Chapter 1

Can We Solve the Agro-biofuel Riddle?

The Various Pieces of the Riddle

The frantic development of biofuels

In the last two decades, the biofuel stage in Europe and the US has witnessed a whirlwind of political mandates, economic incentives and investments, as well as scientific research to promote the production and use of crop-based biofuels. The amount of direct and indirect private and public investment in incentives and subsidies is difficult to quantify.

According to the *Financial Times*, in the US:

> *Investors are sitting on billions of dollars [of] losses after buying into the corn-based ethanol industry that George W. Bush embraced as the answer to US energy woes … Investor losses come as taxpayers have paid billions to support the ethanol industry. More than $11.2bn has been spent since 2005 on tax breaks for companies that blend ethanol into petrol. Billions more have been spent on direct state and federal subsidies for US ethanol production. 'We're looking at an industry that's cost $80bn to get to this point' said Bob Starkey, a fuels analyst at Jim Jordan &Associates, a research group in Houston.* (Allison and Kirchgaessner, 2008)

A similar view is given by a report from the World Bank:

> *Governments provide substantial support to biofuels so that they can compete with gasoline and conventional diesel. Such support includes consumption incentives (fuel tax reductions); production incentives (tax incentives, loan guarantees, and direct subsidy payments); and mandatory consumption requirements. More than 200 support measures, which cost around US$5.5 billion to US$7.3 billion a year in the United States, amount to US$0.38 to US$0.49 per litre of petroleum equivalent for ethanol.* (World Bank, 2008)

According to a study by Kutas, Lindberg and Steenblik (2007) – prepared for Global Subsidies Initiatives (GSI) as part of a series of reports addressing subsidies for biofuels in selected Organisation for Economic Co-operation and Development (OECD) countries – the direct subsidies within the European Union (EU) in the year 2006 amounted to €1.3 billion, but this is an underestimate since it does not include the support to investments in developing the biofuel industry. The direct subsidies in 2006 are equivalent to €0.74 per litre of biofuel (or about US$1 per litre).

The latest rush related to biofuel production is taking place in Asia, especially in Malaysian and Indonesian palm-oil production. According to an article by Patung (2007) in *Indonesia Matters*:

> *The government has offered huge incentives for companies to develop biofuels, primarily derived from palm oil, and many local firms that dominate in the logging, wood-processing and pulp industries have secured big contracts with such overseas companies as Chinese energy giant China National Offshore Oil Corp (CNOOC), which is one among 59 foreign and local energy investors who in January 2007 signed various biofuel-related renewable energy agreements worth US$12.2 billion.*

These investments and incentives have resulted in a boost in the pace of production of biofuels worldwide. 'Production of biofuels (ethanol and biodiesel) exceeded an estimated 53 billion litres in 2007, up 43 per cent from 2005' (REN21, 2007). It should be noted that, in 2006, 86 per cent of this production was ethanol, whose production was concentrated in the US (46 per cent of the ethanol was produced from corn) and Brazil (42 per cent of the ethanol was produced from sugar cane), while the remaining 14 per cent was biodiesel produced from crops, mainly in Europe (World Bank, 2008). 'In Asia, oil-palm plantations cover over 13 million ha, primarily in southeast Asia, where they have directly or indirectly replaced tropical rainforest' (Danielsen et al, 2008).

This frantic development of the agro-biofuel sector has been justified on the following grounds:

- The large-scale production of agro-biofuels can significantly improve energy independence and security, through the reduction of dependency on imported petroleum.
- The large-scale production of agro-biofuels can generate a significant reduction in greenhouse gas emissions.
- The large-scale production of agro-biofuels can help to improve rural development by supporting crop farm income.

The third motivation has been especially relevant in developed countries, where, independently from agro-biofuel production, a huge amount of subsidies is already poured into commodity support programmes in agriculture (about US$20 billion in the US and about US$80 billion in the EU).

