of technological advances in tandem with biotechnological ones.

1.1 Objective

The objective of this work is primarily to satisfy the requirements of a Master’s thesis but also to augment and enrich the understanding of its author and readers on the subject of risk management and perception regarding the inclusion of GM plants within a green economic framework. It is intended to provide a sound basis of information regarding what the risks are, why they are important and to whom. A knowledge gap exists in the green economic context regarding the ways in which risk perception can be managed to include both exploration of the perceptual bias and the means of overcoming rejection of GM plants within green economies.

1.2 Research Questions

The primary research questions approached in this work are:

How important are GM plants to a green economy, and why?

How do perceptions surrounding GMOs influence their inclusion in green economies?

Can a green economy be realized without the inclusion of GM plants?

If not, what is their place within this context?

The knowledge gap identified is centred on perception and the ways in which it blocks or facilitates the inclusion of GM plants in green economic frameworks. Perceptions of risk and potential are central to the inclusion or exclusion of genetically modified plants. Plant biotechnology has not had a green economy as its central driver to focus the goals and research. Corporate and industrial strategies have been the primary drivers of biotechnological advancement which has resulted in resource efficiency being clothed as a set of environmental opportunities. By reorienting plant biotechnology around a green economic framework and within a specified risk profile, the potential for mutually beneficial technological developments exists for society, government, industry and the environment exists.

The genetic modification of plants for use in a green economy represents a scientific achievement which raises complex socio-political and socio-ecological questions. Many of these issues are perceptual and related to risk. Despite the multifaceted objections to large-scale use of genetically modified plants, the pressures of a growing global population with intensified patterns of consumption on existing resources necessitates an innovative solution of which GMOs are an integral part.

2 Methodology

Included in this paper is literature-based research. Drawing from a wide range of sources and academic disciplines, articles were selected based on relevancy and credibility to provide insight into perception and risk related issues associated with the inclusion of genetically modified plants. Within the time limitations imposed by scope, research was obtained exclusively from written sources. The scope of the research itself is limited to risk, perception and potentials of green economic frameworks with the inclusion of GM plants. Detailed discussion of the policies and their outcomes are not included here, nor is a comprehensive discussion of the sociopolitical and economic contexts of the deployment of modified plants in the global context. GM foods and animals are outside the scope of this research.

2.1 Scope

In choosing the research upon which this paper is based, the findings of a previous research project exploring the issues inherent in the genetically modified plant debate were utilized. Through this, seminal works on the subject were identified and further research areas were revealed. Incorporating the findings of this previous research in preventative environmental approaches to environmental management, stakeholder groups with their views, interests, and concerns are juxtaposed with the potentials of biotechnology. A globally shifting economic system with institutionalized input structures is the context of the research, providing the framework. Augmenting this, was further research on risk perception and management, biofuels, and knowledge economies. The literature selection and review was an iterative process in which informational gaps were filled and honed as they were established. Sections of this work were identified and demarcated according to the knowledge base present at its initial undertaking but were added to and rearranged to reflect the broader and deeper comprehension that followed.

2.2 Seminal Works

The OECD Publication 'World Energy Outlook' was the primary source. Other seminal works, or those which were the most comprehensive and informative, were identified to be; Young's paper on GMOs and biosafety drafted on behalf of the IUCN, Ragauskas et al.'s article on Biomaterials, Pimental et al.'s article 'Food v Biofuels', Kamm & Kamm's texts on biorefineries, Kern's text on the strategic potential of plant biotechnology, and Ferretti's work on public participation in decision making. These primary sources served to reinforce the context of the perceptual and risk related issues inseparable from the technological potentials of plant biotechnology.

Secondary sources were drawn principally from peer-reviewed journals from several disciplines and included; Snow et al.'s ESA position paper on biotechnology and the environment, Marquardt et al.'s work on biorefineries, Jaworski's OECD report on 'The application of biotechnology to industrial sustainability', Eaglesham et al.'s work for the National Agricultural Biotechnology Council, and Bastar et al.'s EPSO report 'Plants for the Future'. All sources contributed to a well-rounded understanding and other sources not designated as primary or secondary were not without importance.

Table 2-1 Insight gained from a sampling of source journals utilised

Literature Source Discipline	Generalised Perspective	Revealed Bias or Weakness	Source
Administrative Sciences	Political construction of the common good, acceptable risk	Anthropogenic egoism	Rochet, 2008
Agronomic Research	Possibility	Narrow focus	Snow et al., 2008
Agronomy and Crop Science	Challenges and opportunities	Narrow focus	McIntyre, 2009 Kern, 2002
Applied Microbiology	Process focus	None Apparent	Jansson et al., 2010 Jaworski, 2001
Arid Environments	Realistic applications and yields	Limited applicability	Achten et al., 2009
Biomass and Bioenergy	Ancillary benefits and co-implementation of technologies	Inconclusive	Openshaw, 2000
Bioscience	Potential gains from GM	No discussion of risk	Jansson et al., 2010
Biotechnology (Agricultural)	Intersection between science and society	None apparent	Rasessar et al., 2007
Biochemical Engineering	Petro v biochemistry	Narrow focus	Marquardt et al., 2010 Kamm & Kamm, 2007
Business Strategy	Profit, corporate survival	Self-interest	Resnick, 2004
Chemical Engineering	Technical applications, potential and processes	Lack of risk assessment, applied industrial focus	Marquardt et al., 2010
Defence	Economy and security	Narrow focus	
Economic Policy	Global scale, economic focus,	Specific policies, global	Bretschger, 2010
Economics (Agricultural)	Regulations and trade of biotechnology	Narrow focus	Sheldon, 2001
Energy (Bioenergy)	Possibilities and percentages	Developed country focus	Cayuela et al., 2010 Martin & Ekland, 2011
Energy	Realistic appraisal of potential	Positivist	Lundquist et al., 2010
Energy (Renewable)	Potential/actual performance	No discussion of risk	Mata et al., 2010
Environmental Resource Economics	Resource/ pollution flows, quantitative/statistical analysis	Lack of qualitative data, highly technical	Grimaud & Rouge, 2008
Environmental Science & Tech.	Comparative technologies and environmental effects	Ignores politics	Claren et al., 2010
Env. Values	Limits of scientific materialism	Theoretical	Carolan, 2008
Ethics (Agricultural Environmental)	Stakeholders, precaution, role of the international community	Confounding rather than facilitating	Myhr, 2010
Ethics (Business)	The role of morality in politics	Economic focus	Galie & Bopst, 2006
Future Studies	Long view	Broad brush	Falk, 2007
Human Ecology	Human nature interaction,	Very broad	Pimental et al., 2009
Interdisciplinary (Science & Culture)	Prioritization, risk, epistemology, and theory	Conceptual	Swyngedouw, 2006
Management	Manipulation of regulatory bodies and legitimacy	Self-interest	Aldrich & Fiol, 1994
Molecular Ecology	Environmental risk	Narrow focus	Williamson, 1992
Nanotechnology	Barriers to adoption	Self-interested research	Priestly & Stebbing, 2008
Psychology	Perception and behavioural response	Lack of political or institutional context	Bryant & Dunford, 2007
Research (Policy)	Technical and economic effects on society and environment	None apparent	Green et al., 1999
Research (Risk)	Informational content and conveyance	Presumption of adequate information	Chrysochoidis et al., 2009
Science	Technical potential of nature, risks, confounding factors	None Apparent	Ragauskas et al., 2006 Tillman et al., 2009

World Trade	Yield, sovereignty	Narrow focus	Howard, 2009
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2.3 Frameworks

The frameworks of analysis used for this paper were institutional and that of a green economy. A central theme of ethical and scientific legitimacy runs through the work, serving as a filter through which to explore and analyse the findings. The frameworks were selected based on relevancy with the desired informative but minimally biased presentation of findings in mind. The institutional framework was selected specifically to approach a broad range of charged topics with a dispassionate eye and with the intention to improve both socio-economic and socio-political development.

2.4 Process

Articles were reviewed and notated, colour coded by general subject area, mapped visually, and then used in the drafting of this paper. Ninety odd sources were consulted to provide informational material and a total of seventy-three pages of notes were drafted prior to and alongside this thesis work to highlight salient points from the articles, papers and books consulted. The information has been reviewed multiple times throughout the process of writing to ascertain the clearest way of presenting the information. It has thus been reordered and reworded as appropriate. Following comprehension, the subject is introduced, the reason for the topic selection is then discussed, and then the bulk of the paper follows.

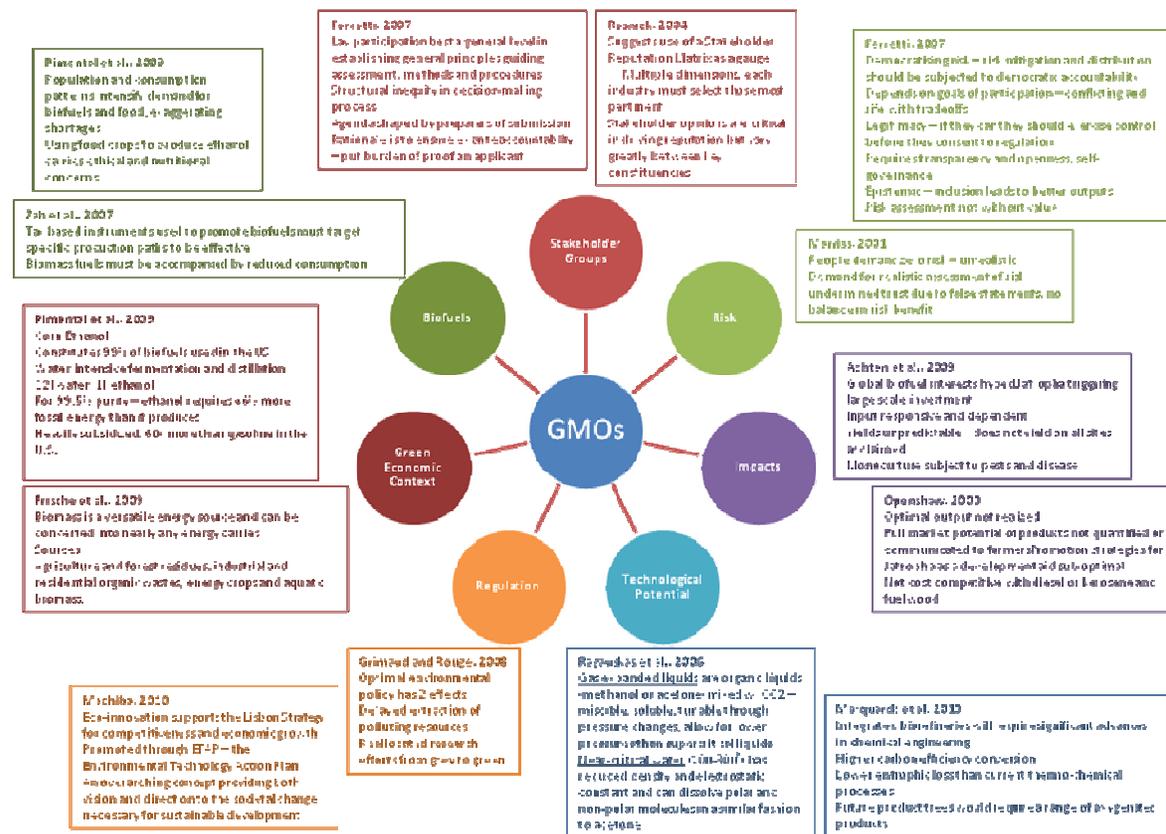


Figure 2-1 Colour-Coded Source Material Mapping by Subject Area

By evaluating the journal articles utilized in the research for this paper, grouping was by discipline. The graphic in blue shows the subject distribution of the journal articles selected according to the number of articles in each discipline; they were weighted towards science, energy, and biotechnology. The rationale behind this selection is that science, in its generalized form, yields a synthesis of science and society which is perhaps a more balanced view than pure science outside its social context. Biotechnology and energy are focal points in the inclusion of genetically modified plants within a green economic context. The graphic in orange represents the main subject areas of books, reports, or policy papers quantified and graphed according to the number of pages contained rather than by the number of sources. This method was a better reflection of the amount of material covered in these source types and shows different foci of the research. Roughly transposing the two charts one can see that material covered in this paper focused on the scientific, diplomatic, economic, technological, and risk associated aspects of genetically modified plants.

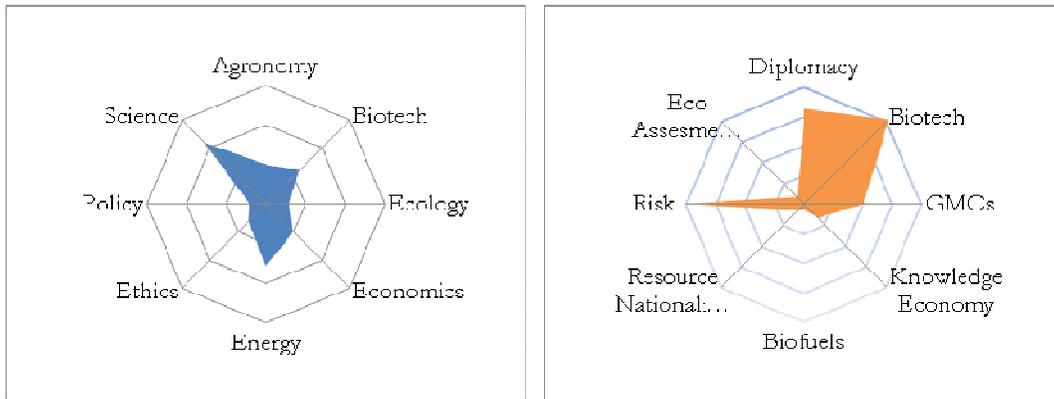


Figure 2-2 Source Material Subject Charting: Journals in Blue: Other Sources in Orange

3 Green Economic Framework

Before a green economic framework is discussed with any explicit detail, let the concept first be defined. There are many ways to conceptualize what a green economy is. What is being discussed in the terms of this paper is an economic structure with a biological basis. Green economies have renewable assets as their source. This stands in contrast with current economic systems using fossil fuels and other petrochemical inputs as the primary driver for economic growth. Bio-based economies have at their core plants, the organisms most efficient at harnessing solar energy (Kern, 2002). Plants are the basis of food chains on all tropic levels and serve as the basis for life on earth. Plant or bio-based resources are “source material derived from a range of plant systems, primarily agricultural crops, forestry products, and processing streams in the food, feed, and fibre industries. Bio-based resources are renewable in the short term. Planting is carried out annually, perennially, and in short rotations for longer growth species” (USDOE, 1999). Bioengineering is an integral part of green economies as it can shorten the time to harvest, increase yield, and photosynthetic activity, reduce water land and fertilizer requirements, and to internalize pest control (Snow et al., 2003).

Green economies are centred on two poles, biomass and knowledge, which build upon the foundations of agriculture as a basis of economic progress and of culture in and of itself (Kern, 2002). Green, bio-based economies are founded in both the non-technical solutions of the past and in the technological capacities of the future. Plants have the ability to meet the complex challenges of the third century, doing more with less (Peck, 2011), producing more usable output with less land, less water, and fewer inputs (Kern, 2002). At its core, a green economy is centred around the sustainable production and conversion of biomass into useful raw material which drives low-impact (environmental) economic growth, and provides a convenient response to global challenges such as a warming climate and mounting resource scarcity (Albrecht et al., 2010). Future-based, knowledge oriented, and biologically centred economies focus on value-added strategies for economic growth (Jaworski, 2001). Knowledge oriented economies are inclusive and sustainable (Albrecht et al., 2002). Common to most definitions of a green economy are the use of low-carbon technologies, green design, a gene rather than hydrocarbon basis, and the incorporation of the goals of ecological sustainability with the equitable distributed benefits of economic advancement (Albrechet et al., 2002).

Currently, the hydrocarbon molecule is the foundation of global commerce, but in the future of green economies, this basis will change to one of biological origin, genes (Armstrong, 2002). Utilizing genes will give economies a broad base and diverse supply of resources to all countries in possession of or with access to genetic diversity by nature of equatorial location or trading agreements. There is the potential that conflict over resources bases will shift to the frontiers of biodiversity when gene-poor and technology-rich countries seek to augment their holdings with foreign bio-feedstock (Armstrong, 2002). This is where advances in biotechnology come into play, what does not exist in terms of species or gene diversity can be created in labs through advanced transgenic processes, negating the latitudinal gradient which favours equatorial countries, and preventing potential conflict (Armstrong, 2002).

3.1 Why it is Desired: Competitive Aspects

A green economy utilises plant-based resources to produce economic growth, maintain and increase standards of living, and enhance national security by reducing reliance on foreign sources of energy (U.S. DOE, 1999). Green resources have the capacity to be dispersed geographically and to reduce the variability in supply and quality accompanying fossil fuel

deposits which are geographically fixed. Plant-based resources have many advantages over fossil fuels in that they are eco-efficient and friendly, potentially non-toxic, and profitable (Albrecht et al., 2010). With these attributes, replacing petrochemicals with plants is a logical, sustainable, and perhaps unavoidable solution to a complex global fuel problem. The inclusion or exclusion of GMOs in a green economy to augment the existing capacity of plants is widely debated.

Plants are central to the survival of humankind (Kern, 2002). They provide the means to overcome the complex challenges of sustainable production, harvest, and processing of the resources required to sustain existing and growing populations. With a dwindling, polluted, and contested resource base, plants allow us to do more with less (Kern, 2002 & Peck, 2011). Higher biomass production is needed, however, and genetic engineering offers a phantasmagoria of solutions which are difficult, and some would argue unwise, to pass up. These include increased growth rates, decreased spatial requirements, prolonged vegetative periods, early flowering and maturation, and an overall reduction in crop loss due to pests and pathogens seem to be positive overall (Bastar et al., 2007).

The use of PBRs (plant-based resources), especially genetically modified PBRs, represents a paradigm shift in industry. Biotechnology and biomimetic processes (low energy and temperature processing) allow industry to move beyond synthetic chemicals in a number of ways (Jaworski, 2001). The fermentation and separation necessary prior to use of PBRs can be accomplished with plant derived enzymes (biocatalysts), biocatalytic surfaces as they are used in metabolic engineering and metabolic engineering itself where cells are engineered to act as mini-reactors (Jaworski, 2001) Using plant derived industrial feedstock is also profitable in that it is durable, non-persistent, non-toxic, and biodegradable.

The exploitation of fossil carbon resources outpaces its regeneration so the direct use of biorenewable resources seeks to satisfy global demand through annual production. A bio-based tree of products will replace and augment that which is currently derived from petrochemicals through the degradation of biomass into its carbon building blocks (Marquardt et al., 2010). An enormous variety of plant species exist as actual and potential inputs with differing chemical compositions and morphologies suited for different products; this can be functionally augmented through applied biotechnology and the genetic modification of plants. Generally, plants provide useful biomaterials in the form of; lipids, starch, cellulose, lignin, proteins, minerals and aromatic compounds (Kamm and Kamm, 2004 & Marquardt et al., 2010).

3.1.1 Supply Security

Supply security is but one of the promises of a green economy. Plants can be grown globally thus the geographic distribution of resources has more to do with national policy decisions regarding land and water use than blind luck or the loci of ancestral occupation. Plant-based resource distribution is significantly different than fossil based resources (Giljum and Eisenmenger, 2003). The geography of energy has already begun to shift due in part to the change in energy demands but also because of changing energy sources (Stansilaw, 2009). “The convergence and collision of climate change and energy security” are driving the shift to plant-based sources. Stanislaw (2009) further argues that by aggressively pursuing petroleum-light energy balances and by promoting clean fuels (i.e. biofuels); global demand for fossil-based resources is shrinking the overall market for petroleum. In promoting biofuels even ahead of their optimal level of development and performance, many nations are deciding to produce them anyway seeding supply in order to grow demand (Stanislaw, 2009 & Green et

al., 1999). Genetically modified plants can lend security in the supply chain of resources in two ways, by localising them, and by increasing the usable yield of plants.

