HANDBOOK OF SUSTAINABILITY ASSESSMENT

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Handbook of Sustainability Assessment

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PART III

SECTORS OF ASSESSMENT

7. Sustainability assessment and energy future: opportunities for Brazilian sugarcane ethanol planning

Carla Grigoletto Duarte, Tadeu Fabricio Malheiros, Amarilis Lucia Castelli Figueiredo Gallardo and Luis Enrique Sánchez

7.1 INTRODUCTION

Energy is one of the most critical aspects of any blueprint to a more sustainable future, and the current world energy matrix, largely based on fossil fuels, requires a major shift to cleaner and renewable sources (IPCC, 2013; UN, 2014). The present share of fossil fuel in the global energy mix is around 82 percent, essentially unchanged from the situation 25 years ago (IEA, 2013).

The necessary transition to a low carbon economy is completely different from previous energy transitions in human history. Renewable energies are valued for their potential environmental benefits, while the main advantages of previous transitions were related to economic factors such as increased productivity and cost reduction or improvements in service quality, such as observed in the transition from animal to steam or from steam to electricity in power services (Fouquet and Pearson, 2012; Grubler, 2012; Pollitt, 2012).

Nevertheless, a number of studies indicate that a meaningful increase of renewables in the world energy matrix remains a difficult challenge (IEA, 2003; IEA Bioenergy, 2009). In contrast, renewable energy in Brazil represents around 40 percent of the national matrix, a remarkable level in comparison with the world average of 13 percent (EPE, 2013a). Hydropower and sugarcane biomass, including ethanol fuel, are mainly responsible for the high share of renewables in the country. In 2012, hydropower represented 13.8 percent, while sugarcane biomass made up 15.4 percent, firewood and charcoal 9.1 percent, and other renewables 4.1 percent of the total energy consumption, while oil and gas contributed respectively 39.2 percent and 11.5 percent, and coal and uranium 5.4 percent and 1.5 percent (EPE, 2013a).

In this context, Brazil and other countries have been adopting policies to incentivize biofuels consumption and production (Sorda et al., 2010). Brazil pioneered energy policies aimed at reducing dependency on fossil fuels by launching, in the 1970s, the major program *Proalcool* aimed at adding ethanol to gasoline. Although its major driver was economic – owing to the oil shocks of that decade – a lasting contribution was a meaningful increase in the share of renewable fuels in the country (Szmrecsányi and Moreira, 1991; Goldemberg, 2007). This makes Brazil an interesting case through which to explore how sustainability is addressed in a sectoral planning process and how sustainability assessment could contribute to a more sustainable energy scenario.

Building on these foundations, in this chapter we explore the (so far) limited role of sustainability thinking in sugarcane ethanol planning. After discussing the shortcomings of the current planning approach based on the sustainability assessment literature, we consider a number of paths that could facilitate embedding sustainability assessment in planning future expansions of the ethanol sector.

In section 7.2 we present a history of ethanol policies in Brazil and introduce the current scenario. This is followed in section 7.3 by a brief discussion about the main impacts of this industry. In section 7.4, we explain the Brazilian energy planning framework of which sugarcane ethanol planning is part. Then, in sections 7.5 and 7.6, we discuss how this planning could be strengthened through the application of sustainability assessment thinking to three key aspects: the goals of the decennial plans and alternatives considered; the content and role of the socio-environmental analysis; and participation and responsibility for actions.

7.2 HISTORY AND CURRENT CONTEXT OF ETHANOL FUEL POLICY

The first sugarcane plantations in Brazil date back to the sixteenth century, the beginning of European colonization. On the Northeast coast, the colonial economy, largely based on sugar exports, was dubbed by historians the "sugarcane cycle."

Currently the country is the world's largest sugar producer and the second largest ethanol producer, behind the U.S. corn ethanol industry (MDIC, 2011). Compared to other energy crops,[1] sugarcane features better results regarding the reduction of greenhouse gas emissions (GHG), production costs and engine performance (Macedo, 2005; Goldemberg, 2007; Goldemberg et al., 2008).