Assuming these three grounds are valid, the governments of the US and the EU have focused on the implementation of this alleged win–win–win solution by setting specific targets, specific subsidies and specially arranged policy strategies. Attracted by the bonanza of a deluge of subsidies, investors jumped in. However, as the heroic efforts to quickly implement this world-saving strategy generated their first results, a lot of problems and unseen side-effects have popped out.

Negative effects on food supply

The most conspicuous of these unforeseen problems has undoubtedly been the worldwide food crisis. Paul Krugman (2008) described the crisis in the *New York Times*:

> *Over the past few years the prices of wheat, corn, rice and other basic foodstuffs have doubled or tripled, with much of the increase taking place just in the last few months. High food prices dismay even relatively well-off Americans – but they're truly devastating in poor countries, where food often accounts for more than half a family's spending. There have already been food riots around the world. Food-supplying countries, from Ukraine to Argentina, have been limiting exports in an attempt to protect domestic consumers, leading to angry protests from farmers – and making things even worse in countries that need to import food.*

This food crisis has several components, including the increasing demand for grains due to population growth and changes in dietary habits, a relative increase in meat consumption (Pingali, 2007) and the occurrence of unfortunate events (such as a couple of poor years of production). But there is a clear consensus that this crisis has been generated foremost by poor policies, and in particular by the frantic development of agro-biofuels.

World Bank President Robert Zoellick, in a letter written to Western leaders, said:

> *What we are witnessing is not a natural disaster – a silent tsunami or a perfect storm. It is a man-made catastrophe, and as such must be fixed by people.* (Spiegel Online International, 2008)

In fact, an internal report generated by the World Bank and leaked to *The*

Guardian was extremely clear in this regard:

> *Biofuels have forced global food prices up by 75 per cent – far more than previously estimated – according to a confidential World Bank report obtained by* The Guardian. *The damning unpublished assessment is based on the most detailed analysis of the crisis so far, carried out by an internationally-respected economist at the global financial body. The figure emphatically contradicts the US government's claims that plant-derived fuels contribute less than 3 per cent to food-price rises. It will add to pressure on governments in Washington and across Europe, which have turned to plant-derived fuels to reduce emissions of greenhouse gases and reduce their dependence on imported oil.* (*The Guardian*, 2008a)

(The World Bank's 'secret' study of April 2008 has now been revised and published, and can be accessed at www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf.)

In spite of the controversy about the exact impact of crops for energy supply on food supply, this opinion has been expressed by many other important figures:

- The Secretary-General of the United Nations (UN), Ban Ki-moon, at a special meeting of the UN General Assembly, warned against investing too heavily in crops for biofuels at the expense of food production (BBC News, 2008a).
- The UN Secretary-General's Special Adviser on the Millennium Development Goals for reducing extreme poverty, Jeffrey Sachs, said: 'Europe's biofuels policy is having a "real impact" on food prices because wheat is being used on this continent to meet its energy demand, rather than to feed people' (Cronin, 2008).
- The previous UN Special Rapporteur for the Right to Food, Jean Ziegler, called biofuels a 'crime against humanity' (Spiegel Online International, 2008).
- The newly appointed UN Special Rapporteur for the Right to Food, Oliver de Schutter, has argued that the EU's policy is misguided: 'The production of rapeseed [and] palm oil destroys the forests in Indonesia. The use of one-quarter of corn in the United States is a scandal, in which taxpayers' money is used solely to serve the interests of a small lobby. I call for a freeze on all investment in this sector' (Cronin, 2008).
- Robert Bailey, policy adviser at Oxfam, says: 'While politicians concentrate on keeping industry lobbies happy, people in poor countries cannot afford enough to eat. Rising food prices have pushed 100 million people world-

> wide below the poverty line, estimates the World Bank, and have sparked riots from Bangladesh to Egypt. Government ministers here have described higher food and fuel prices as "the first real economic crisis of globalization"' (Spiegel Online International, 2008).

The negative effect on CO_2 emissions

Also in relation to the second ground that biofuels are supposedly carbon neutral, there is increasing evidence that clearly contradicts this claim. Increased efforts to analyse the overall effects of large-scale agro-biofuel production point to several hitherto neglected side-effects.