3.1.2 Employment

Policy decisions regarding infrastructure and innovation are inextricably tied to employment (Green et al., 2009 & Eaglesham et al., 2003). Innovations in biotechnology and agricultural productivity have a direct effect on employment as biologically derived fuels have a higher labour requirement upstream than petroleum processing (Mata et al., 2010). Bio-based resources have a lower energy output per unit than petrochemical resources, but much of the value they add is through the provision of employment (Armstrong, 2002). Transitioning to fuel sources with lower overall production efficiency translates into more human labour needed to provide and process it (Hawken, 2004). Biofuel production diversifies both fuel and income sources and boosts rural employment (Mata et al., 2010).

Bio-based economies will create demand for new products and lead to greater employment. This results from lower available energy per unit of plant vs. petrochemical feedstock and smaller scale, localized production and processing (USDOE, 1999). This has a plethora of ancillary benefits such as localised and regionally distributed resources bases, reduced local and global conflict due to resource concentration or distributional benefits (Armstrong, 2002 & Giljum and Eisenmenger, 2003). Gainful rural employment of a growing population can also potentially stem the effects of urban migration, promoting rural revitalization and give purpose and profit to populations of disaffected youth (Armstrong, 2002). Bio-based resources add value to locally produced and processed materials, employ a local labour force, and boost the economy. Engineered plants have heightened adaptive characteristics which can compensate for natural variability in the supply and quality of feedstock (USDOE, 1999). Genetically modified plants, because of their positive attributes, boost the viability of a green economic system which in turn provides greater localized and distributed employment due to the labour intensity of agriculture.

3.1.3 Climate Neutrality

Under green economic systems, resources are produced and processed locally and regionally, transport costs and the resulting CO₂ emissions are also reduced. This represents an obvious diversion from the current global status quo of resource use and processing. The plants forming the basis of green economic systems not only absorb the gasses warming our planet through photosynthesis (Jansson et al., 2010) but also reduce our dependence upon fossil-based fuels and diversify energy supplies (Fritsche et al., 2009). Phytosequestration, or the uptake and storage of CO₂ through photosynthesis, is getting a lot of attention in a climate conscious political environment. Within the green economic framework, plants serve multiple functions, one of which is offsetting and storing the excess carbon dioxide present in the atmosphere. Carbon is biologically sequestered in plant bodies above and below ground, by microbes in the soil, in the soil itself, and in aqueous plants such as algae (Jansson et al., 2010). The use of plants and plant biotechnology for energy and industrial input is essential to lower GHG emissions. PBRs emit less GHGs and can significantly offset CO₂ emissions through Phytosequestration.

3.1.4 Resource Maximisation

Resource maximization occurs through the redesign and closing of industrial and societal material and energy cycles, thus reducing the overall waste generated. More efficient use of

resources through the reallocation of organic waste and waste biomass as inputs for biorefineries both slows natural resource depletion and contributes to industrial sustainability (Jaworski, 2001).

Genetic modification can facilitate processing by modifying cell wall composition, by reducing or removing compounds which inhibit decomposition, or by altering lignin synthesis (Bastar et al., 2007). Plants can also be engineered to enhance their resources use, minimizing water and fertilizer needs and increasing photosynthetic activity. The potential applications of plants for phytoremediation can return spoiled cropland to arable land by removing excess salt, nitrogen, or toxic chemicals (Bastar et al., 2007 and Peck, 2011). The genetic modification of plants facilitates processing into usable feedstock for industry and as fuels, maximizing the benefits conferred to humanity by plants.

3.2 Consumption Patterns: A Partial Solution

Changing the inputs from petrochemical to biological in a system geared toward the paradigm of what Ragauskas et al. refer to as 'bigger, better and more' has limited value (2006). Changing the inputs to biomass represents only the starting point in the process of integration of synthesised biomaterials and biofuels. Accompanying the switch to bio-based resources must be a concerted effort to reduce overall energy use and move away from the generation of energy through combustion (Pimental et al., 2009). For it to gain full momentum, the conversion to a bio-based system requires policy support, commercialization, continuing research and development as well as the conversion of existing, or construction of new, refining infrastructure (Ragauskas et al., 2006). Biorefineries are analogous to petroleum refineries in their basic approach but require advances in genetics, biotechnology, and process chemistry in order to be effective. Yet even with the concerted efforts of divergent disciplines, biomass is, to date, incapable of replacing petrochemical inputs with biological ones. This is due in part to the inherent limitations in the capacity of plants and the land on which they grow, but also brings to light the unsustainable levels at which the world is consuming natural resources (Ragauskas et al., 2006). Population growth and the consumption patterns of society are simply outpacing technological and biological advances (Pimental et al., 2009) Global population is increasing at a rate of 1.7% annually while global energy demand is increasing by 2.5% annually (Pimental et al., 2009). Ragauskas et al., predict a 50% growth in energy demand by 2050 (2009). Regardless of the material used as feedstock, be it plant or petrochemical, energy consumption is outpacing both population growth and energy generation. Without reducing overall energy demand, greening the economy with GM plants is insufficient to mitigate GHG emission and reverse the ecological devastation tied to resource extraction.

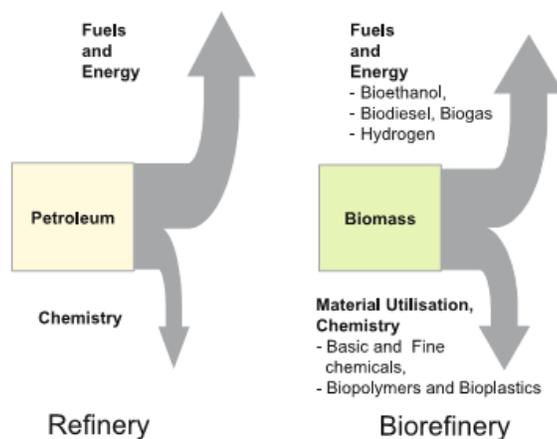


Figure 3-1 Biorefineries Mirror Petrochemical Models

Source: Kamm and Kamm, 2007

3.3 A New Paradigm of Growth

The current dominant paradigm of economic growth is rooted in the presupposition that the inputs for the economic system is in endless supply. Inherent to this pattern of growth are the exploitive treatment of both people and the natural world; resources which are abundant, people, are utilized less in order to extract and process resources which are increasingly scarce, fossil fuels (Hawken, 2004). With a finite petrochemical resource base, the paradigm of growth must be altered. Growth, or ever-increasing wealth, is a paradigm built upon exploitation, use, and waste – it is no longer viable in a green economic framework. Here, growth in the economy is literal; the base of the system itself is life, which embodies cycles of growth and productivity with fecundity and recuperation. Green economics does not operate with the concept of waste but holistically, where what is not used for the primary process is taken up by secondary or tertiary processes. Growth strategies must take into account a finite resource base and switch to renewable sources. The paradigm of growth within a green economic framework must move away from an extractive approach to resource use and towards a renewable, cyclic pattern of use. Using plants as feedstock is the key to this.

3.4 Harmonisation of Goals

Overall, research on PBRs in the context of green, bio-based economies represents the harmonization of environmental science, political and energy centred policies and goals (Bastar et al., 2007). The white biotechnology (i.e. industrial biotechnology), typified by biorefineries, integrates economics with ecosystems by examining the biogeochemistry of forestry management, agricultural production and the utilization of non-food components of food crops as biomass-based inputs to industrial systems (Bastar et al., 2007).

The utilization of plant based resources can and likely will contribute positively to economic growth, high standards of living, and national security (USDOE, 1999). Advances in plant science can improve societal well being through subsequent improvements in the economy, technological processes and environmental efficiency but will be influenced by social policy, land use, funding and resource availability (Ragauskas et al., 2006). Thus the use of plants, as utilized in industrial biotechnical systems, have the capacity to further goals related to the triple bottom lines of sustainability.

3.4.1 Integration with Sustainable Development

A green economic system based on biological capital has the capacity and promise to integrate the principles of sustainability with healthy economies. Economic growth is decoupled from the environmental degradation which compromises the ecological systems on which social equity and economic activity currently depend (Young, 2004). Using biomass for energy and industrial input contributes to the triple bottom lines of sustainability by: creating value and thus increasing capital by using waste as an input; preventing pollution; reducing throughput; and by ethically managing the impacts of production. Thus, bio-based economies are economically viable, environmentally compatible and socially responsible (Jaworski, 2001).

4 Plant Biotechnology

Plants are of vital importance to humankind. Agricultural biotechnology, in brief, is the modification of biological organisms, their process, and products by altering genetic material (Jaworski, 2001). There are multiple advantages to be gained through this such as increased productivity (land, plant yield, target material content, processing), reduction in ecological impact (water, chemical and fertilizer use, environmental degradation) and carbon sequestration (Jaworski, 2001). Many advances are being made through transgenic developments, or the introduction of genes from one species to another. The results of this genetic recombination are traits such as delayed ripening, improved nutrient content or digestibility and countless other ‘improvements’ (Thies and Devare, 2007).

Genetically altered organisms are referred to by a number of names and acronyms which confuses the lay reader and serves to conceal information, intentionally or not, by forcing the researched to scan for multiple terms. GMOs are genetically modified organisms. GEOs are genetically engineered organisms, while GMC refers to a genetically modified crop. There are other acronyms and phrases such as scientific adaptation, technologically enhanced and living modified organisms (LMOs) (Llaguno, 2001 & Armstrong, 2002) but they all refer to organisms, plant, animal, or microbial which contain what is referred to as “novel” gene sequences which do not occur in nature (Cook, 2003 & U.S.DOE, 1999 & Snow et al., 2003). A distinction that becomes important in discussions involving risk is whether the modified organism is living or dead, as this affects factors such as out-crossing and gene spread (Armstrong, 2002). Transgenic modification indicates the presence of genes from other organisms in a host organism’s DNA which could not occur without technological and scientific intervention (Snow et al, 2003). This differs from ‘classic’ plant breeding which is done through normal plant sexual reproduction and is referred to as selective breeding in which plants exhibiting desired characteristics were saved, replanted and bred to eliminate recessive traits which were deemed to be undesirable (Young, 2004) .

The genetic modification of plants through non-sexual means remains a topic of global importance that crosses a menagerie of disciplines. It is a subject that requires complex understanding of the issues, their interactions with one another, and the standpoint of various stakeholder groups.

4.1 Potential

Referencing the writing of Pierre Bourdieu, there are species of capital to include; economic, cultural, social and symbolic, genetic modification renders the statement literal (Helmreich, 2008). Technology is controlled by capital and the appropriation of living nature to economic ends is part and parcel to bioeconomies (Helmreich, 2008). Genetic modification can produce habitat-adjusted varieties, varieties with lower input requirements and accelerated growth.

The promise of GMOs within the green economic framework lies in their capabilities to increase yield, facilitate processing and efficiently utilize land, water and other resources necessary as inputs (Marquardt et al., 2010). The chemical compositions and morphologies of plant species, altered and unaltered through modification can and is providing a dizzying array of products with higher ratios of oxygen to carbon than fossil derived oils. Plant lipids from seeds and algae provide feedstock rich in fatty acids with up to 24 carbon atoms, glucose derived plant starches yield dense helical polymers; other plant components include hemicellulose, lignin, proteins and minerals (Marquardt et al., 2010). Specifically, high lignin and hemicellulose concentrations are desirable but rely upon a cost-effective method of

depolymerisation. Through the mutually reinforcing application of plant biotechnology and chemical/process engineering, land and biomass use efficiency can increase. Integrated biorefineries can provide higher carbon efficiency, lower entropic losses (than thermochemical processes) and lead to the polygeneration of biomaterial, steam and electricity (Marquardt et al., 2010).

The alteration of a plant's chemical composition and morphology can reduce the pre-treatment requirements of biomass which accounts for 20-40% of overall production costs (Marquardt et al., 2010). Other bioprocesses are the target of current research such as the manipulation of photosynthetic rates, increasing from a 2% capture and conversion of solar radiation through the over expression of rate limiting enzymes involved in carbon fixation – this increases photosynthesis and increases dry plant weight (Ragauskas et al., 2006). Altering nitrogen metabolism through the over-expression of glutamine synthase has been shown to increase the tree height by 141% (Ragauskas et al., 2006). Other interventions are delayed or inhibited flowering, reduced seasonal dormancy and lignin suppression to increase cellulose content (Ragauskas et al., 2006). By making the biomass matrix more enzyme accessible, cellulose processing costs can be reduced by factors of 5 to 10 times (Ragauskas et al., 2006). Additionally, the co-production of cellulose with micro-organisms necessary for fermentation based decomposition (into glucose) boosts the capacity of molecular farming by allowing plant processing to begin within the plant itself (Ragauskas et al., 2006).

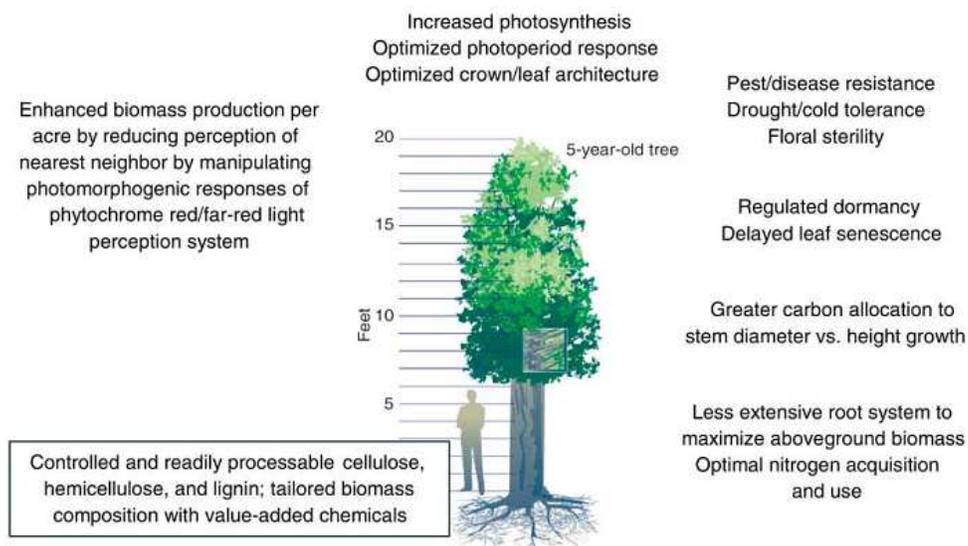


Figure 4-1 Biotechnological Modification of Trees

Source: Ragauskas et al., 2006

Technological advances in processing focus on oxygenated hydrocarbons through the de-oxygenation of carbohydrates. This yields products with polarities unsuitable for direct use as fuels but highly suitable as fuel additives (Ragauskas et al., 2006). Lignin is approached through thermal cracking or two-stage depolymerisation using hydroprocessing and base catalyzation. By-products such as Syngas are produced which contain ammonia and methane, potentially contaminating catalysts comprised of noble metals; they have some potential for conversion through anaerobic fermentation into biofuels but are difficult to convert into

value-added biomaterials (Ragauskas et al., 2006). Processes employing supercritical CO₂, near critical water and gas-expanded liquids as solvents offer superior ecological performance, and reduce overall waste. Such materials are cost-competitive with chemical solvents such as toluene, aniline, and acetaldehyde and thus positively contribute to non-toxic processing (Ragauskas et al., 2006).

Biotechnology must be applied wisely for optimal benefit. The utilisation of habitat-adjusted varieties which are co-planted with a variety of other species avoids soil exhaustion, promotes nitrogen fixation, and lends flexibility in multi-substrate biorefineries (Marquardt et al., 2010). This integrated approach, taking into account scale, proximity, seasonality, and ecologically sound agriculture integrates economic processes with a systems perspective and promotes a model of non-exploitative resource extraction (Marquardt et al., 2010).

Bioengineering has the capacity to increase the uptake of atmospheric CO₂ by up to 7.3 Giga Tonnes/year by manipulating various biological processes. Photosynthesis is improved by increasing the efficiency of solar interception and accelerating the conversion of solar energy into biomass (Jansson et al., 2010). Enhancing the allocation of carbon to deep roots encourages the transfer of carbon to soil where is held captive for longer periods than storage above ground. By improving the tolerance of plants to biotic and abiotic stress, and by increasing saline and draught tolerance levels, more plants survive to absorb CO₂. Biomass quality is 'improved' to increase lignin content to extend storage through both slowed degradation of biomass and reduced lignin synthesis which reduces the energy necessary to break the substance down in biorefining processes (Jansson et al., 2010). Exploring the potential of plant biotechnology is integral to altering the uptake of atmospheric carbon and manipulating the global carbon cycle to offset the effects of anthropogenic CO₂ emissions. Terrestrial and aqueous plants, soil and microbes all function as carbon sinks with approximate capacities of 560GT, 38 000GT, 2 500GT, and 110GT respectively (Jansson et al., 2010).

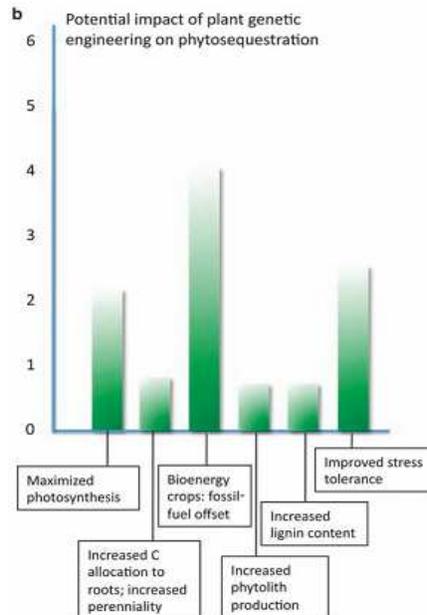


Figure 4-2 Potential Impact of Plant Genetic Engineering on Phytosequestration

Source: Jansson et al., 2010

4.1.1 Bioremediative

The *Salix* species, planted extensively in Sweden, is being explored further due to its dual capabilities as a bioremediative hyperaccumulator and a producer of biomass (Abhilash and Yunus, 2011). Using plants to simultaneously remediate land and produce biomass has not been fully tested and must therefore be approached with caution following further research. The contaminants taken up by plants may pose exposure risks to workers involved in the harvest and processing and have the potential to enter the food chain as animal feed by-products of biorefinery processes (Biksey and Wu, 2009 & Abhilash and Yunus, 2011). The use of marginal or polluted lands where phytoremediative plants are grown raises additional concerns. Marginal lands are often the sole sources of income and or sustenance for rural or impoverished communities (Rist et al., 2009) and do not support plant life or sizable yields without the input of inputs such as fertilizer or soil amendments which potentially offset greenhouse gains (Spangenberg and Settele, 2009). Marginal lands (such as wetlands) are often crucial to the provision of ecosystem services like water filtration and provide habitat for wildlife and insects (Young, 2004).

4.1.2 Economic

Greater economic wellbeing is a potential advantage of genetic diversity in a bio-based economy. In the green economies of the future, plants and not petrochemicals, provide the basic economic unit, as they are the primary source of food, fuel, fibre, energy, and industrial inputs (Armstrong, 2002). GM plants have the potential to localise the industrial, agricultural, and other primary national inputs. Indeed, Kern holds that engineered plants hold the keys to renewable energy and green economic growth (Kern, 2002). The domestic production of fuels which are now geographically dispersed would be possible with biofuels boosting fuel security (Jaworski, 2001).