Ethanol fuel in Brazil gained relevance in the early 1930s, when the government determined that gasoline should contain 5 percent ethanol, as a measure to reduce imports of hydrocarbons (MAPA, 2013a). The country was then entirely dependent on foreign sources of oil, as the first successful oil deposits were discovered only in 1939. An agency named the Institute of Sugar and Alcohol (*Instituto do Açúcar e do Álcool*, IAA) was created with the aim of increasing ethanol production. The Institute launched a set of measures to expand the productive capacity of the sugarcane industry in the Northeast region, still the main producer at this time (Szmrecsányi and Moreira, 1991), including financing sugar mills to diversify into ethanol production and to build industrial plants (Watanabe, 2001).

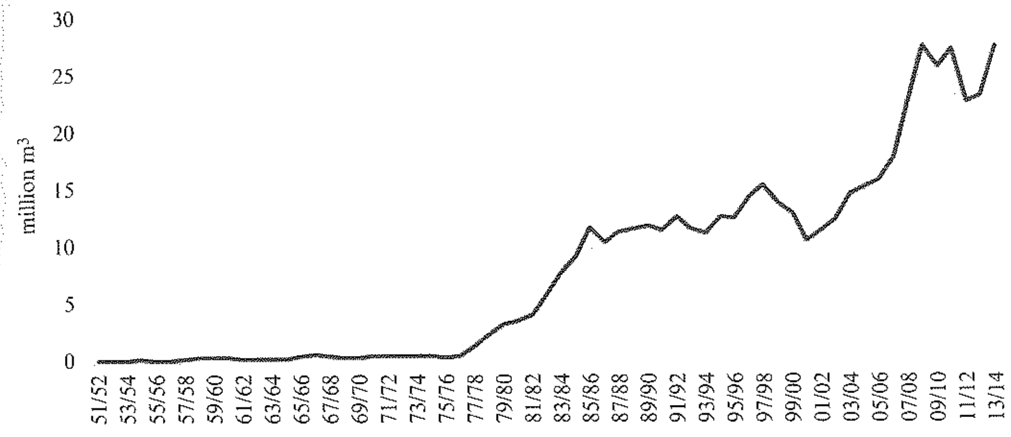
At that time, sugar was the main product of the sugarcane industry. Production flow depended on maritime transport both for reaching external markets and for domestic supply of the South and Southeast regions in Brazil. But, during World War II, maritime transportation was impaired because of the risk of German submarine attacks. At that point the sugarcane industry began to develop in the Southeastern states, closer to consumption centers (Szmrecsányi and Moreira, 1991), and this is currently the main production region. The expansion of the sugarcane industry has continued since that time, driven especially by the adoption of agricultural development plans and the provision of large volumes of rural credit.

During the international oil crisis of the 1970s, Brazil faced substantial petroleum shortages, as well as increased prices. Thus, 40 years after the first ethanol incentives, the

government launched a new program to foster ethanol production for fuel – *Proalcool*, the National Ethanol Program. The program included measures to create a new market, to boost agricultural and industrial productivity, and to protect producers from market risks (Moreira and Goldemberg, 1999). In order to reduce dependence on gasoline, investments in technological development were favored, aiming at developing car motors that were exclusively ethanol powered, a goal reached in the early 1980s.

Szmrecsányi and Moreira (1991) argue that *Proalcool* was important to sugarcane producers especially because, along with the oil crisis, the international sugar prices were low, and the future was uncertain for the industries that had been expanding strongly focused almost exclusively on sugar production. Therefore, the ethanol incentive was also a suitable solution to the problem of excess capacity of the sugarcane agribusiness.

The program led to a rapid expansion of ethanol fuel production. Brazilian production increased by more than 15 times in nine years[2] – rising from 0.66 million cubic meters in the 1976/77 harvest to around 10.5 million cubic meters in 1985/86 (Figure 7.1).



Source: Developed from ALCOPAR (2013); UNICADATA (2014a).