A number of studies have focused on the initially neglected effects of the conversion of natural land covers, such as rain forest, grass land, peat land and savanna, into monocultures or plantations for biofuel feedstock production in Brazil, the US and Southeast Asia. According to a recent study by Fargione et al (2008) published in *Science*, this conversion can create a 'biofuel carbon debt' by releasing 17 to 420 times more CO_2 than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels. Applying a similar method of analysis based on a worldwide agricultural model which estimates emissions from land-use change, Searchinger et al (2008) calculate that corn-based ethanol, instead of producing 20 per cent savings (as claimed by biofuel supporters), nearly doubles GHG emissions over 30 years and increases GHGs for 167 years. Biofuels from switchgrass, if grown on US lands, will increase emissions by 50 per cent.

Therefore, it is easy to predict that if a terrestrial ecosystem can no longer hold carbon (its structural biomass), this negative effect on the climate will also have a negative effect on biodiversity. A recent study, in fact, found that the conversion of forest to biofuel plantations not only will increase emissions for 75–93 years, but will also have a negative effect on biodiversity (Danielsen et al, 2008).

Analyses of the implications of land-use changes have also been performed for the UK. In a detailed report prepared by the Policy Exchange think tank (2008), a panel of scientists advised the UK government to immediately abandon targets and subsidies, since the best way to reduce CO_2 emission is to avoid further deforestation and protect existing natural covers as much as possible. Commenting on a request from Greenpeace and Oxfam to the British government to stop a policy demanding the inclusion of biofuel at pumps across the country, the UK's Chief Environmental Scientist Robert Watson called for a delay. He said: 'biofuel policy in the EU and the UK may have run ahead of the science' (BBC News, 2008b). As a matter of fact, the British Parliament has asked the EU Parliament to reconsider the attention being given to biofuels, which may be detracting from other, less expensive yet more

effective ways to reduce transportation-sourced CO_2 emissions. The Commons environmental audit committee has come to this realization, and the MPs did ask the European Union to abandon its target of 10 per cent biofuel use by 2020 (*The Guardian*, 2008b). In addition, in February 2008 the Canadian Parliament's standing committee on agriculture and agri-food delivered a recommendation for the withdrawal of a bill imposing mandatory levels of biofuel in the fuels used for transportation (REAP Canada, 2008).

A commentary in the *New York Times* by Rosenthal (2008) neatly makes the point:

> *The destruction of natural ecosystems – whether rain forest in the tropics or grasslands in South America – not only releases greenhouse gases into the atmosphere when they are burned and ploughed, but also deprives the planet of natural sponges to absorb carbon emissions. Cropland also absorbs far less carbon than the rain forests or even scrubland that it replaces.*

To make life more difficult for biofuel proponents, a Nobel laureate in chemistry, Halmuth Michell, has recently cautioned the government of the Philippines against rushing into biofuel development because there is little energy to be gained from it. 'When you calculated how much of the sun's energy is stored in the plants, it's below 1 per cent. When you convert into biofuel, you add fertilizer, and then harvest the plants. There's not real energy gained in biofuel' (Burgonio, 2008). This last comment introduces the key aspect of the issue: are agro-biofuels a viable and desirable alternative to fossil energy? This aspect will be treated in detail in the following chapters.

Government reaction to this mounting evidence

Within the EU

After this series of events, the EU finally decided to change the Directive EC 2003/30, which had been issued in May 2003. It required Member States to place a minimum proportion of biofuels and other renewable fuels on their markets. The indicative reference value for these proportions in the old normative was 5.75 per cent of market share (in energy content) of all petrol and diesel for transport purposes by 31 December 2010.

A long discussion between EU Member States, the European Parliament and the European Commission over how to change the old directive generated an agreement reached in Brussels in December 2008. This increased the target for the proportion of renewable forms of energy in the EU's road transport fuel from 5.75 per cent to 10 per cent by 2020 (EUobserver, 2008)!