4.2 How Biomass is Changing the System

The transition to a bio-based economy and thus to plant based raw material inputs, allows for both resource maximization and localisation. It is the organic phase of capitalism, one in which life is the surplus bioeconomy (Helmreich, 2008). As technology is controlled by capital, the re-appropriation of living organisms in nature allows for species of capital to be defined into categories such as symbolic, economic, social and cultural (Helmreich, 2008). Further reduction of novel organisms through processes such as molecularization act to reduce plants to the very molecules they produce, their drug affinities, transferable elements, and delocalised units. While enhancing the usefulness and transferability of PBRs and bioengineering, this reductionist view necessitates rigorous ethopolitics as living organisms are reduced to what they provide and are not viewed as live forms (Helmreich, 2008).

The use of biomass for energy and industrial inputs is changing the systems of energy provision, land use, commodities pricing and others in many ways. The geographic dispersion of resources is perhaps one of the more interesting alterations to the global socio-environmental and socioeconomic dynamics as it allows for a redistribution of resources. Changing the inputs for energy and industry, the utilization of biomass has the capacity to shift the existing balance of power gained through technical expertise (Ferretti, 2007). The change precipitated by changing the technical economic paradigm can influence the balance of relative privilege in the energy sector (Green et al., 1999).

4.2.1 Geodistribution

Biomass is changing the economic system by changing the inputs. Hydrocarbons are being replaced by gene sequences; this elevates both the real and theoretical value of genetically modified plants. What is not possessed by developed countries in biodiversity can be created with technology to overcome the latitudinal diversity gradient (Armstrong, 2002). There are implications of this transition that can be mitigated, at least partially, by genetic modification. National security and global power balances will be challenged as alliances with oil rich countries decline in importance and those with countries rich in biodiversity are elevated (Armstrong, 2002 & Giljum and Eisenmenger, 2003). This is assuming of course that industry is playing fair.

Generally, the sectoral structure of an economy determines its efficiency in energy use and other areas (Bretschger, 2010). This underlines the importance of the proper utilization of biomass so that plant products are put to their highest use within a value chain (Ragauskas et al., 2006). The technologies which are employed in society are themselves a reflection of the underlying power politics and serve to reinforce the existing structures of wealth, influence, and access (Conca and Dabelko, 1998). The ecologically authoritarian deployment of genetically modified plants and other species cannot be separated from the political agendas and strategies of the governments supporting such actions (Conca and Dabelko, 1998). This is yet another area where political sovereignty comes into play with GMOs.

In the Stockholm Conference on the Human Environment held in 1972, the primary point of agreement was centred upon the primacy of state sovereignty, yet sovereignty is the very thing which most interferes with the objective consideration and regulation of the global environment and the commonality of basic resources such as clean air and water (Conca and Dabelko, 1998). We are of one earth but of several worlds which are ecologically interdependent. Environmental threats and concerns such as those posed by genetically modified organisms are influencing and modifying global standards of behaviour which is seen as a threat to sovereignty (Conca, 1998). Ecosystems and the environmental services which they provide and foster do not coincide with the socio-political boundaries of nations. The scalar mismatch created by nations regulating 'their own environments', which are in reality part of non-discrete global environmental systems, frustrate attempts at responsible ecological management (Conca, 1998). This is confounded further by the global trade of PBRs, living and dead which infiltrate and contaminate the living inventory of societies the world over.

The geographic dispersion of resources which are mediated by the availability of arable land and irrigation water has significant implications (Giljum and Eisenmenger, 2003). "A new great game over energy is at hand" the rules of which are still being drafted (Stanislaw: 3, 2009). Economic volatility, energy security, and climate change are forces driving resource nationalisation and supporting a more broadly dispersed biological basis for the global economy and for energy. This shift is altering the geographic away from Saudi Arabia and towards, China, India, and Africa (Stanislaw, 2009). The relocalization of the global supply chain within national borders has broad security implications. Not only do we not have to procure our resources from the global supply chain but also we do not have to travel or do diplomatic tap dances or agree to trade policies of compromise in order to assure their continued provision.

4.2.2 Resource Maximisation

We no longer have to live with what we have in terms of biological resources. Genetic modification allows us transcend the rudimentary offerings of evolution and create

customizable biological efficiency (Peck, 2011). The eco-innovations of biotechnology exploit the novelty of plant traits to increase production, facilitate processing, and assimilate PBRs into a system designed to utilize petrochemicals (Machiba, 2010). The underlying goal is not just to decouple economic growth from environmental degradation (Young, 2004) but to reduce the pollution of and risk to the environment resulting from resource utilization (Machiba, 2010). The eco-innovations of biotechnology have the capacity to catalyse absolute decoupling through system innovation, leapfrogging incremental adoption and fundamentally changing how the needs of society are met. By converging agricultural innovations with biotechnological ones, green growth policies encouraging environmentally rational investment while building compatible infrastructure is made possible (Machiba, 2010).

5 Biorefineries

Biorefineries are poly-product systems with multiple inputs, capable of integrating the production of food, feed, fibre, fuel and industrial inputs. Through a multistage and adaptive set of processes, biologically derived materials are refined and converted into a broad palette of raw materials (Kamm and Kamm, 2004). Biotechnology's role in supplying a biorefinery lies in its capability to intelligently manage the physiochemical characteristics of biologically derived feedstock and to manipulate microbial and chemical sequencing to optimize processing efficiency (Kamm and Kamm, 2007). As stated earlier, biorefineries parallel petroleum refineries in the end products and processes they employ but integrate biotransformation with physiochemical processes (Marquardt et al., 2010; Green et al., 1999 & Ragauskas et al., 2006). A generalized schematic of the biorefinery concept follows in the figure below.

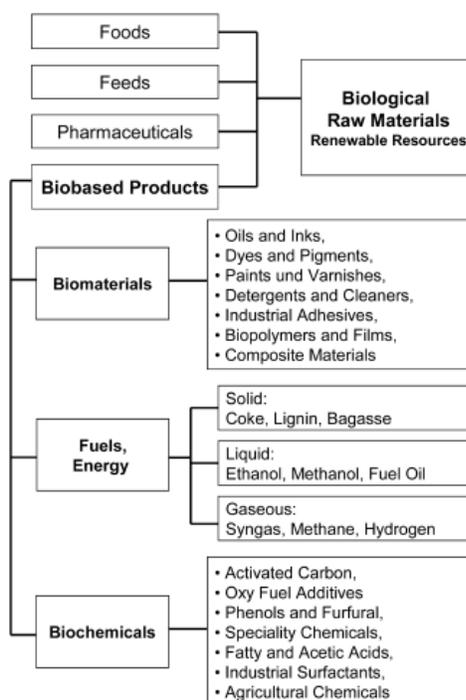


Figure 5-1 The Biorefinery Concept

Source: Kamm and Kamm, 2004

The product classes of raw materials are broad and dependent upon both the feedstock and processes employed. Each grouping from the table below has its own specific product tree and value chain in its corresponding industry (Kamm and Kamm, 2004 & Mata et al., 2010). Genetic engineering offers the potential to customize the plant material itself to produce specific product trees (Kern, 2002). One example of this is the alteration of algae to produce the higher lipid yields desirable for biofuel production (Pimental et al., 2009). Several primary types of biorefineries exist within the current techno-economic framework though it is possible to generalize; they are delineated by phase and by process and are chosen based on their desired product flows.

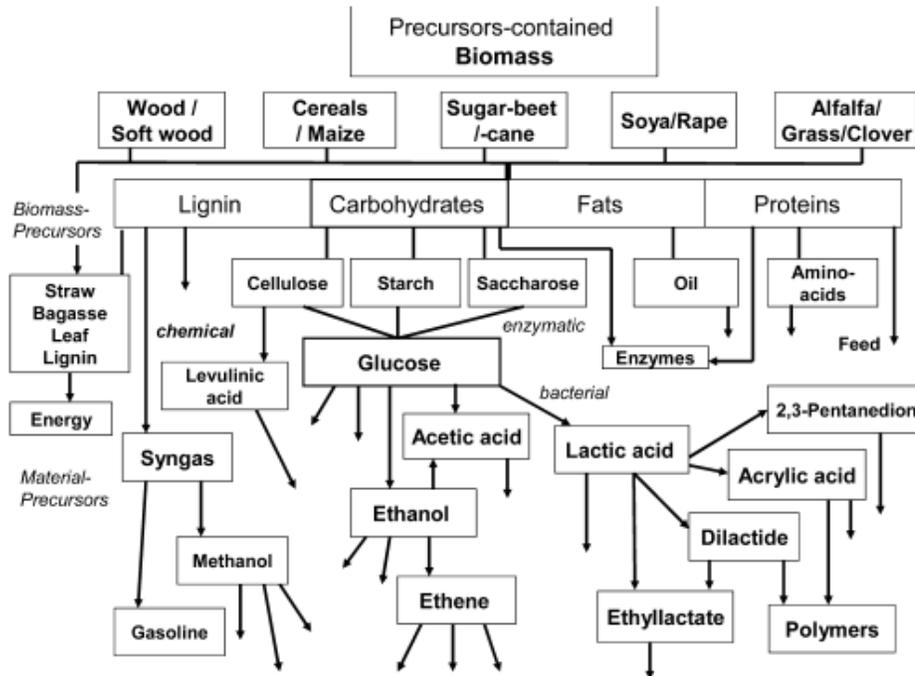


Figure 5-2 Sample Schematic of a Biorefinery Showing a Product Tree

Source: Kamm and Kamm, 2007

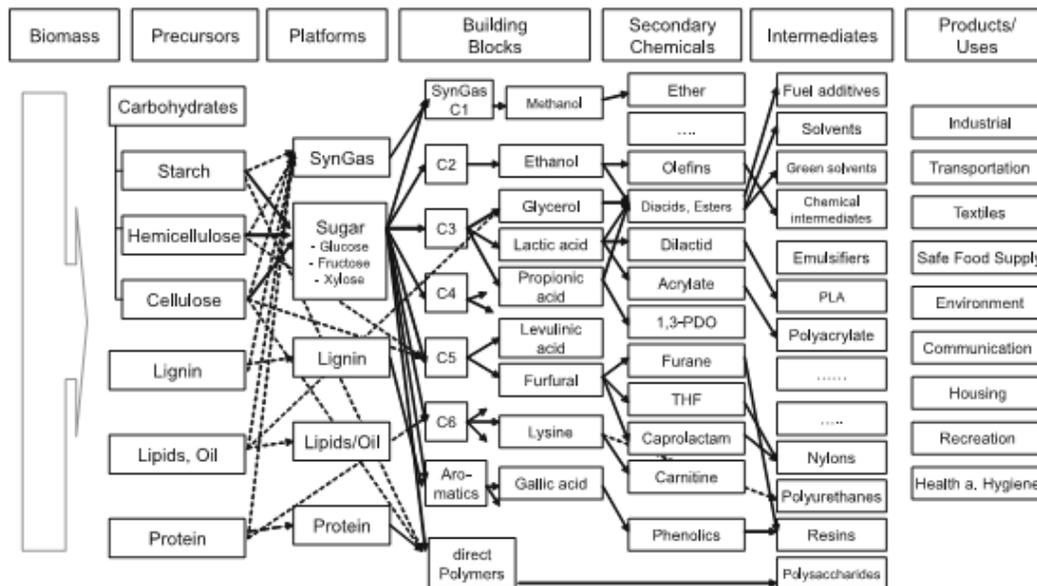


Figure 5-3 Sample Bio-Based Product Flow

Source: Kamm and Kamm, 2007

5.1.1 Phase 1

Phase 1 biorefineries are dry-milling, requiring the input of separated dry grain such as corn, rye, wheat and others as feedstock. They rely on the processes of mechanical separation, plasticisation, chemical modification, and biological conversion and are characterized by fixed processing capability and inflexibility in processing capabilities (Kamm & Kamm, 2007).

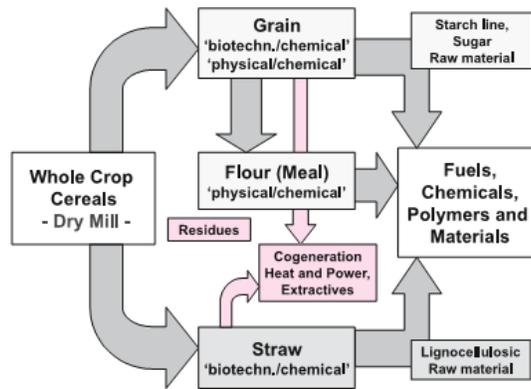


Figure 5-4 Dry-Milling Biorefinery Schematic

Source: Kamm and Kamm, 2007

5.1.2 Phase 2

Phase 2 biorefineries use wet-milled grain such as grass as feedstock. In contrast to phase 1, they exhibit some flexibility in the end products they can produce and employ both wet-fractionation and pressing (Kamm & Kamm, 2007). As a by-product, phase two biorefineries produced press cakes which can and are repurposed as either animal feed or a soil amendment (Achten et al., 2008).

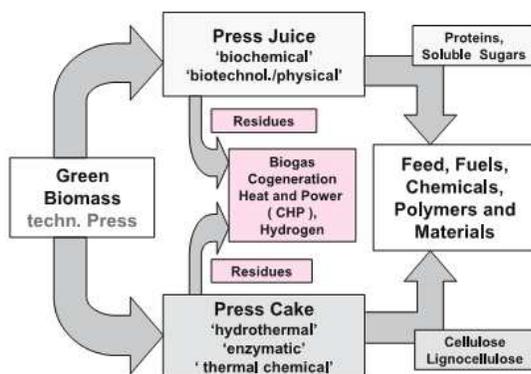


Figure 5-5 Wet-Milling Biorefinery Schematic

Source: Kamm and Kamm, 2007

5.1.3 Phase 3

Phase 3 biorefineries are adaptive having flexibility in both their feedstock and end products. As a result of this, phase 3 biorefineries are capable of serving multiple industries. Processes are tailored to the physiology and chemical composition of the biological raw material utilized as input. Lignocellulose biorefineries, designated as phase 3, use dry, woody plant biomass from reeds, straw, wastepaper and trees, often using the whole crop, or unseparated biomass. Dual-Platform biorefineries produce both sugar and syngas (Kamm and Kamm, 2007).

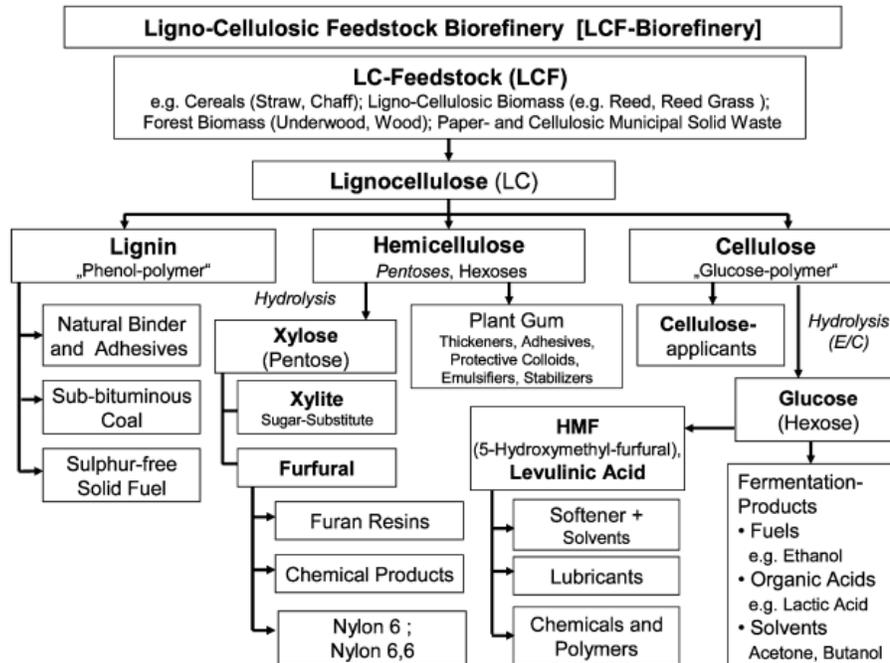


Figure 5-6 Lignocellulose Biorefinery Schematic

Source: Kamm and Kamm, 2007

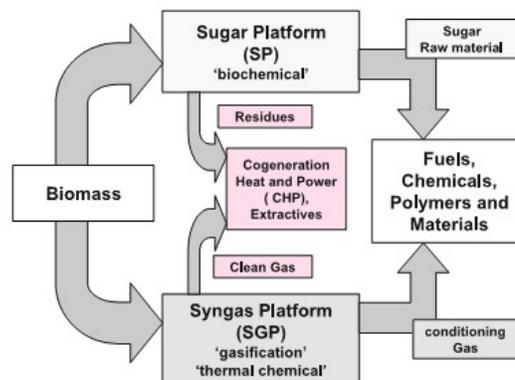


Figure 5-7 Dual-Platform Biorefinery Schematic

Source: Kamm and Kamm, 2007

6 Understanding Risk

Risk, as defined by Snow et al. (2003), is the likelihood of a hazard being realized, where a hazard is a phenomenon with the potential to cause harm or undesirable effects. The assessment and management of risk is process-oriented and thus logically at odds with the product-oriented paradigm of scientific rationality. This causes discrepancies in risk assessment and conflict between the supporters and opponents of genetically modified plants as PBRs. One may ask which risks are being examined. Risks to human and animal health, risks of changing economic and political power balances, risks associated with unintended consequences are all being evaluated. The real problem with risk management and assessment lies in the meaning and focus of risk (Eaglesham et al., 2003). Risk management and assessment are interrelated and the issues associated with risk are themselves entwined. The production of allergenic proteins may be tied to insect resistance, damage to non-target organisms, gene flow, ethics, and the economization of nature (Eaglesham et al., 2003). Risk assessment, in many cases, ignores the broader issues and in doing so undermines public trust. Risks associated with GMOs require a systemic perspective to ecological analysis and are done little justice by disaggregating a complex web of interaction into discrete categories like finances, agriculture, or biodiversity. To fulfill the interests of the public, the focus of risk should be; to discover whether or not GMOs can and do enhance the capacity of and positively contribute to the sustainability of systems; and whether they bolster community renewal (Eaglesham et al., 2003).

The perceptual basis of risk is diverse and dependent upon various lenses of scrutiny; economic, naturalistic, developmental, social justice, and food security (Eaglesham et al., 2003). For this and many other reasons, risk assessment itself is at a crossroads. Dynamic and a slave to many masters, risk assessment attempts to measure and weigh the potential harm to complex and non-discrete systems and to a heterogeneous global society (Eaglesham et al., 2003).

6.1 Types of Risk

GMOs pose risks in several dimensions: economic; security; and to established instruments of power such as militaries and the media (Snow et al., 2003). Risk and precaution go hand in hand, the extent of the later resulting from a society's understanding and tolerance of the former. Risk thresholds are far from absolute, mired in perception and assigned value, the perception of risk is tied to familiarity and bisected by real versus perceived risk (Ferretti, 2007). Diplomatic channels are stressed by legal actions of the WTO, conflicts with the Biodiversity Treaty under the Cartagena Protocol and by dwindling access to trans-boundary resources such as water needed to grow burgeoning transgenic biofuel crops. Water is especially pertinent in debating the inclusion of genetically modified plants as PBSs in that agriculture utilizes roughly 2/3rds of the world's fresh water which has consequently fallen in availability by 2/3 in the last fifty years (Snow et al., 2003). Modification has the capacity to improve draught and saline tolerance in plants and algae has the ability to directly utilize polluted or saline water (Jansson et al., 2010).