Figure 7.1 Brazilian total ethanol fuel production, from 1951/52 to 2013/14

In the second half of the 1980s, *Proalcool* suffered a gradual decline, as government funds dwindled, oil prices decreased and sugar prices went up. In that period, economic and fiscal crises resulted in a scarcity of public resources, hindering the continuity of some government programs (Mello and Paulillo, 2005). The adoption of neoliberal policies by the new Brazilian government in 1990 changed the whole scenario of sectoral governance. The deregulation process included the abolition of the IAA and the removal of price control mechanisms within the ethanol market. Economic policies also resulted in an inflow of gasoline powered imported cars, shifting the demand towards less ethanol consumption. In this context, producers abandoned ethanol to invest in sugar again, leading to a massive ethanol supply crisis and consequent consumer dissatisfaction with ethanol powered cars.

In contrast, an act establishing new emission standards for motor vehicles offered an incentive for ethanol. Federal Law 8723, enacted in October 1993, raised the bar by establishing more stringent emission limits to be implemented by 1997, and set an immediate mandatory content of 22 percent ethanol in gasoline throughout the country. As a consequence, ethanol output increased from 11.5 million cubic meters to 15.4 million cubic meters in the period 1993–97 (Figure 7.1), but fell again to 10.6 million cubic meters in the late 1990s.

Analysts identified several weaknesses in the ethanol industry in that period, including the heterogeneous technological level of mills operating throughout the country, low professionalization, with the majority of ventures being family-run, competition based largely on low wages and extensive expansion of production area (Vian and Belik, 2003; Paulillo, 2007), and these characteristics were barriers to a transition to a governance model where government was no longer in the center. After several attempts to create a new governance model, in 1997 a new trade organization emerged – the Sugarcane Industry Association (*União da Indústria de Cana-de-Açúcar*, UNICA) – congregating 121 of the 133 mills operating in the most important production region (São Paulo state). The mission of UNICA is "to play a leading role" to consolidate the industry "as a modern agro-industrial complex equipped to compete sustainably, in Brazil and around the world, as suppliers of ethanol, sugar and bioelectricity." Its self-labeled sustainability mandate should be noted, as it introduces a characteristic that was not historically a feature of the sugarcane sector.

A new cycle of expansion then began in 2003 with the development of *flex fuel* engines, an innovation that allowed consumers the flexibility to choose any mix of gasoline and ethanol to fuel their cars. Flex fuel vehicles were well received in the market, so that in 2013, just ten years after their inauguration, 62 percent of the automobile and light vehicle fleet were flex fuels, representing 94 percent of annual sales in that year (UNICADATA, 2014b, 2014c). As a result of this innovation, investment in the sugarcane ethanol sector was at a record high, promising an energy revolution (Goldemberg, 2007).

Output grew from 14.7 million cubic meters in 2002/03 to 27.5 million cubic meters in 2008/09 (Figure 7.1), when the growth cycle was interrupted again. The world financial crisis put one-third of the industry in trouble, owing to the high levels of indebtedness. Market restructuring was required, and several acquisitions occurred – initially by larger national producers and then by multinational companies (Jank, 2011; Nastari, 2012). The 2008 crisis, coupled with unfavorable weather, obliged Brazil to import ethanol. Imports peaked in 2011/12, reaching 1.5 million cubic meters, and declined almost to zero in the following years (UNICADATA, 2014d).

Despite its potential to become a leading fuel ethanol exporter, the sugarcane sector in Brazil is still facing barriers to its expected expansion. Globally, biofuels are losing ground to tight oil and shale gas, affecting export expectations. In Brazil oil production is poised to increase significantly owing to new oil discoveries in the continental shelf (known as pre-salt layers), whose extraction is predicted to maintain Brazil's position as one of the main oil and gas producers until 2035 (Petrobrás, 2014). Fiscal policies, on the other hand, have had a strong influence on the competitiveness of ethanol. In 2012 gasoline taxation was reduced as an inflation control measure, leading many consumers to choose gasoline instead of ethanol (Farina et al., 2013; ANP, 2014).