This decision prompted another wave of outrage among NGOs and civil

society. Together with Friends of the Earth Europe, Lobbycontrol and Spinwatch, Corporate Europe Observatory (CEO) decided to confer the award for 'Worst EU Lobbying 2008' to the biofuel lobbyists in Brussels (www.worstlobby.eu/2008/home_en).

Within the US

The Energy Independence and Security Act of 2007 mandated the use of 36 billion gallons (136 billion litres) of biofuels by 2022, with significant requirements for cellulosic biofuel and biodiesel production. This is an increase of more than 500 per cent on current production levels.

No major changes in existing policies took place in 2008. As a matter of fact, the amount of money already committed to the ethanol cause in the future is quite impressive:

> *Total undiscounted subsidies to ethanol from 2006–2012 are estimated to fall within the range of $68 billion to $82 billion. Implementation of a higher Renewable Fuels Standard (e.g. 36 billion gallons per year by 2022) would increase total subsidies by tens of billions of dollars per year above these levels.* (Koplow and Steenblik, 2008, p96)

It should be mentioned that several groups are attacking the pro-ethanol policy in the US. A few titles found on the web say it all: 'Worse than fossil energy' by George Monbiot (2005); 'Smell of gigantic hoax in government ethanol promotion' (Hecht, 2007); 'Bio-foolery is causing "food shocks"' (Baker and Craig, 2007). It is unclear at present whether President Obama will maintain the existing subsidies for biofuels, but he has picked Steven Chu (a Nobel laureate in physics) as his Energy Secretary. Professor Chu is a well-known supporter of second-generation biofuels (from cellulosic biomass).

The Riddle to be Solved

Reading the various pieces of the riddle listed above cannot help but prompt a series of disturbing questions.

Are crop-based biofuels truly a viable and desirable alternative to fossil fuels?

It becomes difficult to suppress the uneasy feeling that nobody bothered to check the validity of the underlying and justifying grounds before joining the mad rush for the 'solution' to humankind's energy problem. As a matter of fact, in the rest of this book we will claim that none of the three grounds used to justify the frantic development of agro-biofuel is even close to being valid.

Is the energetic predicament confronting human societies something never faced before in human history? Can we learn something useful about agro-biofuels from our past experiences concerning energy and society?

The answer to the latter question is: 'Yes, we can' (illustrated in Chapters 2–7). There is a pretty good understanding of basic energetic principles applied to the functioning of human societies, and this experience clearly indicates that agro-biofuels are not a viable or desirable alternative to oil. Interestingly, as early as 1945 Samuel Brody, in the last chapter of his masterpiece on energy conversions in US agriculture, commented as follows on renewable energy sources:

> *it is said that we should use alcohol and vegetable oils after the petroleum energy has been exhausted. This reminds one of Marie Antoinette's advice to the Paris poor to eat cake when they had no bread.* (Brody, 1945, p968)

Since then, consistently, all those working in the field of energetics have ruled out the possibility of substituting fossil energy with biofuels. The actual large-scale production of agro-biofuels is only possible because of the large amount of oil being used in the production process. If the production process of agro-biofuels were to be self-sufficient, i.e. cover its own energy expenses with its own biofuel, then the net supply of agro-biofuel could not fuel even a negligible fraction of the transport sector of a developed economy.

If none of the assumptions used to justify the rush into agro-biofuels are true, and the well-established discipline of energetics considers the substitution of agro-biofuels for oil nonsensical, how can we explain the agro-biofuel madness?

Seeking the Solution to the Biofuel Riddle

On the type of solution we seek

This book has been written in an attempt to understand why and how society got carried away with the biofuel madness, and why this folly developed in the first place. In other words, ours is an attempt to solve the 'biofuel riddle'. Solving this riddle is anything but easy, since it requires putting together many pieces of a puzzle, pieces that belong to different typologies and dimensions of analysis. It requires a complex explanation, and complex explanations are not welcomed in a society like ours, addicted to reductionism. Nobody wants to waste time trying to understand issues; people look for plain facts, for the one and only 'truth', like the type of information presented on TV in the narrow span of time available between commercials.