6.1.1 Economic

Economic risk is tied to the success of the crops and to the relative advantage gained through the deployment of GM crops over unmodified ones to the environment. The yield of genetically modified crops is an essential factor in their profitability. Often touted as a developmental necessity, the economic benefits from GMOs are typically funneled away from

smallholders and concentrated in the hands of industry; in spite of this, smallholders bear the financial burden of more expensive seed with uncertain yield and thus uncertain ROI (Snow et al., 2003 and Young, 2004). Economic risk is also derived from financial speculation in biotechnology, which mirrors and stimulates bio-speculation (Helmreich, 2008).

6.1.2 Security

Security risks are associated with food and energy resulting from the lack of viable agricultural land (Armstrong, 2002). The provision of food, fuel, fibre, and industrial inputs from sources within national borders reduces the necessity to maintain amicable trade relations with other nations but increases the need to protect these same resources (Kern, 2002). Unmodified seeds can be saved from the previous year's crops and do not require annual repurchase. Genetically modified seed, as it embodies the intellectual property rights associated with the technology and research used to produce it, cannot be saved from year to year, but require direct annual repurchase from the seed company (Llaguno, 2001).

There are perceived threats of agricultural bioterrorism associated with the widespread adoption of GM seeds (Armstrong, 2002). A small handful of companies, namely the top ten in biotech seeds, control 2/3 of the global seed market, of which a single corporation directly controls 23% and indirectly controls 87% through the seed and trait licensing of GM crop plantings (ETC, 2008). Even more ominous are the cross-enabling agreements between biotech firms which cross-license plant germplasm, nullifying competition between biotech firms by eliminating intellectual property litigation (ETC, 2008). The result of this is that a very small number of corporations control prices, necessary chemical inputs, and the underlying technologic research of most GM plants. Many countries are understandably nervous about this cartel-like monopoly, which in a bio-based economy, would translate into a controlling interest. The figures below give a visual overview of the seed industry's connections, not only with one another through cross-licensing agreements, but also with other industries such as chemical and pharmaceutical (ETC, 2008 & Howard, 2008).

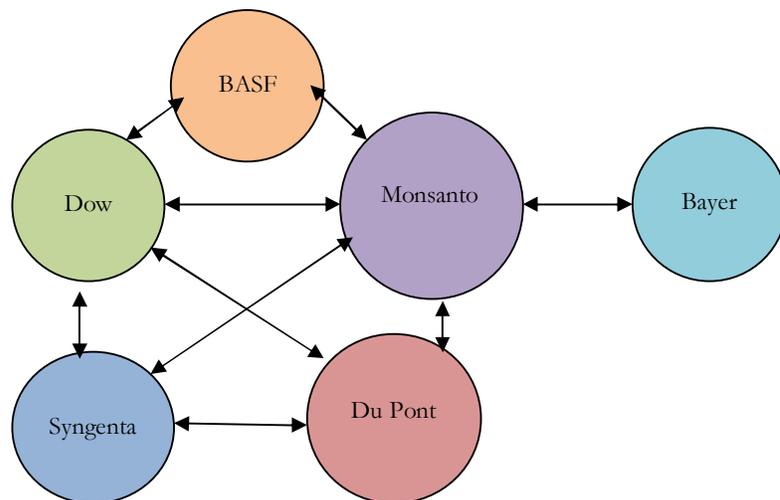


Figure 6-1 Cross-Licensing in the Seed Industry

Source: Howard, 2009

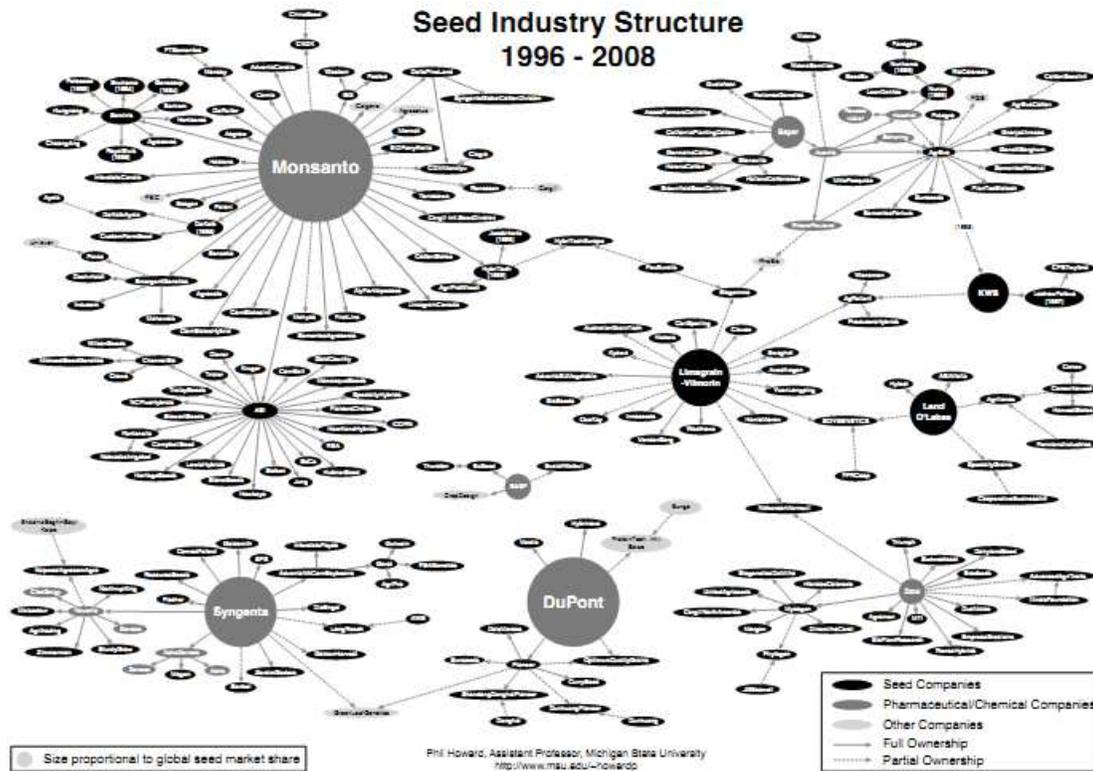


Figure 6-2 Seed Industry Structure

Source: Howard, 2009

6.1.3 Informational

Informational risk stems from a lack of information, skewed information, information that is outright false, and asymmetries of information (Ferretti, 2007). Corporations with the right to withhold information and reinforce asymmetries of information, commonly do so as it is in their best interest. Information in the context of intellectual property rights is power (Ferretti, 2007). Asymmetries arise not just from imbalanced informational content but also from the pithy amount of information available to the public, a current hindrance with biotechnology (Chrysochoidis et al., 2009). Difficulties arise when developed and non-developed nations alike demand data and information regarding GMOs from industry and government. This information is generally proprietary and reveals the uncertainty or imbalance in benefit from genetically modified seed. Information is also subject to cultural bias and filtering which accounts for tremendous variance in the perception of risk (Snow wt al., 2003).

6.1.4 Waste Streams

Biotechnology is being discussed in this paper only in terms of its use as industrial feedstock, but even the most efficient process has some waste. Industrial waste streams of biological origin are bound to make their way into animal feed at some point and therefore into the food chain. Post-process biomass is being used as fertilizer and for soil augmentation in various forms such as plant meal, sludge, and biochar. This is done in an effort to functionally replace harvested crop residues which remineralize, amend, and protect, to maintain soil biota, conserve water, and aid in carbon sequestration (Lal and Pimental, 2009 & Cayuela et al., 2010). Of these post-process applications, Cayuela et al. (2010) have determined that

biochar was most instrumental in facilitating carbon sequestration. Biosolids such as dry and wet distiller's grains, by-products of maize-based ethanol production, are being sold as feed for both livestock and poultry, thus representing a relatively direct pathway into the food chain and therefore an enormous risk (Biksel and Wu, 2009). Many of these biosolids have concentrated mycotoxins and or reduced digestibility or nutritive content which may adversely affect the health of feed animals ingesting it (Biksel and Wu, 2009).

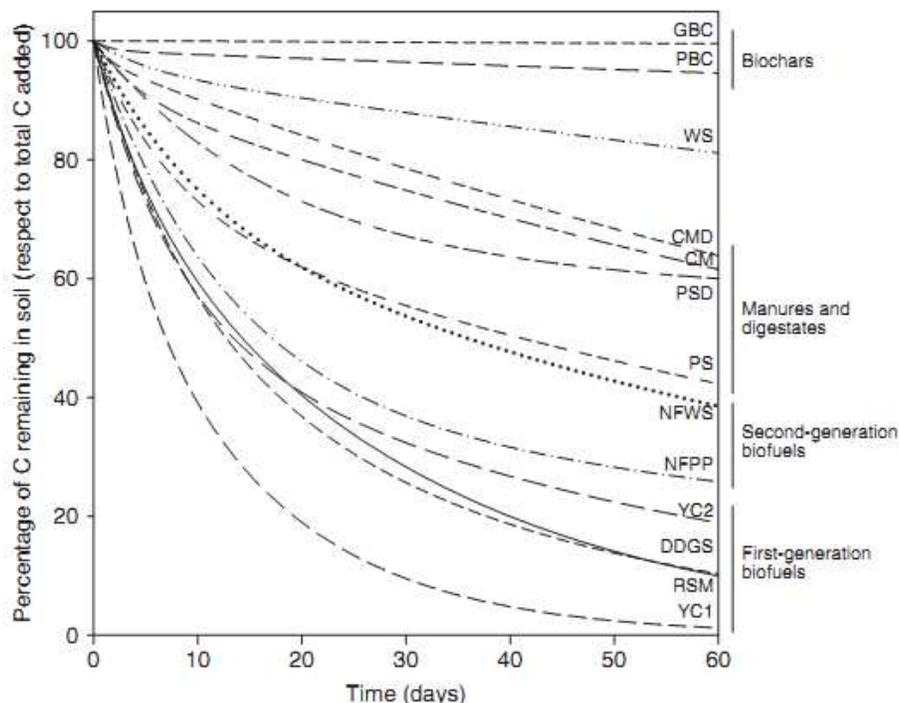


Figure 6-3 Carbon Storage Duration by Biorefinery By-product Type

Source: Cayula et al., 2010

6.1.5 Health: Glyphosate

Though the focus of this paper is not GM foods, the possibility exists for GM plants and their derivatives to enter the human food chain. The health risks imposed by glyphosate are thus important to address due to the severity of the risk it poses. There has been evidence of Bt toxin leakage through root systems and gene transfer to soil bacteria (Llaguno, 2001) which is negatively impacting soil vitality (Cook, 2003). This same type of horizontal gene transfer has been predicted to occur in the digestive systems of humans (Snow et al., 2003), where intestinal bacteria swap genes with ingested Bt foods and begin producing insecticides in situ (Young, 2004). The implications of this are the internal production of insecticides within the intestinal systems of terrestrial mammals consuming GM plants which will likely interfere with the bacterial colonies aiding in digestion and absorption of food and nutrients (Ramessar et al., 2007). While studies have shown that genes producing the herbicide glyphosate are destroyed during digestion by ruminants, the mono-digestive processes of humans and other animals do not subject genetically modified genes to the same stress and may allow for bacterial transference to intestinal bacteria (Ramessar et al., 2007). Glyphosate has also been shown to depress photosynthetic activity, compromising the growth and CO₂

sequestration capabilities of the plants modified to produce it as herbicidal protection (Ziobiolo et al., 2010).

6.2 Different Scientific Paradigms of Risk

There are differing scientific paradigms in support of and in opposition to the large-scale use of genetic modification in agriculture. Control over the genome equates to control over biological and ecological systems themselves (World Bank, 2007). There is an enormous potential for exploitation depending upon the motivations and methods underlying and utilized in the development of GM plants. The level of risk is determined by the scientific paradigm chosen. It is important to understand the differences in scientific worldviews in order to accurately conceptualize and understand some of the contentious issues inherent to GM plants.

Two distinctly different paradigms are exemplified by the North American and the European political stance on GM plants; they are scientific and social rationality (Isaac & Kerr, 2003). The differing paradigms echo through legislation drafted on each respective side and is a source of great consternation for the WTO and other institutions. In essence, scientific rationality is progress oriented and product based. In this paradigm, decisions are made by the judiciary and are founded upon the premise that risk is inherent in innovation and that GMOs are free from appreciable harm until they are scientifically proven to be otherwise. Scientific rationality represents the industrialization of science (Somerville, 2000) where information is power and the practical application of scientific innovation and understanding is a prerequisite of funding (Atanassov et al., 2007 & Ferretti, 2007).

This stands in direct conflict with the paradigm of social rationality in the EU which is process-based and emphasizes precaution, not only in biosafety but also in developmental contexts (Young, 2004 & Isaac and Kerr, 2003). Risk is unacceptable in this framework and the burden of proof for the safety of a product is shifted to the company which must show, beyond doubt, that GMOs are safe (Isaac & Kerr, 2003). Decisions regarding the safety of biotechnological innovations such as GM plants are made consensually and risk is democratized by including an element of citizen participation in the regulatory process (Ferretti, 2007). The necessity of public funding is acknowledged as a key element in balancing the applied focus of private investment in science (Eaglesham et al., 2003) As a result of this, multiple public-private partnerships have been established with universities and industry to nurture an element of public benefit in the development and assessment of GMOs (Albrecht et al., 2010).

6.3 Management of Risk

The management of risk depends upon an understanding of the types and sources of risk. Risk is managed through participation, communication, regulation, and through the way in which risk is defined. The scope considered by those evaluating and managing risk is influenced by scalar politics.

6.3.1 Risk Communication

Risk is communicated primarily through media which, as an institution, is dependent upon the openness and corporate culture of biotech companies for accurate information. Risk carries with it the socio-cultural aspects of relative optimism, education and value-similarity (Chrysochoidis et al., 2009). Thus, media communications regarding the use of plant

biotechnology must take into account the dynamic that will occur between the cultural elements of the message and the cultural filters or contextual symbology of the target group for effective risk communication. Value similarity depends upon an educationally influenced understanding of technological meaning or purpose which is itself confounded by the dynamics of who benefits from biotechnology (Chrysochoidis et al., 2009). Value conferred to industry or government does not transfer to the populace and thus is not perceived as value to the general population. Corporations may have the rights of individuals in some countries but as collectives they harbour vastly different needs and perceptions centred on self-sustenance of the organisation which does not extend to the preservation of the environment in which they exist; individuals have no such luxury.

Much of the problem with risk communication for plant biotechnology lies in its short supply. When information is released, it is often poorly targeted, misleading, or missing substantive content (Marris, 2001). Information regarding the risk involved in the deployment of plant biotechnology is not appropriately targeted or culturally coded to adequately communicate the risks imposed by biotechnology to the general public and thus exacerbates rather than alleviates resistance and confirmatory bias associated with GMOs (Chrysochoidis et al., 2009). This disconnect in risk communication seems to be an obvious error in oversight or arrogance on the part of biotech corporations but by far is not the only one.

6.3.2 Democratisation

The democratization of risk is integral to garnering public trust through public involvement (Ferretti, 2007). The nature and type of the actual participation determines the relationships that form between lay people and those deemed to be experts on various aspects of genetic modification. Involvement has many functions; it legitimises decision-making, generates loyalty, and is looked upon favourably by consumer and nongovernment organisations (Ferretti, 2007). Public involvement is a means to overcome the democratic deficit so glaringly evident in the development and regulation of GMOs in the parts of the world where they were so quickly adopted (Ferretti, 2007).

There is growing demand for transparency concerning the nexus between technology, the natural environment, and society. The citizenry demands empowerment through greater proximity to the regulatory process and participation within it. Partially an expression of self-governance, participatory regulation lends objectivity and strengthens the epistemic claims of biotechnology. Additionally, even the appearance of equity can facilitate cooperation and aid claims of legitimacy, though without functional manifestation, this appearance can intensify resistance and mistrust (Ferretti, 2007).

Involving the public is a proposition fraught with difficulty but one necessary to oppose the established hegemony that industry and multinational corporations have in regulatory processes (Ferretti, 2007). Extending participation in regulatory frameworks to the public may be the only real way to rectify the structural inequity inscribed in the regulatory process itself which inscribes labels of acceptability on risks which are framed in terms of economic or scientific progress (Ferretti, 2007). Such a proposition opens the door again to normative discussion regarding biotechnology, which while not directly scientifically relevant, has inestimable social relevancy.

Different countries and cultures have approached citizen participation in the regulatory process in different ways. In the capitalist North American context, the involvement of lay citizens in public debate concerning GM plants has been dismissed as emotional, unscientific, and inefficient (Ferretti, 2007). The widespread adoption and planting of GMOs was

surreptitiously substituted for scientific study as evidence of their safety, validating its use by the sheer force of its presence. In the gradualist EU context, ethical concerns and consumer interests are regarded as valid and given due consideration though much of the public comment is excluded as being outside the scope of allowable input (Ferretti, 2007). The established EU system has its failings, excluding non-specialized actors and limiting the time horizon for challenge to 30 days, requiring expert-level information (Ferretti, 2007).

While arguably necessary, public participation in regulation must integrate criterion for participatory exclusion least public resources be wasted by an inefficient process which allows for commentary outside the scope of the problem (Ferretti, 2007). Yet this scope must be very cautiously set so as to include the full range of public concerns regarding biotechnology. If this is not done, there would be no change from the current status which excludes participation and guides risk assessment through exclusionary and narrow scoping. Careful consideration of different regulatory levels shows that generalized processes, which guide assessment and methodology, are perhaps the best loci for lay participation (Ferretti, 2007).

Without including the public in the regulatory process there is the danger that legal frameworks will be bypassed to approve GM plants for release, leading to street protest, mistrust and anger rather than productive public involvement (Ferretti, 2007). Access to information, negated by the application of intellectual property rights to genetic sequences, is a cornerstone of this participation. The provision of confidentiality to biotechnology corporations has allowed them to avoid scrutiny of both product and process and the discourse which would serve as an ethical filter (Young, 2004). This opacity could perhaps be compensated for by public control or input in regulatory procedures, providing that all social parties are represented (Ferretti, 2007). Further, citizen participation and involvement could provide the means to overcome the precedent of distrust established by biased experts with economic interests who have tipped the balance of power in decision making to biotech corporations advantage by using technical expertise as a means of stacking the deck (Ferretti, 2007).

Global designs of regulatory systems do not allow for the dynamism and quick progression that corporate funded and speculation fuelled research and development displays (Young, 2004). As a result of this, technology is outpacing our collective ability to regulate it and provide oversight; there is no functional safety mechanism to moderate the accelerated progress of biotechnology (Young, 2004).

7 Perception

Perceptions of risk lie at the heart of current political climates in which GM plants are publicly untouchable. Facts and information regarding the underlying science, motivation for development and nature of risk are not presented objectively. Additionally, and perhaps more importantly, the perceptions regarding GMOs are subject to both social filters and relations to reality which are culturally and geographically modulated (Carolan, 2008). It is important to understand risk in light of perceptual variability as uncertainty about the safety of GMOs is ultimately derived from a consensus about what is unknown but is interpreted differently through what *is* known (Carolan, 2008). Perceptual issues surrounding GMOS incorporate definitional, moral, and temporal dimensions as well, which further complicates objectivity. Value is applied to perceptions of biotech through the subtle use of language and is used differently by different groups. Opponents to GMOs deploy words like integrity, invasive, disturbance, unnatural and others, while proponents put forth words like innovative, extraordinary, improvement etc (Carolan, 2008). Moral dimensions of perception lie in the normative frameworks of what should and should not be or be done with and through technology – again, there is a vast range of socio-cultural difference. Temporally based perception carries an inherent bias emphasizing those people who are currently living and is supported by the political structure of voting. Those in existence now are fragmented perceptually from those who will live in the future (Carolan, 2008).

7.1 Misperception of GM Plants

A behemoth perceptual issue lies in the misunderstanding of the public's concerns by biotech companies. Marris (2001) cites seven observational mismatches that lead to institutional misunderstanding of public response to GMOs leading to skepticism and distrust.