Understanding requires time and reflection. One cannot really understand an issue for another person; at the most one can try to explain it. Real understanding of a complex issue must be achieved independently. It requires putting together various dimensions and analyses of different aspects in a coherent, complex picture. So if the reader is expecting us to simply say what is right and what is wrong with agro-biofuels, what should be done, and who is responsible for this mess, then he/she will be disappointed with this book.

This is not a book that will provide a series of straightforward explanations. Unfortunately, you cannot solve complex riddles with a simple key. In reality, it would be easy to give an explanation to the riddle by adopting simplifications. For example, two comments – by, respectively, Venezuelan President Hugo Chavez and 2008 Nobel Prize winner Paul Krugman (see Box 1.1) – provide pretty good simplified solutions to the biofuel riddle.

Box 1.1 *Examples of simplified solutions to the biofuel riddle*

Chavez's solution

Chavez said in a national address this week that increased production in Latin America would not help the region's poor or bring electricity to rural communities. Instead, crops like corn, meant for food production, will be diverted to create more biofuels so that 'illogical, absurd and stupid capitalism can continue its voracious growth'. (United Press International, 2007)

Krugman's solution

Where the effects of bad policy are clearest, however, is the rise of demon ethanol and other biofuels. The subsidized conversion of crops into fuel was supposed to promote energy independence and help limit global warming. But this promise was, as Time *magazine bluntly put it, a "scam". This is especially true of corn ethanol: even on optimistic estimates, producing a gallon of ethanol from corn uses most of the energy the gallon contains. But it turns out that even seemingly "good" biofuel policies, like Brazil's use of ethanol from sugar cane, accelerate the pace of climate change by promoting deforestation. And meanwhile, land used to grow biofuel feedstock is land not available to grow food, so subsidies to biofuels are a major factor in the food crisis. You might put it this way: people are starving in Africa so that American politicians can court votes in farm states. Oh, and in case you're wondering: all the remaining presidential contenders are terrible on this issue. One more thing: one reason the food crisis has gotten so severe, so fast, is that major players in the grain market grew complacent.* (Krugman, 2008)

Chavez's explanation is based on simplifications associated with socialist ideology about the market economy, while Krugman's explanation is based on simplifications performed by a smart economist analysing the functioning of the market economy. These two explanations can be considered 'very good' in terms of the narratives used. By adopting an easy narrative they end up providing a similar explanation: something went wrong and someone can be blamed for it. For Chavez, the culprit is illogical, absurd and stupid capitalism; according to Krugman, the culprit is the bad policies made by inadequate incumbents.

But how useful are these explanations? In relation to that given by Chavez, even China has realized that one must learn how to live with capitalism. We must tame it, not eradicate it. Since we cannot get rid of capitalism, it is important to explain which decision-making mechanisms within the capitalist system did not work properly with agro-biofuels, and why. Can we learn something from this failure, in order to do better in the future?

In relation to the explanation given by Krugman, the bad choices made by inadequate incumbents do not address the roots of the problem. Does the riddle of biofuels indicate a unique inadequacy among specific people writing policy about a very complex problem, or does it indicate a systemic inadequacy in the process used to generate decisions about very complex problems? If we want to know how to tame the capitalism with which we have to live, then we have to learn how to develop decision-making mechanisms capable of generating wise choices under pressure.

In fact, we claim that the systemic failure of quality control highlighted by the biofuel delusion is not due to bad people making bad decisions, but is rather the predictable outcome of a decision-making process that is called on to generate swift changes in an extremely complex socio-economic system in which several mode lockings are in place. The complexity of the system guarantees that many powerful forces operate against the proposed changes. Agro-biofuel is a perfect form of pseudo-change, suggested in order to preserve the status quo.

Can we learn something from the processes behind the promotion of agro-biofuel policies?

Yes. We believe that the agro-biofuel delusion represents a highly relevant case study in relation to future discussions of ambitious policies aimed at generating swift changes. In these future situations, scientific information will be mixed with social information in a super-charged political arena. It is extremely important to guarantee the quality of this mixing. Educated professors, world-class specialists, Nobel Prize winners: any of these could provide the 'right' explanation for a particular event, but they can handle only one issue and one

perspective at a time. Nobody, no matter how smart and educated, can solve the complexity of the sustainability predicament by using only a single perspective or simple disciplinary knowledge.

In this book, we claim that the frantic implementation of policies on agro-biofuels has been possible because of a peculiar situation in which the establishment – governments, academic and financial institutions, and many non-governmental organizations – agreed that the naked emperor was wearing new invisible clothes. This situation has nothing to do with the 'bad' nature of capitalism; on the contrary, capitalism has proved pretty efficient at avoiding hoaxes. Nor were those involved necessarily bad people, or unperceptive. No, the situation was created because society as a whole did not want to see that the emperor was naked. Using available knowledge in the field of energetics, it would have been easy to perform a scientific analysis of the agro-biofuel proposal and detect imminent problems. However, the knowledge accumulated in the field of energetics was willingly ignored.

The explanation of the biofuel riddle requires an answer to yet another disturbing question: How is it possible that the academic establishment of developed countries has been buying the sloppy narrative about the advantages of agro-biofuels, to the degree that the scientific community has been generating a deluge of technical assessments backing up agro-biofuel policies?

The answers we provide in this book

The approach we use in this book is somewhat different from the approach generally adopted in conventional scientific journals engaging in the debate on agro-biofuel performance, or in reports or journal articles that aim to popularize these issues. In fact, conventional scientific debates on sustainability dilemmas tend to be carried out by two sides 'throwing numbers at each other over the fence' (an effective expression coined by Jeroen van der Sluijs). In these battles over numbers, each side worries only about checking the accuracy of its own calculations. This behaviour has led to a dialogue of the deaf, meaning that the numbers disputed by the opposing sides usually reflect the adoption of different conceptualizations or meanings. Numbers are often generated within different systems of accounting or, worse, reflect logically independent ways of characterizing different pieces of a bigger picture.

Any quantitative assessment of the sustainability issue must be necessarily developed within a particular narrative: a local definition focusing on just one aspect, referring to only one dimension and one scale of analysis (Giampietro et al, 2005; 2006). When dealing with different scientific analyses developed within different narratives, we find quantitative assessments which may give results that are non-equivalent, and therefore not reducible to each other. Therefore, when dealing with quantitative analysis applied to the issue of

sustainability, the focus of the debate should be on the quality of the narratives chosen for making the calculations, rather than on numbers. That being said, we claim that the vast majority of the discussions found in the literature over the performance of agro-biofuels are based on numbers generated within irrelevant formal protocols, i.e. useless narratives.

We strongly believe that this obsessive focus on numerical details (syntax) rather than on the big picture (the semantics behind the numbers) has significantly contributed to weakening the scientific evidence produced and used to debate the feasibility and desirability of agro-biofuels. For this reason, we have chosen to focus first of all on the quality of the narrative – the robustness of the semantics – and the use of metaphors to appeal to the common sense of the reader. We felt it necessary to carry the reader on such a long journey because we are convinced that in order to fully understand the folly of crop-based biofuel production, we do not need more sophisticated mathematical models, more data or additional fancy calculations providing more accurate estimates. We believe that what is needed is a proper understanding of the issue, which allows us to see through the maze of numbers and make judgements using our common sense.

This book contains three interwoven threads, all of which are very relevant to the agro-biofuels riddle:

1 The idea of replacing fossil fuels with agro-biofuels is impractical. The fact that humans must find a substitute for fossil energy does not mean that this substitute should be, at all costs, crop-based biofuels. Indeed, we argue in Chapters 2 and 7 and part of Chapter 8 that, in respect to the task of powering a significant fraction of the metabolic pattern of modern economies, agro-biofuels are not a feasible (let alone desirable) substitute for fossil fuel.
2 The presentation of a general methodological approach to check the feasibility and desirability of alternative energy sources (not restricted to agro-biofuels). This method is based on concepts within the fields of energetics and bio-economics and is illustrated in Chapters 3, 4 and 5 and in the two appendices. Knowing from experience that energy is a notoriously elusive concept, as much as possible we use plain narratives and simple numerical examples when introducing technical concepts to make things more accessible to the reader. In particular, taking advantage of the similarity between economic analysis and energetic analysis – when defined within the framework of bio-economics – we attempt to illustrate basic concepts using economic examples, which are generally easier to follow for non-specialized readers. However, we could not avoid addressing the technical/scientific aspects of the analysis. Therefore, we warn the reader that these chapters deal with a theoretical analysis of how to frame the

discussion about the quality of alternative energy sources. This is certainly a relevant topic to the issue of agro-biofuel, but it widens the discussion to a more comprehensive analysis of the energetic predicament and the search for an alternative to oil. Readers who are not interested in this more comprehensive analysis can just skim the text of these chapters.

3 The discussion of the implications of the agro-biofuel riddle in relation to the use of science for governance. The riddle of agro-biofuels points to a systemic failure in the quality control of the science used for decision-making. Silvio Funtowicz and Jerome Ravetz (1990a, b) coined the label 'post-normal science' to refer to the predicament faced by science in this millennium. Chapters 8 (partly) and 9 deal with the sociological and procedural aspects of the use of science in the policy choice of the large-scale production of agro-biofuels.

There follows a brief outline of the book, chapter by chapter, giving the reader a better idea of how we will answer the questions raised above.

Chapter 2: Learning from the past

This chapter offers a historical view of the relation between socio-economic development and energy. It explores the big discontinuity in the basic energy metabolism of socio-economic systems that lies behind the transition from rural to urban society. The goal of this chapter is to illustrate that the technical progress associated with the Industrial Revolution was based on a dramatic reduction in the use of land, labour and ecological services in the productive sectors of the economy. This reduction was made possible by the increasing use of oil. The idea behind substituting agro-biofuels for oil is the opposite: to reduce the use of oil by increasing the use of land, labour and ecological services.

Chapter 3: Not everything that burns is a fuel

This chapter can be seen as a crash course in energetics. It provides a set of energetics-associated narratives that have been ignored by the proponents of agro-biofuels. These narratives are crucial for studying the feasibility and desirability of primary energy sources and energy carriers in modern societies. This chapter introduces the basic principles of energetics: the distinction between energy, power and useful work; the concept of metabolism; energy grammars; and the distinction between endosomatic and exosomatic metabolism. We arrive at the concept of net energy analysis, leading to the concept of energy return on investment (EROI).

Chapter 4: Patterns of societal metabolism across levels: a crash course in bio-economics

This chapter provides the basic principles of bio-economics, leading to the

concept of bio-economic pressure (BEP). In particular, it addresses the need to check internal and external biophysical constraints on the feasibility of metabolic patterns, and the need to perform analysis across the hierarchical levels of organizations. The metabolism of the parts must be compatible with the metabolism of the whole. Within this general framework, the chapter explains why the two concepts of EROI and BEP are essential in performing a quantitative assessment of the feasibility and desirability of energy sources in a developed society.

Chapter 5: Assessment of the quality of alternative energy sources
This is the most technical chapter of the book, addressing key theoretical issues. Energetics and bio-economics require two things: first, a definition of semantic concepts; and second, a formalization of these concepts into quantitative analysis. In relation to this task, we provide an overview of the treacherous quicksand of energy analysis and an example of the type of problems faced by scientists willing to check the feasibility and desirability of agro-biofuels as an alternative to fossil fuels. Believe it or not, 'energy' is a semantic concept that is very slippery when it comes to formalizations. Performing energy analysis requires deciding how to deal with the summing of 'apples and oranges'. For this reason, this chapter presents a set of basic conceptual distinctions that are required to perform a sound energy analysis. In particular, when it comes to the definition of quality for an energy source, it is essential to make a distinction between: primary energy sources and energy carriers; the output/input energy ratio of energy carriers generated and consumed in the operation of the energy sector; and the power level achieved in the energy sector.