1) The public is either for or against biotechnology. The issue is not binary in nature and thus elicits a full range of response and conditional support. While there is fairly broad support for certain applications like pharmaceuticals, others such as the GM foods, generate strong opposition.

2) It is assumed that the public is both irrational and uneducated, generally or on the specifics of the technology. This misinterpretation originates from the emotive response that consumers have to objectionable issues. In reality, the level of public education varies geographically and the primary source of confusion stems from misunderstanding regarding biotech's specific divergence from conventional breeding. It could be argued that the information regarding the specific proprietary technologies is intentionally sparse; more information and knowledge about GMOs has been shown to polarise rather than placate the public, biotech companies are aware of this (Marris, 2001).

3) GM plants are painted as holistically “unnatural”. In point of fact, the creation of novel transgenic organisms, not the enhancement of certain naturally occurring traits, is what is arguable in defiance of nature. The public is understandably concerned that science is pushing nature too far with GM plants and industrial agriculture in general, given the level of uncertainty surrounding the long-term effects. GM plants are not the sole focus of this concern which encompasses the large-scale use of pesticides, antibiotics, and animal feed promoting indirect cannibalism (Marris, 2001).

4) Another assumption is that the pharmaceutical applications are exempt from negative public scrutiny, and that concerns revolve solely around agricultural applications. While the

medical usage of GM plants is more acceptable, this is largely in part to the rigorous testing and mandatory labeling that accompany pharmaceutical use. The real problem here is the lack of public access to information, untested release into the environment and labeling.

5) Biotech companies also assume that the BSE (Bovine Spongiform Encephalopathy or Mad-Cow) scandal generated disproportionate and irrational reactions to all GM products. While partially true, it is naive to think that this incident is the only salient point of comparison in the collective public consciousness. Memories of dioxins in animal feed, contaminated processed foods, and pesticide laced produce all contribute to concern over problems of carelessness and lack of oversight in the global food, feed, and fibre supply chains (Marris, 2001).

6) Presuming that the public will accept only zero-risk scenarios portrays lay people as unrealistic. In reality, risk is intrinsic to nearly everything; what is demanded is a realistic, objective, multidisciplinary, and transparent assessment of it. Without this, the public cannot balance risk against benefit and understandably distrusts simplified corporate statements.

7) Marris' last observed misperception regards equity and benefit sharing. Amusingly enough, the biotech companies which seek large-scale capital gain through the patenting of what many would argue is common property (life); portray the public as selfish in their rejection of GM plants. The paltry assumption is that the developed world wants to keep innovations to itself and doesn't want the developing world to benefit. What the public wants is an explanation of why GM products, which are the proposed mechanism of salvation (through development and resource provision) of the developing world, are being peddled and pushed in countries already producing agricultural products in excess of what can be used. There is justified skepticism regarding the underlying argument (Marris, 2001).

Table 7-1 Biotechnology: Perception versus Reality

	Corporate Misperception	Public Reality
1	The issue is binary, the public is either for or against biotechnology	Acceptance varies depending upon the technology and its application
2	The public is irrational and uneducated	Confusion stems from biotech's diversion from conventional breeding, education varies geographically
3	GMOs are regarded as holistically unnatural	Transgenic organisms are what the public rejects
4	Pharmaceutical applications are exempt from scrutiny which is focused on agricultural applications	Medical uses are more rigorously tested and labeled which is what the public demands
5	BSE has unfairly coloured public response to GMOs	BSE and other incidences of contamination, corruption and corporate abuse of power has bred skepticism
6	The public demands zero-risk	Demand for realistic, objective and multidisciplinary assessment of risk
7	The developed world is selfish	Mismatch of corporate purpose and marketing reality

Source: Marris, 2001

In light of Mariss' paper (2001), it could be argued that much of the fuss surrounding the public's perception of GM plants was and is created by the biotech industry itself through a failure to understand the concerns of the public. The industry's ensuing failure to communicate information appropriate to assuage the widespread civic indignation regarding the genetic modification of plants, bacteria, and microbes could represent the progression of this misunderstanding. Poorly recognized and oversimplified stakeholder concerns are to blame for the existing state of reputational failure with plant biotechnology (Resnick, 2004). This generalised misunderstanding fuels what is now a firmly established mistrust of the biotechnology industry and corporate enterprises.

7.2 Management of Perception

Missteps made by Monsanto and other biotech giants have devastated the reputation and long-term survival of the industry itself (Resnick, 2004). Reputation reveals the character of a corporation; it is an external manifestation of the managerial practices, corporate culture, and human capital of the organization (Resnick, 2004). For this reason, biotech corporations using stakeholder reputation matrices to gauge the most pertinent opinions of key constituencies may find greater success in cultivating positive public perception and thus generating public acceptance of biotechnologies (Resnick, 2004). Not all knowledge is equal, quantity of information is valued over quality, and risk assessments evaluating only the phenomena which have been objectified are accepted by the scientists, policy makers and politicians deemed as valid participants in legal proceedings (Carolan, 2008). It is their interests which are being recognized and not those of the public. For this reason it is important to have information available to and geared towards regulatory *and* lay groups in order to gain the support of both who chooses and who acquiesces (Carolan, 2008). Without information, the lay population is limited by the epistemic trust originating from what they believe, which may have no basis in fact. Specific trust in specified technologies and generalized trust in biotechnology as a whole must be gained through information, appraised based on its source, content, and amount. This information is lacking, primarily due to the practice of protecting intellectual property. Hence the mechanisms of ownership and secrecy, through which profit gained from the commodification of life, are the same ones which threaten to undermine public and regulatory acceptance of those life forms (Chryssochoidis et al., 2009).

7.2.1 Advertising

Metaphor is an interesting component in the perception of biotechnology in that it allows for something to be understood in terms of something else – a crucial tool in advertising new and unprecedented technologies for which people have no real reference. Yet metaphor conceals as much as it reveals and allows for subliminal manipulation (Hellsten, 2002). It can hide what is not known and play upon deeply rooted fears of mortality, manipulating emotion through the use of visual and conceptual association. For these reasons and others, it is deployed mercilessly in advertising, a tool of ambiguity, attaching positive symbols and therefore positive emotions to products (Hellsten, 2002). Biotechnology corporations have used metaphor in advertising to assuage the fears and fire the hopes of what they have perceived to be the represented by the general population, but as has been discussed earlier in this paper, they were not entirely correct. As a result of this, advertisements for biotechnology have steered away from agriculture and focused on medical applications and non-human symbology, promising control of disease through the techno-scientific modification of nature to render it safe and subservient to the needs of humankind (Hellsten, 2002). Ironically, in their quest to visually transform the fear of the populace into hope, biotechnology advertising has reinforced negative associations of playing God or of

uncontrolled and threatening nature (see appendix A for images) by invoking them in advertisements (Hellsten, 2002).

7.3 Stakeholder Groups

Though it is certainly possible to carry out a more detailed analysis, seven primary groups of stakeholders, with subsets within each group, are held to be important and warrant consideration within this work. They are farmers, consumers, industry, pressure groups, investors, organisations (to include government), and lastly the non-human world. It is paramount that each group be identified and understood prior to acting for or against them or their interests. Their trepidation regarding the inclusion of GM plants in a green economic framework is multifaceted and the scope of their concerns is valid.

1) As stakeholders in the debate surrounding the GM plant inclusion, farmers can be separated into three primary subgroups, smallholder, corporate, and industrial in order to represent the diversity of interests and concerns. Smallholders are trying to make a living; they are carrying on traditions and have strong connections with the land itself. Corporate farmers are interested in efficiency and profit. Industrial farm enterprises are concerned with efficiency, cost, quality of output, and with the minimal processing of agricultural products to convert them into useful inputs for industrial processes.

2) Consumers are comprised of no less than three distinct groups – those in developed nations with precautionary governments, those from developed nations dominated by the free-market system, and those in developing nations. This is a gross simplification produced by painting with a broad brush. The simplified classification is important as it correlates directly with access to accurate information, relative control over agricultural activities, and consumer choice. In general, consumers interact with plants on many levels, as part of natural landscapes, as food products and components, as pharmaceutical ingredients, and as additives to cosmetics, cleansers, fuels, and fibres. The element of choice in the purchase or use of genetically modified products is undeniably important to consumers. Each individual has their own risk tolerance which is influenced by numerous factors such as economics, perception, health, information, and governmental approach.

3) Industry is a broad category of stakeholder group which is dominated by economic interests. The sectors of food, feed, fuel, pharmaceuticals, textiles, chemicals, and transportation are the most obvious examples (Kern, 2002). Industry generally seeks to maximise profit – in terms of GM plants, this translates to minimising input, processing costs, and emissions, maximising usable life, integrity during transport, and augmenting desirable physical properties. In the textile industry, for example, there is focus on the raw material having the right texture, dye permeability, or tensile strength. GM plants that self-defoliate, produce silk, or have longer more uniform fibres are sought after (Kern, 2002). In the pharmaceutical industry, different characteristics are deemed pleasing. There is need for shelf-stable and affordable vaccines, medicinal components and uniformity in active compounds sourced from plants (Bastar et al., 2007). Each industry essentially seeks customisable inputs.

4) Pressure groups also bear mention in that they exist to manipulate public, private, and organizational opinion for the reward of profit. While consumers, farmers and environmental non-profits don't tend to incentivize pressure groups to push their messages, industry, investors, and organizations with large potential contracts, do and handsomely. Pressure groups are motivated by unadulterated economic interests and concern themselves with little else.

5) Investors, private and conglomerate have the goal of profit maximisation. The higher the risks the higher the potential payoff can be. Their interests are not necessarily at odds with social, environmental, and ethical concerns but have a far closer alliance with the interests of industry. Long and short-term interests differ, so the timescale of investment speaks to the level of concern assigned to sustainability, ecological, and health impacts of genetically modified plants.

6) Organisations are comprised of several distinct types such as; interest groups, politicians, aid organisations, international organisations, nongovernmental or environmental organisations, etcetera. Each has a different viewpoint and thus a different agenda specific to its composition (Jamali, 2008).

7) The non-human world is the obvious silent stakeholder (Spicer, 2007 & Driscoll and Starik, 2004). It is the world in which we live and is comprised of the systems on which all life on earth is reliant, directly or indirectly. In a responsible and ethical society, our voices must all speak up to represent the natural world to ensure its integrity, protection, and continuation. Without the benevolence of organisations and other stakeholders empowered and motivated to act on its behalf, the natural world remains unrepresented (Spicer, 2007).

Table 7-2 Stakeholder Groups: Interests, Advocates, and Adversaries

	Stakeholder Group	Primary Interest	Advocate	Adversary
1	Farmers	Subsistence, profit, efficiency	Smallholders, Corporations	Corporations, Smallholders
2	Consumers	Safety, cost, quality	ENGOS, Organizations,	Industry, Investors
3	Industry	Profit, efficiency	Organizations, Investors, Industry	Consumers
4	Pressure Groups	Profit	Whomever is paying	Whomever isn't
5	Investors	Profit maximization	Hedge funds, Lobbyists	ENGOS
6	Organizations	Multiple, dependent upon group	Group dependent	Group dependent
7	Non-human world	Self-perpetuation, existence	ENGOS, NGOs, GOs	Industry, Investors

7.3.1 Motivations and Interests

The intricacies of the various stakeholders' viewpoints are not of general interest and so shall be excluded from discussion in this paper. Rather than go into detail, it is useful to understand that regardless of the stakeholder or their various motivations or interests, there are generalised camps that have formed in the debate surrounding the inclusion of GM plants in green economic frameworks (Young, 2004).

One camp, upholding the premises of social rationality, holds that GM plants are dangerous until proven safe. This camp is risk averse and believes that the stakes are far too high for the level of uncertainty posed by genetic modification of plant life and other living organisms. Their stance is thus adversarial, cautious, and focused on the health and safety of biotic and abiotic environments, human, animal and ecosystem health. Another camp, that of scientific rationality, is focused solely on the positive potentials of plant biotechnology (Bigler et al.,

2008). For the second camp, GM plants are safe until proven to be harmful and require only short-term, isolated study prior to deployment. A third camp questions the motivations behind the development of GM plants in the first place. Applied science comes under scrutiny here, as does private funding of the sciences. The intent underlying the development of transgenic plants is questionable to this camp and corporate interest is viewed with suspicion. A fourth camp is that of aid organisations and governments considering the adoption of GM species for agricultural benefit, food or fuel security, or economic gain. In theory, this group carefully scrutinises the potentials and risks inherent to GMOs attempting to weigh their relative benefits.

It must be reemphasised that these are generalised viewpoints which do not strive to be all-inclusive but rather to provide a representational understanding of the majority. There may be elements of each which some readers find fault with, but it must be stressed that in painting the issue with a broad brush, detail is sacrificed and nuance is lost. There are poles which have developed in the global normative debate over whether or not GM plants should be considered valid components in green economies of the future. These differences of opinion lie principally between developing and developed worlds, between precautionary and free-market governmental systems, and are divided along the line of social and scientific rationalities (Isaac and Kerr, 2003).

The risk tolerance that groups of people have for their natural environments and especially their cropland is directly related to their dependence upon it. Risk tolerant societies such as the United States import (13.7% of global) nearly as many agricultural products as they export (19.2% of global) and are thus more equipped to endure potential damage to their croplands so long as the global supply network is functional (Armstrong, 2002). The US also has the largest area of arable land per capita of all world countries at 0.6 ha per person (World Bank, 2011). This helps to explain their cavalier behaviour regarding GM plants which is not shared by countries within the EU with figures ranging from 0.1 to 0.3 ha per person (World Bank, 2011).

It must be acknowledged that the genetic engineering and modification of plants serves as a lightning rod for global agricultural issues many of which can be attributed to intensification and industrialisation of conventional agricultural practices (Eaglesham et al., 2003). There are risks and distinct problems associated with plant biotechnology however which must be considered. "Biomass has the potential to become one of the major global primary sources during the 21st century" (Jaradat: 309, 2010). The socio-economic and political implications of this are very complicated. The global society is caught, it can afford neither to forgo the potential benefits of plant genetic modification and its role in GHG mitigation, nor can it accept the undesirable or risk laden aspects (Tillman et al., 2009). Environmental problems associated with GM plants have a strong social dimension and thus become politicized (McIntyre, 2009). The underlying science becomes a pressure point and a tool for political leverage in regulation in the polarized debate, but in the end, politics trumps science (Tillman et al., 2009 & McIntyre, 2009).

8 Barriers to Emergence of a Green Economic System

The future of a hydrocarbon based economy is limited (USDOE, 1999) but the transition from it is perhaps the most challenging and promising alternative with the potential to positively affect economic, social and environmental change (Bastar et al., 2007). The rising price and increasing difficulty in the extraction and acquisition of fossil fuel resources is driving the transition, as are the severity and immediacy of climate change, the demand for new materials, and the market-push of innovative technology (Bastar et al., 2007).

As of yet, bio-based products have barriers to overcome which currently inhibit their economic competitiveness. Infrastructure is expensive to build, integrate, and is geared towards fossil fuel inputs. One of the most difficult issues in transitioning to a biologically based economy is fitting carbon chemistry into a system designed for hydrocarbon chemistry (U.S. DOE, 1999 & Albrecht et al., 2010). Infrastructure must be retrofitted where possible to accommodate PBRs as an interim step taking advantage of existing refineries and subsidy schemes currently directed towards petrochemical inputs (Amon et al., 1998). Before agricultural fields can hold equal footing with oil fields, they must be considered and treated as critical, not only to food security, but also to national infrastructure responsible for economic continuation and development (Armstrong, 2002). Novel applications of plants arguably require novel species which drives forward R&D into plant biotechnology (Bastar et al., 2007). The utilization of PBRs without biotechnology is limited by the native traits of complex molecules inhibiting identification, processing or refining (USDOE, 1999). Plants, with trait and content specific modification, will carry the transition to a green economy forward by reducing the cost and energy necessary for fermentation and refining of plant materials for use as industrial feedstock.

8.1 Objections

There are a multitude of issues surrounding genetically modified plants. Some are tied directly to genes displacing hydrocarbons as the economic base but most are not. Some are environmental issues, some social, still others are political concerns surrounding resources and sovereignty; all are intertwined with ethics, legality and science. There is nothing that can be singled out as unrelated to anything else; this is why the inclusion of GM plants presents such a complicated dilemma.

8.1.1 Environmental

Environmental systems are highly complex, many aspects of which affect and are affected by agriculture (Kirschenmann, 2003). Agricultural fields, be they for food, fuel, pharmaceuticals, or fibre, are open systems interacting with biogeochemical cycles (such as water and nutrient flow) and animal, insect, microbial and human populations (Kern, 2002). Land fragmentation, scarce water, deforestation, climate change, biotic/abiotic balance, and biodiversity are inextricably intertwined and thus are not effectively evaluated in labs, or in tightly controlled short-term field tests which isolate variables. Predator prey relationships can be altered by changing the availability or composition of plant derived food and nutrients which can affect plants, animals, insects, and microbes alike (Kirschenmann, 2003). The subsequent imbalances in ecological communities and food webs could be catastrophic. Testing to study the effects of GM plants on complex systems must have time scopes appropriate to the natural systems being studied in order to yield useful or temporally accurate results.

Environmental concerns surrounding the development and planting of GM crops are held to be very serious by a number of stakeholders and analysts to include large and smallholder farmers, consumers, industry, public and private investors, all manner of organisations to include government, and the non-human world. With genomic sequencing, research scientists have made GM plants into apomicts which breed true from generation to generation in order to meet the requirements for patenting and to ensure product reliability. Because of this, GM plants do not express recessive traits which may be undesirable (Busch, 2004). Though appealing for industrial use, consumer, smallholders, and scientists are very concerned that plants without recessive traits, and consequently without the ability to adapt to changing conditions, will introduce a level of risk that is unwise. Apomicts out-cross with wild but sexually compatible species occurs through the aerial transfer of pollen resulting in hybrid varieties between wild and transgenic species which exhibit unpredictable trait combination and expression (Llaguno, 2001 & Young, 2004). This leads to two more serious concerns. One, that modified crops, such as those producing the herbicide Bt, will potentially outcompete with native, unmodified species reducing biodiversity and become invasive by developing a tolerance to the herbicide used to control them (Young, 2004; Bartsch, 2009 & Eaglesham et al., 2003). Two, that any illusions held that plant species can be effectively contained once outside the lab is illogical. It must be acknowledged that there is no recall mechanism for GM plants (Young, 2004).

It has generally been accepted that containment of transgenic pollen is impossible outside of the lab and that gene flow will occur between GM crops and their wild relatives (Thies and Devare, 2007). Gene flow is the mechanism through which so-called superweeds develop which exhibit enhanced fitness and survival due to increased herbicide resistance. The increased resistance of wild but hybridised relatives which are considered to be weeds encourages an increase in herbicide use which has detrimental social, ecological, and economic impacts (Thies and Devare, 2007).

GM plants are bred for to exhibit a number of characteristics that, while of commercial value, may also have serious ecological impacts. These include but are by no means limited to: insect, mould and herbicide resistance; self-produced pesticides, drought, salt, heat and habitat tolerance; extended shelf life; altered ripening and texture; reduced allergen content; improved nutritional profile; and countless others (Kern, 2002 & Cook, 2003 & Bastar et al., 2007). Industrial applications of plants seek to modify structural content (Snow et al., 2003), facilitate processing (U.S. DOE, 1999) or enhance physical characteristics (Kern, 2002). The ecological impacts of these alterations are largely unknown.

The ecological sustainability of land is a serious concern. Industrial agricultural systems already push soil vitality to its limits with monocropping, chemical fertilisation, pesticide dosing, and heavy machinery. The 'novel' traits mentioned in the paragraph above are already suspected of causing damage to non-target species of insects, microorganisms, and fungus (Snow et al., 2003). Weeds and pests are already showing signs of adaptation to the very pesticides and herbicides incorporated into the genomes of the crop plants (Bigler et al., 2008).

The rate of adoption prior to full scientific comprehension of the long terms effects of GM plants is held to be alarming. As of 2010, no less than 29 countries were growing GM crops to total approximately 158 million hectares (James, 2010). Herbicide tolerance has been the dominant trait and represents 61% of GM crops, the trait experiencing the fastest growth were insect tolerant varieties at 17% (James, 2010). Stacked traits, those with more than one trait incorporated into the genome of the plant, represent 22% (James, 2010 & Bigler et al., 2008).

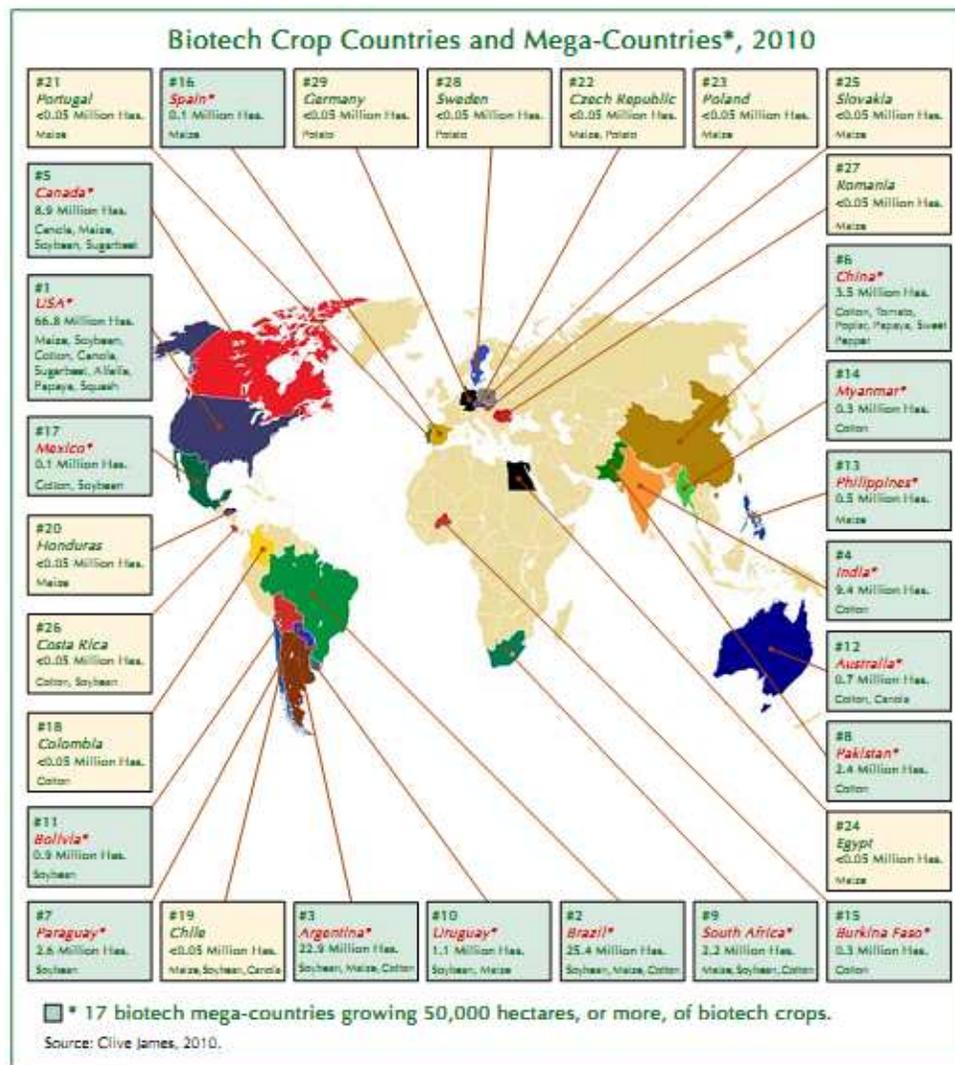


Figure 8-1 Global Area of Biotech Crops with Trend lines

Source: James, 2010

8.1.2 Social

The potential social benefits that accompany the shift to a green economy are numerous and complex. They are intertwined with both scientific and economic benefits in that increased levels of health and economic equity have positive social implications stemming from gainful employment, access to education and the availability of energy (World Bank, 2008). The pharmaceutical prospects of GM plants and their potential as edible vaccines have incalculable positive social implications (Young, 2004). However, if these claims are false, as the Union of Concerned Scientists suggests in 'Failure to Yield', the risks associated with unknown consequences of GM plants must be carefully reconsidered (Gurian-Sherman, 2009).

Communication is a litigious social issue in the row surrounding GM plants. Full informational disclosure is incompatible with a patent-based, competitive business model seeking to corner the global market on plant seeds (Young, 2004). Public perceptions of GM plants are far from overwhelmingly positive for a surfeit or reasons. Disclosure of information is one reason; society resists what it does not understand and it cannot understand what is not even disclosed. Risk is another reason; social risk perception is variable and culturally mediated (Bartsch, 2009).

Generally, civil society is concerned with risks to human, animal and ecosystem health. This is influenced by the relationship between science and society at large. Between the two groups, acknowledging that scientists themselves are members of society, there is a sense of alienation and distrust due largely in part to the politicisation of science and the ensuing manipulation and misrepresentation of data. There is growing trans-disciplinary understanding of the issues at hand but politics and science are still separate fields with divergent skill sets and limited interaction. Business and industry, in contrast, are the long-term mistresses of politics which fuels societal distrust of both political and corporate endorsement of GM plants (Eaglesham et al., 2003).

Overall, transparency is a problem with GM plants. For even as they are regulated, they do not at present carry mandatory global labelling. What labelling does exist is not uniform to cover products containing GM ingredients or derivatives (Young, 2004). Consumers therefore do not have the ability to make informed choices regarding their purchase or refusal to purchase GM foods, fuels, or pharmaceutical products which can be interpreted as an infringement upon their rights (Eaglesham et al., 2003).

8.1.3 Scientific

There is no separation of science from the underlying social conflicts that necessitate its practical application. The criticism of scientists attempting to study the effects of GM plants is symptomatic of a larger social trend where the social value of science itself is under attack and suspicion (Somerville, 2000). Somerville holds that this is principally due to the industrialisation of science by large corporate entities and serves as the genesis for fears that multinational corporations are seeking to control global food markets through GM seeds (Somerville, 2000). Biotechnology is a tool; its use and nature of composition determine the overall products. Corporate agrobiotechnology, ignoring peer review, precaution, and the complex network architecture of biological systems have generated wonder and horror in the global scientific community with highly questionable applications of transgenics (Kirschenmann, 2003).

Labs are structured and rule-oriented, yet they are all about experimentation. Researchers understandably are caught up in the possibilities of new discoveries but must verify findings and carefully document results. Unfortunately, they must also compete for funding which complicates the integrity of science itself (Eaglesham et al., 2003). In nations where scientific research is funded primarily (65%) by private enterprise (Washburn, 2007), there is an emphasis on applied research with practical and profitable application. In those which science is largely funded by the public, the quest for greater understanding remains open-ended (Eaglesham et al., 2003). Generally, public research is underfunded, which grants privately funding projects the advantage (Eaglesham et al., 2003). The ability to create new organisms with novel characteristics is an incredible boon to scientists unhindered by ethical constraints. When viewed free from normative prescriptions, the potentials for GM plants are endless. Funding for science provides the normative framework dictating what science *should* be doing.

It cannot be stressed enough that there are fervent ethical concerns associated with the motivations and products of private research in plant biotechnology.

8.1.4 Ethical

Genetic modification is arguably the natural progression of agricultural productivity (Kern, 2002). For more than 10 000 years, humanity has continually improved its ability to increase agricultural benefit through innovations such as the plow, water wheel, tractors, combines, and hybrid breeding; plant biotechnology is the logical progression (Kern, 2002). Humans have been developing plants themselves through isolation, cross-pollination, artificial pollination and selective breeding for more than 8 000 years (Kern, 2002). The advances in the last thirty years have delved into the genomes themselves, giving us the ability not only to improve existing varieties but also to create new ones through transgenic recombination (Kern, 2002 and Snow et al., 2003).

There exists significant and heated discussion on the subject of whether or not scientists *should* wield what has been called “god-like power” over the living organisms (Young, 2004). Ethical concerns over normative judgments are perhaps best tempered with hard data. There are ontological, epistemological, and moral dimensions to the debate. Ontology, or the nature of being, drives the ethical debate but rests upon both moral and epistemological questions of how we should be altering other living organisms in the world and to what end (Carolan, 2008). Competing knowledge claims put forth by corporations and independent scientists have confused the issues and interfered with grounded understanding regarding the risks posed by GM plants. Information is not presented objectively and is subject to social and cultural filters which contribute to ethical confusion. Normative or moral claims about what scientists should be doing or on the sanctity of life directly affect public opinion and ethical judgments. Is it ethical for corporations to issue statements rife with subtle value judgments or to publish temporally irrelevant results? These are questions that we must ask of ourselves (Carolan, 2008). Politics too, greatly influences the relationship that science has to society and warrants ethical consideration. The politicisation of issues surrounding GM plants, by those with little or no trans-disciplinary understanding or scientific background, can alienate scientists from the non-scientific public and introduce bias (Somerville, 2000).

8.1.5 Political

Economic, social, ethical, scientific, and legal issues all become political issues when larger scales are examined. Political objections to the inclusion of GM plants in green economic frameworks are suffused with scalar politics. Following WWII, ‘high’ and ‘low’ politics were decoupled, that is security, and stability were disassociated from trade relations (Isaac and Kerr, 2003). Balancing free trade, precaution, choice, and equity (global and intergenerational) is no easy task. Trade and aid are political considerations with plants as a common element; both are subsets of foreign policy (Isaac and Kerr, 2003).

Far from being limited to the regional scale of farms themselves, GM plants are highly relevant across scales from regional to global. The additive impact of agricultural policies is something that multinational governmental institutions are acutely aware of, especially as aggregate impacts influence global biogeochemical cycles and thus have global effects (Busche, 2004 & Young, 2004). Regulation of biotechnology however, varies regionally, inhibiting coordination and concerted action. At the level of nation states, debate surrounding GM plants focuses on aid, development, equity, trade, security, and sovereignty.

The inclusion of GM plants into foreign aid is a very contentious political issue given the various other concerns associated. Interest in plant biotechnology is driven by concerns over population growth, poverty, infectious disease, climate change, environmental degradation, and a general decline in natural resources (Kirschenmann, 2003). The acceptance of GMOs has been made a provision to the acceptance of aid packages, forcing choice for recipient countries (Young, 2004). It does not take a politician to understand that this poses some very serious problems.

8.1.6 Economic

Economic concerns about GM plants run the gamut from individual crop yields to international commodities pricing and global trade. Small and large farms alike have differing economic risk tolerances to uncertain agricultural outputs resulting from changing seed varieties as this affects profit and solvency. Transgenic crops claim to improve yield while reducing other costly inputs such as fertilisers, pesticides, and labour intensive tilling (Bigler et al., 2008). This potential must be weighed against tried and true methods which require time spans in excess of those allotted for in GM field tests of modified crops. To date, long term studies have not verified claims these claims.

The reallocation of agricultural profit that occurs when farmers utilize genetically modified seed is a necessary consideration. Modification adds value and thus cost to each seed, increasing the material costs to farmers (Young, 2004). As GM plants are developed by private industry, the selfsame industry is capturing the profits and the premiums from these seeds. Smallholder farmers often operate with very narrow margins and are tenuously solvent (Kirschenmann, 2003). The move from what will be referred to as 'traditional' to genetically modified seed, redirects income from farmers to chemical corporations developing and selling modified seed which may require specifically tailored fertilizers or pesticides for optimal production; these required inputs secure customer loyalty and ensure corporate profit (Kirschenman, 2003 & Young, 2004). Thus, rather than aiding horizontal development by increasing the income of farmers, Kirschenmann (2003) argues that the purchase and subsequent annual repurchase of transgenic seed creates dysfunction in farm economies and puts them on an 'input purchasing treadmill'. The rising cost of seed has both direct and indirect social repercussions. Social networks between farmers, which are typically cooperative, become competitive or even predatory as profit margins become even slimmer. Farms become larger and more mechanized and there are fewer farmers (Kirschenmann, 2003).

The long-term impact of GMO plants on soil fertility is of economic and environmental concern. While theoretically reducing the need for pesticide and or herbicide inputs, the costs to farmers may be lower in the short term (Bigler et al., 2008) but long-term studies have not confirmed this as a positive trend. This introduces a larger ethical and financial issue associated with genetically modified plants in general; research funding. If the funding is public as opposed to private it affects the results of the research (Atanssov et al., 2007). Privately funded research yields proprietary data within the framework of Intellectual Property Rights, which functions to inhibit public scrutiny of the results and yields biotechnology with more commercial than social value (Bastar et al., 2007 & Atanssov et al., 2007). Research and development of biotechnical solutions is both lengthy and expensive which motivates corporations to push for regulatory approval and places upward pressure on the price of the innovation (Jaworski, 2001). Bastar et al. (2007) have recognised this in their 'Plants for the Future' report and the EU has moved to establish cooperative, publically funded biotechnology research initiatives with universities in an effort to both mitigate the

outcome of privately funded biotech and to stay ahead of the curve with the bio-based economies of the future.

8.1.7 Biopiracy

Biopiracy is a term applied to the use of genes, which some consider to be part of the global commons, for personal or corporate profit. Private corporations have utilised plants from other nations and registered patents on their genomes without compensating or consulting the host country (Young, 2004). This re-appropriation of material and information across national lines and from the public to the private domain is part of what advanced plant genetic modification relies upon for novel traits. The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (Article 27.3) allows countries to exclude from patentability, biological processes, plants, animals and microorganisms, but that does not prohibit countries such as the US, which allow the patenting of life, to take advantage by patenting GM plants created using material from other nations (Young, 2004). The size of the market incentivises such risky or questionably ethical behavior by biotech companies. By 2000, 20% of the corn, 50% of soy, and 75% of the cotton planted in US fields was GM herbicide resistant (Krimsky, DATE). The U.S. agricultural market was 50% saturated with GM crop varieties as of 2008 (Bigler et al., 2008) and has the economic potential to grow 30 to 70 billion USD in the near future (Kern, 2002). The European bio-economy market represents no less than two trillion Euros with strong potential for growth (Albrecht et al., 2010). The Cartagena Protocol on Biosafety, far from prohibiting GM plants and the Biopiracy upon which they are often built, merely *recommends* that each country develop its own biosafety protocol (Young, 2004).

8.1.8 Legal

The regulation and monitoring of plant biotechnology are simply not keeping pace with the advancements occurring in the field (Young, 2004). The two basic regulatory approaches mirror the paradigms of social and scientific rationality; scientific rationality which utilises product-based, judicially rooted decisions; and social rationality which is process-based and reliant on consensus decision. The first is progress oriented and thus accepts minimal risk, holding that innovations are safe until proven otherwise. The second takes a precautionary approach, accepts no risk, and presumes that biotechnological innovations are dangerous or harmful until it is shown with sufficient credibility that they are not (Isaac and Kerr, 2003). A battle is raging within the framework of the WTO on GMOs which represents not only the definition of risk but also the extent to which trade will be permitted to influence the domestic political sovereignty of member nations (Isaac and Kerr, 2003).

GMOs gained a legal foothold when representatives from Monsanto asked the United States government to regulate them, ostensibly to lend validity and the pretence of safety to genetically modified organisms (Busch, 2004). Monsanto and other biotechnology companies later asked the US government to deregulate GMOs in order to speed innovative products to market (Busch, 2004). 1980 yielded the 1st patent on a living organism, 1987 bore the 1st large-scale release of GMOs into the environment, and by 1994 GMO foods were reaching consumers in the United States. Though this legal faux pas was not repeated in other nations, it serves as a legal precedent upon which other regulation is based and against which other regulation is compared (Salzman, 2010).

The most prominent piece of international legislation regarding the genetic modification of plants is the Cartagena Protocol on Biosafety (as part of the Convention on Biodiversity); it was adopted in 2000. It focuses on transboundary movement, LMOs and risks to human

health but fails to address liability for GMO engendered harm to ecosystems and the biota within them, to include us (Young, 2004). Though it requires signatories to regulate the introduction of LMOs, there are sizable loopholes for direct use, processing, and ingredients intended for human pharmaceutical use. The Biosafety Clearing House addresses capacity issues associated with developing nations, introducing and asserting precaution but falls short of any definitive measure of prohibition or proof in regulating GMOs (Young, 2004).

Other instruments have been put into place more quickly such as UNIDO's Voluntary Code of Conduct for the Release of Organisms into the Environment, adopted in 1992. It encourages the establishment of regulatory regimes and establishes generalised principles guiding the environmental introduction of organisms. UNEP's Technical Guidelines on Safety in Biotechnology was adopted in 1995 facilitating informational exchange, evaluating risk in biotechnology and to monitor and support research (Young, 2004). Supporting these auxiliary measures is the Codex Alimentarius adopted jointly by the FAO (Food and Agriculture Division of the UN) and WHO (the World Health Organisation). It established guidelines for labelling, production, and processing of foods and Working Principles for Risk Analysis (WHO, 2002). Binding international legislation still lags behind the development of new biotechnology products and interim overtures have been all but toothless leaving market forces to self regulate (Young, 2004). The result is that GMOs are released into the open environment and remain largely unregulated.

8.1.9 Public Trust

There is no cross-disciplinary consensus on the meaning of trust, thus no way to facilitate the integration of biotechnology, ensure cooperation, and reduce complexity in the interest of stabilising democracy, economic growth or promote efficiency in plant based resource use (Chrysochoidis et al., 2009). Trust must be based on both similarity and agreement and is a necessary component of social capital and productivity, yet the need for public trust is overlooked and underestimated by biotechnology corporations (Bretschger, 2010 & Chrysochoidis et al., 2009). The incorporation of biotechnology into biologically derived industrial feedstock, given that there exists no absolute separation from consumer products and food chains, introduces risk into routine behaviours of grooming and eating; trust is critical in this context (Chrysochoidis et al., 2009). It is a social phenomena, driven by epistemology, what we believe to be true (Carolan, 2008) which is influenced by access to information.

The sources of information determine the validity of the content. Environmental organizations are given the most credibility in the biotechnology arena, seconded by medical professionals and academia, but family and friends are trusted more than expert sources, far more than the manufacturers of biotechnology which are looked to only for emergency information in times of acute crisis (Chrysochoidis et al., 2009). Trust is affected by prior belief, negative press and metaphorical context (Chrysochoidis et al., 2009 and Hellsten, 2002). Public trust is, for better or worse, being manipulated by biotech corporations eager to sell their products. The public face of genetic engineering morphed first into genetic modification and now into the very general category of life sciences in an effort to diffuse the public outcry against it (Hellsten, 2002).

8.2 Biofuels

It is impossible to address the inclusion of GM plants in the context of a green economic framework without mentioning biofuels and going into some depth as the transportation sector accounts for 27% of nearly one third of total energy demand (EIA, 2010).