Chapter 6: Neglect of available wisdom
This chapter starts with a quick overview of some of the most important authors, their contributions and the key concepts developed in this field. In fact, attempts to integrate economic analysis with biophysical analysis have a long history. These attempts aimed to improve our understanding of the functioning and evolution of human societies. This chapter provides a critical appraisal of the recent applications of energy analysis to the issue of agro-biofuels. The ongoing controversies on the 'right' quantitative assessment of output/input ratios are evaluated against the theoretical discussion provided in Chapter 5.

Chapter 7: A reality check on the feasibility and desirability of agro-biofuels
This chapter presents a quantitative analysis based on data sets derived from the two most impressive large-scale experiments yet established: ethanol production from corn in the US, and ethanol production from sugar cane in

Brazil. The quantitative assessment presented in Chapter 7 confirms that which is well known in the field of energetics: that is, that agro-biofuels are not even close to meeting the policy goals of energy security against the future consequences of peak oil and a reduction in GHG emissions. In the US, the low output/input ratio of energy carriers makes the solution unfeasible; in the case of Brazil, the low power level achieved in the process of ethanol production makes the solution undesirable. Towards the end, this chapter touches upon a related point: the implications of peak oil for the search for alternative energy sources.

Chapter 8: Agro-biofuel production is not good for rural development

This chapter checks the validity of the third policy goal justifying agro-biofuel mandates: the alleged positive effects on rural development and the support of crop farm income. In relation to this, we expose the current misunderstanding about the relationship between technical progress in agriculture and rural development. Technical progress in agriculture is currently based on high-input monocultures (the so-called 'paradigm of industrial agriculture'), which are required to boost the productivity of the production factors. The paradigm of industrial agriculture was developed to get rid of farmers; thus its historic goal, obviously, is incompatible with the goal of rural development. Our point is that the biofuel policy implemented by many developing countries will translate into the replacement of traditional land-use patterns – with their goals of sustaining and reproducing local communities – by large-scale monocultures for feedstock production. These plantations have the goal of boosting the production of commodities per hectare by eliminating local communities.

Chapter 9: Living in denial

This chapter addresses the last aspect of the riddle: If agro-biofuels are neither feasible nor desirable, why are we investing so much in them? This chapter points out the existence of a serious failure in the quality control of the scientific inputs used for decision-making. Indeed, in this chapter we argue that the above phenomenon can only be explained by a more systemic problem associated with three different types of lock-in taking place in society:

1 The ideological lock-in. When dealing with sustainability, nobody likes to acknowledge the obvious fact that sustainability has to do with change (ageing, death, turnover of incumbents in the power structure). Sustainability is often confused with the preservation of the status quo. This is at the basis of the ideological assumption of perpetual growth anchored in Western civilization.
2 The academic lock-in, generated by the formation of granfalloons (see glossary) within the bureaucracy of science. This leads to the generation of flawless formal analyses within invalid narratives.

3 The economic lock-in, caused by the efforts of private corporations to avoid losing economic resources invested in the biofuel sector. These forms of lock-in tend to generate a Concorde syndrome: the continued implementation of a given idea, even after it has been recognized as a failure.

Chapter 10: Where do we go from here?

In this chapter, we conclude that acknowledging the need to extricate ourselves from the folly of high-tech, crop-based biofuels does not mean that there is no future for bio-energy. On the contrary, a more critical and effective use of biomass for energy purposes is possible and desirable. But we should keep in mind the existence of severe socio-economic and ecological constraints. In regard to the use of science to govern sustainability issues, the agro-biofuel folly has unveiled a systemic challenge to the use of science in the field of technical innovation.

From energetic analyses of modern society, we can also learn something positive; the actual pattern of energy consumption is so extravagant that there is a large margin for readjusting to a lower level of energy expenditure that can still provide a more than decent material standard of living. The only requirement for this solution is wisdom. The world cannot be changed according to our wants; we ourselves have to adjust to the challenge of sustainability by using reflexivity.