8.2.1 How they Turned Public Opinion against Them

Current incantations of green energy are economically and ecologically inefficient and maintain the present reliance on fossil fuels as sources of energy (Pimental et al., 2009). The fermentation and distillation of biofuels is water and energy intensive. Ethanol, to take an example, requires up to 12 litres of water per 1 litre of ethanol and consumes 46% more fossil (1.5 litres of fossil fuel per 1 litre of cellulosic ethanol) energy than it produces resulting in a net energetic loss of 68% (Pimental et al., 2009). Soy derived biodiesel represents a net energy loss of 63%, rape seed and canola -58%. Oil palm, providing the only semi-promising figure for improvement at -8%, on closer examination gains an offset of 30% through the use of methanol for transesterification (Pimental et al., 2009). Algae, though it promises 30-50% oil content, suffers the same fate as terrestrial plants which have a 18% oil extraction efficiency rate; projected yields of algae based fuels for 15USD/barrel have become 800USD/barrel (Pimental et al., 2009). What keeps the dream of ethanol and other biofuels alive are heavy subsidies (60 times the subsidisation of gasoline in the US) and the promise of greater rates of efficiency in the future (Pimental et al., 2009). The primary criterion in a sustainability assessment of biofuel is a net positive energy balance which none of the following exhibit (Fore et al., 2011).

Table 8-1 Net Energies of Various Biofuels

Biofuel Type	Net Energy
Corn	-46%
Switchgrass	-68%
Soy Biodiesel	-63%
Rapeseed/Canola	-58%
Oil Palm	-8%

Source: Pimental et al., 2009

8.2.1.1 Jatropha

“A more bio-based economy offers hope for both developed and developing countries. For developed countries, it presents the opportunity to use their technological capabilities for national security of energy and chemical supply. For developing countries, it provides the potential at least partially to leapfrog the age of fossil fuels and petrochemicals to the age of more environmentally-friendly biofuels and biochemicals that can be produced locally, improving the economy and quality of life” (Jaworski; pg 1, 2001).

Jatropha deserves special mention, as it is arguably the most prominent example of biofuel’s failure to produce its projected benefits and did much to taint popular public opinion on the inclusion of plants in the biofuel strategies of green economies. Though the varieties of Jatropha utilized were not genetically modified, its large-scale failure is still relevant and creates associative bias.

Jatropha illustrates the poorly executed promotion of biofuels as developmental aids. While appropriate for small-scale applications in which the accessibility and price of diesel fuel is prohibitively expensive, Jatropha is more expensive than diesel, kerosene, and fuelwood (Achten et al., 2009 & Openshaw, 2000). The global interest in biofuels triggered large-scale investment in Jatropha based upon its hypothetical and optimal potentials but failed to

consider the realities of its practical application. Similar to palm oil, Jatropha is tolerant to draught and climactic variance, has few pests (animal, insect or microbial), is easy to establish, grows quickly, and has a high oil yield (Openshaw, 2000). As with all plants, yield is dependent on land quality and upon the input of water and nutrients, this was reflected in its cultivation in sub-Saharan Africa (Openshaw, 2000). With 16 – 18 carbon atoms per molecule, it is heavier than diesel which has between 8 and 10. As a result of this, Jatropha oil is more viscous and has a lower ignition quality (Openshaw, 2000). Averaging at approximately 0.73 USD/litre, Jatropha does not even come close to being cost competitive with diesel or kerosene with average costs of 0.11 USD/litre and 0.22 USD/litre respectively (Openshaw, 2000). In addition to its cost, the optimal markets for Jatropha’s various products were not quantified or communicated, rather, its use as fuel was subsidised subverting its most profitable market as oil for the production of soap (Openshaw, 2000). Jatropha is one biofuel that has turned popular opinion against biofuels. Touted as a means through which to encourage renewable energy use and access, promote socioeconomic development, reduce poverty, and improve the environment, Jatropha fell far short of all these goals (Openshaw, 2000).

Table 8-2 Relative Price of Jatropha against Diesel and Kerosene

Fuel Type	India USD/l	Nepal USD/l	Zimbabwe USD/l
Jatropha oil	0.73	0.80	0.67
Diesel	0.07	0.15	0.11
Kerosene	0.17	0.24	0.25

Source: Openshaw, 2000

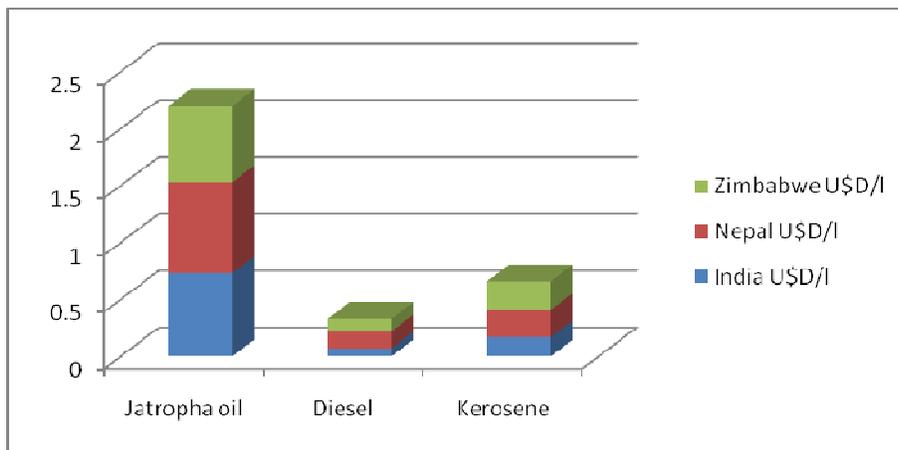


Figure 8-2 Relative Price of Jatropha against Diesel and Kerosene

Source: Openshaw, 2000

8.2.1.2 Algae

Algae also deserves special mention when discussing biofuels as it represents, not the errors of the past as with Jatropha, but the promise of the future. The appeal of developing algae stems from its superior oil yield, its use of aqueous rather than terrestrial environments, low eutrophication potential and use of polluted or saline water (Mata et al., 2010). Algae also

hold great appeal due to the global diversity of suitable species, their range of metabolisms (autotrophic, heterotrophic, mixtrophic etc...), ease of cultivation, and short growth cycles. It is a suitable feedstock for multiple fuels, capable of producing biodiesel, methane, ethanol, and others (Mata et al., 2010). Algae's ancillary benefits are also appealing as it can be used for wastewater treatment, for the removal of industrial CO₂ emissions, as a post pressing fertilizer, and for the extraction of other compounds. Algal derivatives have high economic value and, like all biofuels, a specific value chain associated with its products and by-products (Mata et al., 2010).

Yet on closer examination, algae fuels have higher environmental impacts than other biofuels due to the upstream impacts of its required fertilizer and CO₂ inputs (Clarens et al., 2010). This setback is being effectively addressed through research in industrial and municipal symbiosis in which water and nutrients are derived through co-location with industries using algae to absorb CO₂ from flue gas emissions and or by wastewater, effluent and source separated urine from sewage and water treatment facilities as inputs (Mata et al., 2010 & Clarens et al., 2010). Even with this, the current technological capacity does not render biofuels derived from algae to be cost competitive with fossil fuels. While estimates were initially far lower, the price per barrel would have to be between 240USD and 332USD just for processing costs to be met; this is a break-even price representing zero profit (Lundquist et al., 2010). Its best use may yet be in hydrogen producing fuel cells rather than as biodiesel (Mata et al., 2010).

8.2.1.3 Pitting Biofuels against Food Crops

Biofuels and food crops are dependent upon the same resources for growth, harvest and processing (Pimental et al., 2009). First generation biofuels and biorefineries utilized existing agricultural outputs (i.e. food crops) as their feedstock (Kamm and Kamm, 2004 & Borsche et al., 2007). This created conflict by directly pitting fuel crops against food crops. The economic impacts of this were direct and undeniable as the global prices of grains, cereals, and animal proteins increased by 10 – 20% (Busche et al., 2004 & Pimental et al., 2009). This incentivised farmers to switch to the production of fuel rather than food crops and further exacerbated the rise in food prices and competition for land (Bastar et al., 2007).

8.2.1.4 Land Use

In an increasingly competitive and populated world, getting more from the finite amount of arable land is the object of the game. Intensified use of existing arable land not the increase in hectares used is the objective. Plant biotechnology is making use of land in a technically efficient manner, increasing the biologically tolerable plant density, maximizing photosynthetic activity, and shortening maturation (Peck, 2011 & Ragauskas et al., 2006).

According to the UNFAO's Statistical Yearbook for 2010 which provides figures up to 2008, the percentage of global arable land is 11%, of which a scarce 1% is used for permanent crops but 26% is used as pasture (FAOSTAT, 2010). These figures point to a global food system which prioritises the use of land for the production of animal protein rather than plant matter. It is a problem that is intensified by increasing levels of economic development and consequent rise in demand for meat (Albreicht et al., 2010). This small percentage of arable land is under further pressure from growing populations seeking more space for residences and roadways, and threatened by the pollutants stemming from the various metabolisms of human society and industry (Swyngedouw, 2006 & Pimental et al., 2009 &). A reallocation of this land from food to biofuel production would not only exacerbate food shortages and prices but would be insufficient, with current technologies, to supply energy needs (Pimental

et al., 2009). As global biofuel programs gain momentum, pressures on land and water use also increase, further incentivising land use conversion which results in a net increase in GHG emissions (Melillo et al., 2009 & Tillman et al., 2009). Vague legislation, intended to allow for flexibility, has enabled counterproductive development in the biofuels industry, incentivizing land use conversion and agricultural reallocation of food croplands to fuel crops (Tillman et al., 2009).

In 2006, Sweden was producing 8 dry MG ha⁻¹/yr (of Willow), the US 10-22 dry MG ha⁻¹/yr in short rotation woody plant species, and Brazil was producing 20 dry MG ha⁻¹/yr (Ragauskas et al., 2006). A conservative estimate of the global average was 10 dry MG ha⁻¹/yr (Ragauskas et al., 2006). These yields are insufficient to meet global targets for fossil fuel replacement with biofuels such as the EC's Biofuels Directive which mandates that a mere 2% of all diesel and transport fuels must be derived from biomass (Ragauskas et al., 2006).

The idea that biofuels in their current forms can replace fossil fuel inputs represents a techno-economic paradigm that isn't working and has a basis in abstraction rather than reality (Green et al., 1999). The boom in biofuel production is representative of the mutual reinforcement of technical and institutional change, but reinforces sectoral privilege rather than socio-economic benefit stemming from the technological developments in biofuels (Green et al., 1999). Biofuels are attainment focused where precedence is given to possible positive outcomes and risk is approached enthusiastically (Bryant ad Dunford, 2007).

8.2.2 Environmental Performance

The environmental impacts of biofuels are often far greater than those caused by fossil fuels. When Life Cycle Analysis and Environmental Impact studies are appropriately scoped so as to include process by-products, water, land, and energy use, biofuels lose quite a bit of their lustrous appeal. The cost and processing of biofuels is not the only problem with plant-derived fuels. Other impacts of biofuel production include loss of wildlife habitat through increased domestication of land and an increase in food commodities pricing due to displacement or reallocation of food crops. Food and biofuels are dependent upon the same resources. The water supply for agricultural applications is diminishing the world over; demand for it is intensified as fuel crops require irrigation. Soil erosion is another serious problem associated with biologically derived fuels. When crop residues such as corn stover(stalks) and other plant bodies are harvested in their entirety, soil is neither protected nor replenished, resulting in erosion, runoff and the ensuing acidulation and eutrophication of water bodies (Pimental et al., 2009).

Land use changes are the primary culprit in the indirect emissions associated with biofuel production; they are also excluded from the scope of calculations more often than not, distorting quantitative figures used to evaluate the sustainability and efficiency of green energy projects and policies (Martin and Eklund, 2011; Fritsche et al., 2009 & Melillo et al., 2009). The carbon intensity of biofuels cannot be accurately assessed without including land use change, water use, contribution to eutrophication, fossil inputs, all processing and transportation, and by-products (Melillio et al., 2009; Cayuela et al., 2010; Spangenberg and Settler, 2009 & Clarens et al., 2010). In examining this, four different biofuels were evaluated by Clarens et al. (2010) in terms of their environmental impacts. Five parameters were tabulated, land, energy and water use, eutrophication potential and GHG emissions. Interestingly enough, algae, which uses the least amount of land for cultivation has the highest environmental impact. This shows that multi-criteria analysis must be used to gain an accurate and useful evaluation of the relative potentials of biofuels.

Table 8-3 Impact Categories of Biofuel Production

Fuel Type	Land (ha)	Energy (MJ) x 10 ⁴	GHG (kg CO ₂ equiv) x 10 ⁴	Water (m ³) x 10 ⁴	Eutrophication (kg PO ₄ - equiv)
Algae	0.4	30	1.8	12	3.3
Corn	1.3	3.8	-2.6	0.82	26
Canola	2	7	-1.6	1	28
Switchgrass	1.7	2.9	-2.4	0.57	6.1

Source: Clarens et al., 2010

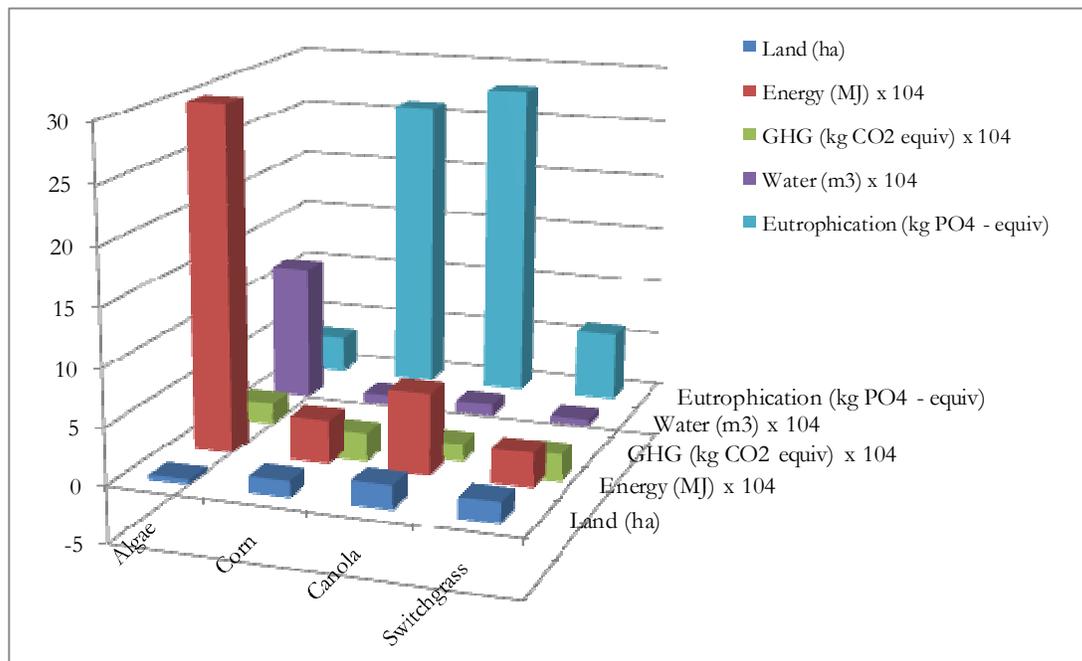


Figure 8-3 Impact Categories of Biofuel Production

Source: Clarens et al., 2010

Looking at the preceding figures, one can gain a better visual comparison of the relative performances of different biofuels and the associated environmental impact by feedstock type. Algae, though it has low land use and eutrophication potentials, is energy intensive. The land requirements of corn and canola, illustrate why food and biofuels are coming into direct competition. Switchgrass, though it receives little mention in the media, and perhaps for good reason, seems to exhibit the most conservative resource use and overall impact of the biofuels compared here. It must be noted that different biofuels exhibit different chemical characteristics and energy yields as fuel.

There is a clear trade-off between lower environmental impacts and minimizing GHG emissions which must be thoroughly assessed prior to supporting biofuels directives through political and economic means (Zah et al, 2007). Tax-based instruments must be very carefully targeted to specified production pathways in order to avoid development in the biofuels industry that is counterproductive to political, economic, and environmental goals (Tillman et al., 2009 & Zah et al., 2007). In a study carried out for the Swiss government by Zah et al. (2007), an attempt was made to assess this trade-off through the aggregated assessment of environmental impacts. This is illustrated in the following figures.

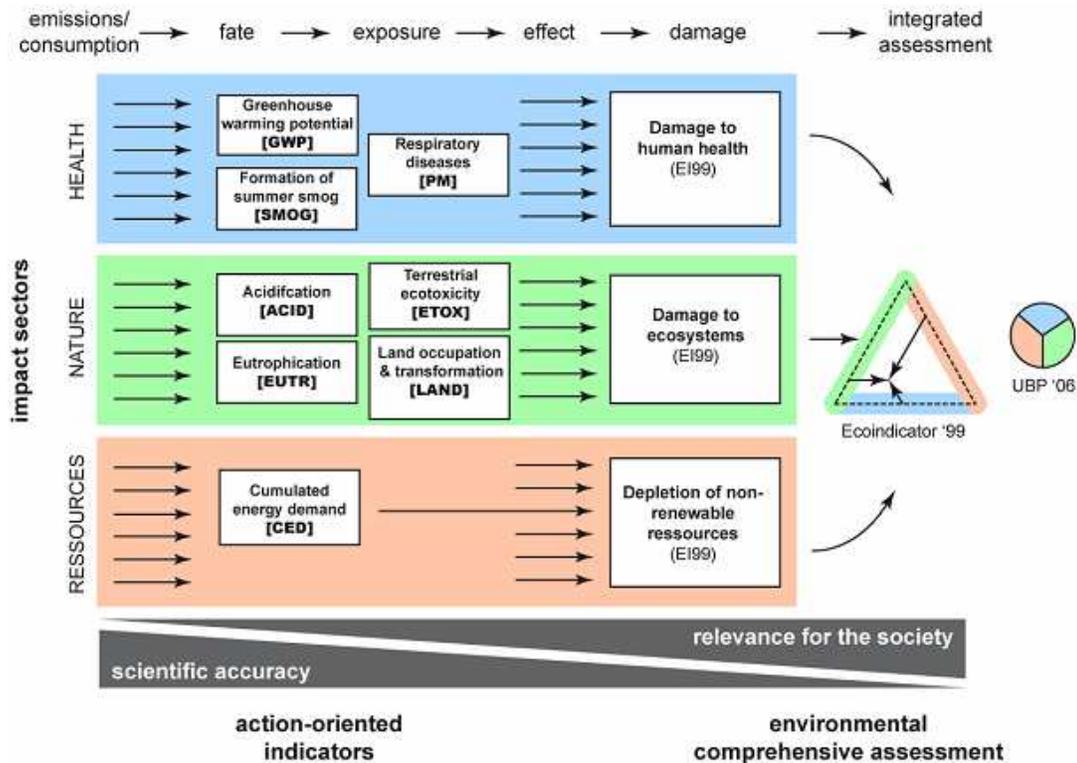


Figure 8-4 Sectors & Indicators of a Comprehensive Ecological Assessment

Source: Zah et al., 2007

In the figure above, the factors which make up the composite Ecoindicator used in the study for the Swiss government are elucidated (Zah et al., 2007). While not fully inclusive, this work represents the most comprehensive assessment of biofuels to date. In the figure below, the Life Cycle Assessment (LCA) compared unblended biofuels according to; greenhouse warming potential (GWP), non-renewable energy demand (CED) the summer smog potential (SMOG), fertilizer use and runoff (EUTR), and finally their relative ecotoxicology (ETOX). For the purposes of the Swiss study, the chart was colour coded to reflect the relative greenhouse warming potentials of each fuel, but overall examination reveals some fuel types as having far greater impacts than others have. Studies such as this one serve as the basis of recommendation for policymakers. They are necessarily limited in scope and leave out as much or more information than they reveal. Yet decisions must be made and scopes must be established. Climate change is a global hot button issue and the focus of multinational protocols and conferences such as the recent COP held in Copenhagen, thus it makes sense

that politicians are currently focused on the GHG emissions or potential emissions of various biofuels in their transitions toward greener economies.

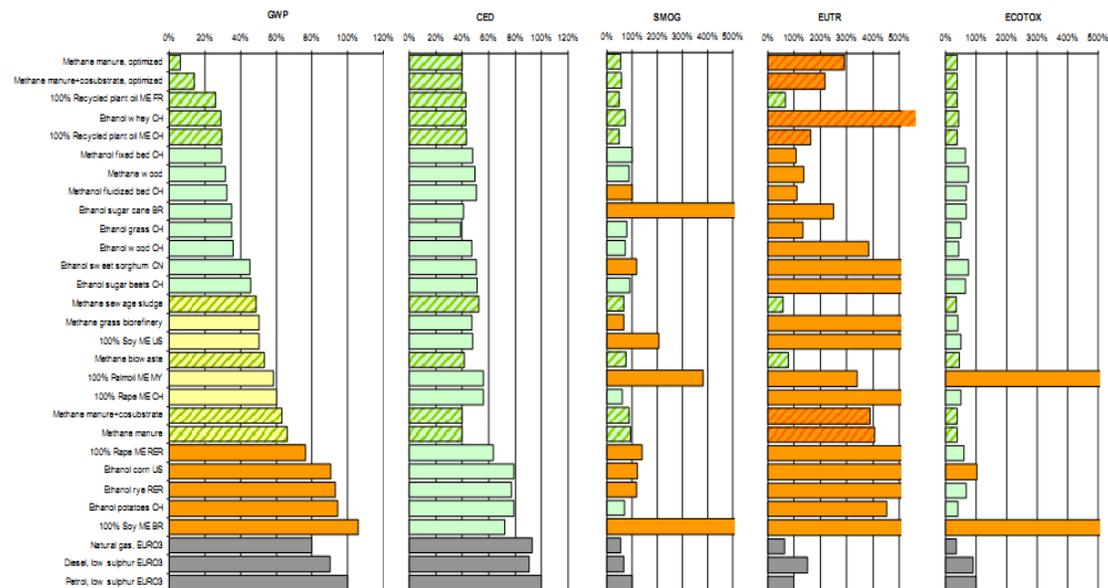


Figure 8-5 Eco-Analysis of Biofuels

Source: Zah et al., 2007

Diverse applications and sources of biologically derived fuels, while intended to reduce the environmental impacts of energy use and mitigate emissions associated with climate change carry environmental impacts far higher than fossil fuels (Zah et al., 2007). As discussed in a previous section, waste streams are often left outside the scope of studies examining the environmental impact, risk, and omitted from calculations of energetic yield (Claren et al., 2010; Mata et al., 2010 & Melillio et al. 2009). Water use calculations frequently do not include wastewater treatment, disposal, and transport (Clarens et al., 2010). Nor do they account for unforeseen inputs such as additional fertilizer or disposal and treatment of unusable by-products (Openshaw, 2000 & Martin and Eklund, 2011). Waste paradigms are shifting; large-scale industrial material cycles are closing due to the integration of ecological and technical metabolisms. Industrial symbiosis may provide the means through which biofuels and the processing of biomaterials can be utilized with closed cycles and near zero waste. Residual heat from biofuel processing can potentially be utilized through co-location (Martin and Eklund, 2011). Stand alone biofuels plants, when examined in terms of material flows often exhibit a poor input output balance and rely upon fossil inputs (Matin and Eklund, 2011).

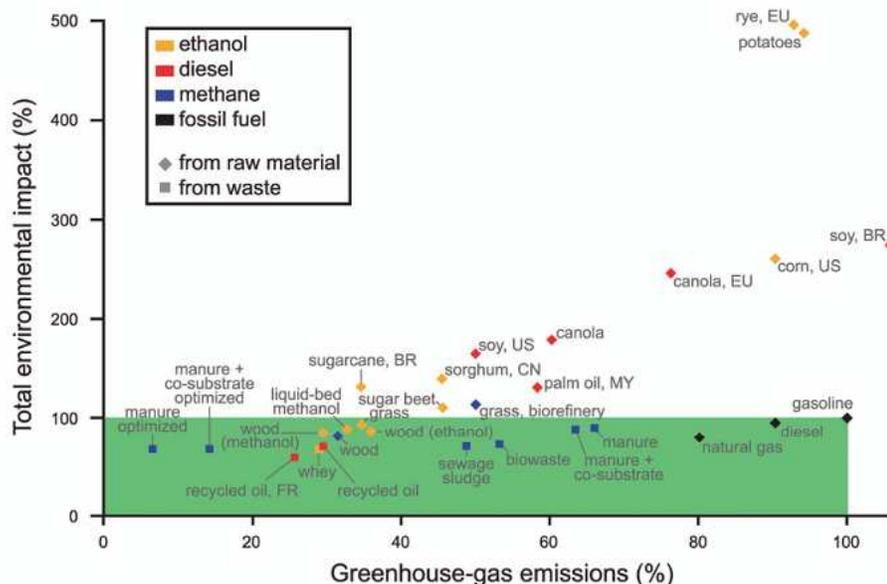


Figure 8-6 Greenhouse Gas Emissions by Biofuel

Source: Zab et al., 2007

8.2.3 Energy Use

Substituting biofuels for petrochemical fuels carries forward the host of problems associated with patterns of energy use. Growth in energy use is outpacing population growth at 2.5% to 1.7% and perhaps our capacity to generate it (Pimental et al., 2009). Energy demand is projected to grow by 50% by 2025 (Ragauskas et al., 2006). The allocation of the energy that is produced reflects patterns of inequity whereby the small percentage of people residing in developed nations consume 70% of global energy supplies, leaving 75% of the global population with only 30% of the energy generated (Pimental et al., 2009). Burning ethanol also produces air pollution releasing peroxyacetyl nitrate, acetaldehyde, alkalates and nitrous oxide which also have environmental impacts (Pimental et al., 2009). Biofuels were introduced as a means of transitioning away from polluting fossil fuel and an avenue to achieve sustainable development; even in the 2nd and 3rd generation, they are imperfect at best (Martin and Eklund, 2011).

8.2.4 Biomass' Highest Use

Biomass has always been used as a raw material; the progression to fossil fuels and back to biomass has been a process of continuous evolution (Marquardt et al., 2010). Following the utilization paradigm of fossil fuels, where more than 90% of the carbon is used solely for its energy content, does not represent an intelligent or efficient utilization of biomass, and may be responsible for the negative yields associated with biofuels (Pimental et al., 2009 & Marquardt et al., 2010). Though the initial purported use of biomass was for the generation of energy through combustion, this does not represent its highest potential use. There is a cascading value chain of quality uses, at the bottom of which lies thermal utilization (Peck, 2011). "The petrochemical product tree will be replaced by a bio-based alternative" (Marquardt et al., 2010:pg. 2228) in which the value chain itself is inverted; feedstock will be selected on the basis of the suitability of reaction pathways which are themselves dependent upon molecular structures harbouring desired functions (Marquardt et al., 2010). Process and

supply chain synthesis can be integrated when biomass is selected or engineered for its highest potential use rather than for its availability or low price.

Through sophisticated biorefineries, biomass can yield thousands of useful products and provide an opportunity to redesign the industrial value chain, long before lignocellulose is burned (Marquardt et al., 2010). First tier extraction yields high value plant extracts utilized for fragrance, flavour, and those used directly as food products and nutraceuticals. Second tier extraction produces polysaccharides, lignin, and chemicals. It is not until the third tier of biomass processing that fuels are generated (Ragauskas et al., 2006). Thus, when fuel becomes the desired primary product of biomass, as with *Jatropha*, all other possible high value products are ignored or sacrificed to produce fuel. This, in tandem with inefficient conversion processes, leads to the lack of economic viability of biofuels.

Biotechnology has the capacity to alter plants so that they yield higher concentrations of valuable compounds and biological matrices that are more easily broken down through enzymatic rather than thermo-chemical or mechanical processing (Ragauskas et al., 2006). The direct use of biorenewables, their degradation into C_1 building blocks, or, their gasification or methanation will create a new range of products and transform the value chain of plant extracts into a dynamic structure changing with the technological improvement of extraction capabilities (Marquardt et al., 2010).

9 Putting GM Plants back on the Political Table

GMOs, for reasons of contention, contestation, and public uproar, have been all but taken off political tables, at least publically (Andrée, 2007). While the inclusion of genetically modified plants is politically treacherous, the potentials inherent in custom crafted organisms are impossible to ignore as world economies prepare to move away from fossil and towards biological fuels, industrial feedstock, food, fibre (Kern, 2002). Projected figures for global population are expected to grow from the current figure of 6.1 billion people to 8.9 billion by 2050 (UN, 2004). Additional resources will be required to meet the needs of that many people, to included resources that are already scarce or generating competition for access such as land and freshwater.

Bio-based economies are the answer to the ills of today's carbon-based resource dependency. Severe global problems have been caused by dependence on and use of non-degradable and polluting petrochemical feedstock, the availability of which does not match or meet growing demand (Bastar et al., 2007). The bio-based strategies advocated in green economic frameworks represent sustainable solutions which minimize the environmental impacts associated with development, reduce or eliminate toxins, and strive to mitigate the uncertainty caused by the uneven distribution of oil deposits and a changing climate (Bastar et al., 2007).

There are many reasons why GM plants were brought to the table in the first place, most of which are still valid. Key societal challenges such as managing the nutritive and quality of life demands of the approximately nine billion people predicted to inhabit the earth by 2050 drive innovations focusing on yield and efficiency (Albrecht et al., 2010). Poverty is persistent; there has been a noted increase in the rate and toll of infectious diseases. Natural resources and petrochemical reserves are declining – biotechnology, for these reasons and others cannot be ignored (Kirschenmann, 2003). The global population is growing, that is not contested, and diets are changing, as are trade patterns, the climate and petrochemical reserves (McIntyre, 2009). With this come growing demands for productivity, competition for land and energy needs which are perhaps met with bioenergy. This is reflected in the rising prices of global commodities to include food, water and fuel (McIntyre, 2009)

Whether your views hark to Malthus in that population is dependent upon resource supply or to Boserup in that population growth is the driver for agricultural development, it is clear that something needs to be done (Siedow, 2001). Smil suggests that humanity starts by acting as intelligent omnivores by taking up the slack in our current agricultural system while applying technology wisely (Siedow, 2001). Genetic modification is not the only way forward; there are other pathways to meet the needs of growing populations such as the reduction of meat consumption or more efficient management of renewable and non-renewable stocks (Peck, 2011). Regardless, we cannot feed or provide energy and resources to burgeoning populations without making significant changes to our current agricultural and industrial systems.

While GM plants are not a stand-alone solution they are arguably necessary for fossil fuel substitution (Borch et al., 2008). Used in tandem with careful deployment, and other technologies such as crop control, bio-pesticides, and spectroscopic sensing, GM plants represent an important element in the transition to a green economic system (Borch et al., 2008). Wise use of these bio-based products necessitates that each crop's value chain be efficiently utilized and that fuel plants are selected on the basis of ecological, energetic, and technical efficiency rather than by ready availability.

Many of the problems associated with GM plants lie in the future, on the other side of time (McIntyre, 2009). What is feasible now does not match the potentials inherent in biotechnology. As a global society, we must look at the innovations of the present with an eye toward the future. Current risks associated with biotechnology may become irrelevant through further development and study and so should not be rejected out of hand. The mitigation and balancing of risk against potential is a process that must occur, but one that necessitates the provision of information which is currently proprietary (Bretschger, 2010). In order to weigh risk and potential, intellectual property rights and the privacies they engender must also be weighed and perhaps redressed.

According to Bretschger (2010) climate change is currently the biggest imminent threat to sustainability. Its potential effects on GDP are undeniable in both magnitude and distribution. A rise in global temperature of 6°C correlates to a loss of 5-10% of global GDP, 10% of which will occur in poor countries (Bretschger, 2010). Without interventions to increase the resilience and adaptive capacity of plants, the primary inputs for bio-based economies, this will severely impinge upon natural resource availability, affecting development, food security, economic stability, and societal wellbeing (Bretschger, 2010).

With food prices increasing by nearly 60% in 2008 and oil swelling to 150USD/barrel (a process which is currently repeating itself) the trade contraction of 2009 and the recent banking failures, moving to an economic system which integrates social and environmental considerations into its very structure is highly logical (Bretschger, 2010). Mechanisms which bolster the sustainability of interconnected systems simply must be addressed by policies such as the Green New Deal (Bretschger, 2010). Optimal economic and environmental policies have the effects of stability, growth, delayed extraction, and resources preservation (Grimaud & Rouge, 2008). The current petrochemical economy is grey and oriented toward short-term gain; this is the source of many environmental problems which have ripple effects in society and economy alike. Environmental degradation, far from being the negative externality it is treated as, is undermining the economic systems creating the pollution (Grimaud & Rouge, 2008).

10 Conclusion

Perceptions of genetically modified plants interfere with the application of advances in plant biotechnology to systemic economic changes while they serve to some extent as a safety brake on the uncontrolled uptake of GMOs, they also have the potential to hinder the potential overall societal gain to be had through the application of GMOs. Green economies, while they may function without modified plants at a later stage of technological development, seem to require them as a bridge technology. Biorefineries can utilize unmodified plant matter as feedstock; however, with current physiochemical processing still require the input of too many resources (water, energy and petrochemicals) to make PBRs environmentally or economically competitive in the short run. Advances in plant engineering are currently at a phase of development which can compensate with genetic manipulation what for what is missing in process engineering. Viewed solely in the context of the problems which genetic modification seeks to address, the biotechnical solutions offered are logical and appealing. Viewed in broader context of global ecology, however, the potential problems accompanying these solutions may well outweigh in importance the solutions available through the use of GM plants.

To use an idiom, with plants, upon which our lives depend, we are all better off with the devil we know than with the devil we do not know. GMOs represent enormous uncertainty and pose risks which we may or may not have the capacity to overcome should they be realized as harm in our biosphere.

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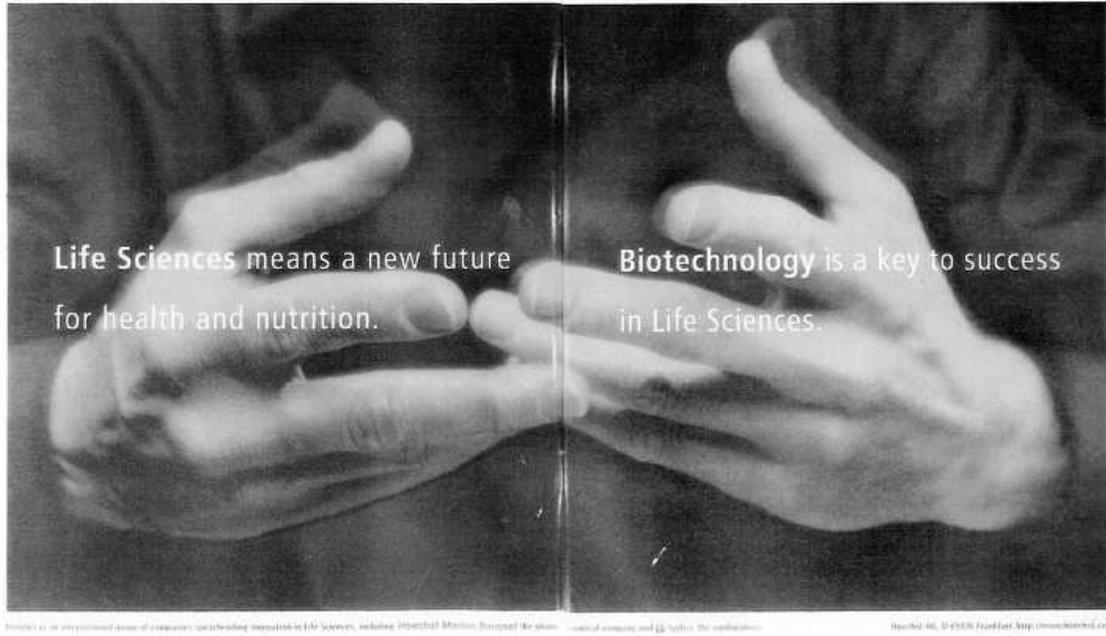
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Appendix

Health and nutrition are predominant concerns of the future in which biotechnology holds the key to innovation. Hoechst Marion Roussel, one of the world's leading pharmaceutical companies, is seeking biotechnology to develop highly effective drugs to fight against currently incurable diseases. On the other hand, Hoechst Schering Agrar, is ensuring sustenance for the world's growing population through integrated crop production.

The Future in Life Sciences **Hoechst**



Hoechst is an incorporated division of Hoechst AG, a leading international life sciences, including Hoechst Marion Roussel, the pharmaceutical company and Schering, the pharmaceutical company. Hoechst AG, D-65926 Frankfurt, <http://www.hoechst.com>

Figure 4. The nature of the life sciences, Hoechst.
Newsweek, 13 April/*Der Spiegel*, 30 March 1998.

The venom of a snake helped us formulate a life-saving drug. Hoechst.

In a number of civilizations, snakes have long been revered as a symbol of healing.

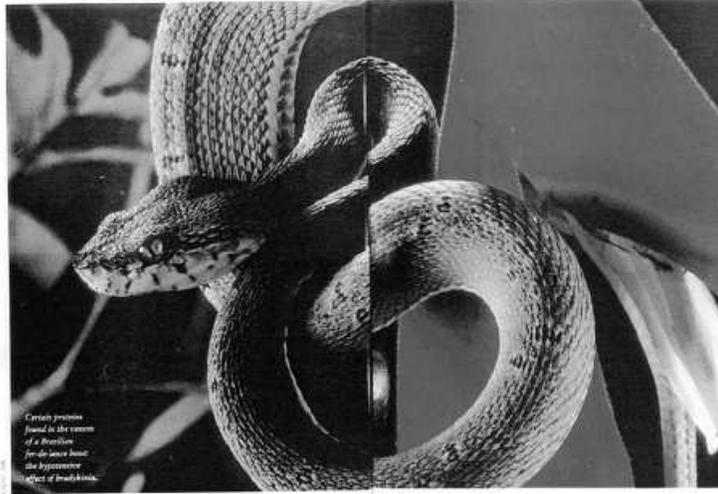
It was 90 years ago that scientists developed a better understanding of exactly how snake poisons act in the human body.

Protecting the heart and the cardiovascular system.

An example of research in this field is an active substance used to treat cardiovascular disorders.

The human body contains certain tissue hormones called kinins, which reduce blood pressure and open the blood vessels. Now it has been discovered that the blood-pressure-lowering and vasodilating action of the kinins can be boosted by proteins found in the venom of a Brazilian pit viper.

Scientists at Hoechst Marion Roussel, our pharmaceutical company, have used this discovery to synthetically produce these



Certain proteins found in the venom of a Brazilian pit viper have the hypotensive effect of bradykinin.

proteins and thus develop a new life-saving drug. Research into cardiovascular disorders has always played an important role at Hoechst.

In 1904, Hoechst researchers were the first to synthesize the hormone adrenaline. Other vital developments followed, including edema therapy and preparations to dissolve blood clots.

Today, Hoechst Marion Roussel offers one of the broadest lines of cardiovascular products.

Cardiovascular disease is still the No. 1 cause of death, which is why fighting this important problem is a matter so close to our hearts at Hoechst Marion Roussel.

Hoechst is an international group of companies spearheading innovation in health care, nutrition and industry. With a staff of 145,000 people worldwide, annual sales total DM 52 billion.

Hoechst AG, D-65926 Frankfurt, <http://www.hoechst.com>

Finding new ways.

Hoechst 

Figure 5. Improving nature, Hoechst.

Newsweek, 14 April 1997.