According to UNICA, out of a total of 384 mills, 44 have shut down since 2009 and 33 have filed for bankruptcy (Mello, 2014). Despite the hurdles, ethanol production increased again in the 2013/14 harvest, but forecasts for the coming years are not predicting the end of the crisis (EPE, 2014).

There is, on the other hand, potential for a significant technological breakthrough with the introduction of the so-called second generation ethanol,[3] which can increase productivity from the existing crops. Sugarcane mills producing first and second generation ethanol, sugar, electricity, chemicals and plastic will become biorefineries, potentially producing a wide range of hydrocarbon products from diverse feedstocks (Naik et al., 2010; IEA Bioenergy, 2013; Popp et al., 2014).

Government policies have always been paramount to the development of ethanol in Brazil. The 40-fold increase in production from 1973 to 2014 (Figure 7.1) largely resulted from government initiatives such as the provision of credit to expand production, incentives for technological development and regulation of ethanol content in gasoline. This section has demonstrated that such policies, largely driven by promoting economic growth, have not been consistent over time. In the next section a summary of their sustainability implications is presented.

7.3 KEY ISSUES IN ETHANOL SUSTAINABILITY

Although sugarcane ethanol is a renewable and "clean" energy source, it is important to note that these characteristics are not necessarily synonymous with sustainable energy. Being renewable is positive for countering climate change, while being clean can be associated with pollution control. Nevertheless, thinking from a sustainability perspective requires looking beyond these agendas to include other fundamental issues to be considered in the conception and planning of any new project (Gibson et al., 2005). For example, biodiversity and social inequality – issues of great concern in biofuels projects and policies – are certainly critical to sustainable development (Jackson, 2009; Rockström et al., 2009; Stiglitz, 2012). After the Brazilian biofuels boom in the early 2000s, the potential impacts of sugarcane ethanol were discussed in public arenas and scrutinized in the scientific literature. Drawing from this literature, key issues are summarized in Table 7.1. Such a synoptic view highlights that it is not meaningful to ask if ethanol fuel is sustainable or not without a defined context – sustainability in practice depends on how it is produced and the associated impacts within each specific context.

Table 7.1 shows that trade-offs are pervasive in analyzing sustainability in the ethanol industry. Examples include:

- energy crops can potentially be detrimental to food security and biodiversity although their carbon footprints can be low;
- energy crops can be a threat for family farming, as they concentrate property, but large farms can afford to restore riparian vegetation (an initiative that is beneficial to biodiversity and water quality) while in small plots growers need to maximize land use and can hardly afford to restore ecosystems;
- reduction in water consumption can be made, but at the cost of jobs, because mechanical harvesting results in cleaner stems delivered for crushing but requires a smaller workforce;
- mechanization improves work safety and health at the expense of cutter jobs.

Table 7.1 *Key issues in sugarcane ethanol sustainability*

Issue	Description
Food security	The energy market offers better prices than the food market, so potential replacement of food by energy crops can take place, resulting in increases in food prices. While some researchers demonstrate that it is possible to expand energy crops without threatening food availability and prices (Godfray et al., 2010; Rosillo-Calle, 2010), others affirm that biofuels are already influencing the prices (von Braun and Pachauri, 2006; Pimentel et al., 2009; FAO, 2011). Other studies show that, just by a minimal increase in livestock efficiency, the newly available area for agriculture expansion would be sufficient to allow sugarcane expansion without compromising other crops (FGV, 2008).
Family farming	Owing to the need for continuity in their feedstock supplies, mills pressure their neighbors to produce sugarcane, which can imply changes in the agrarian structures. Small and medium properties can be acquired, be leased or become providers of the mill, excluding family farming from the biofuels industry. Thus, instead of promoting poverty alleviation in rural areas, biofuels expansion could impair family farming (Bermann et al., 2008; REBRIP, 2008; GNESD, 2011).
Biodiversity	Despite the existence of laws protecting natural habitats and limiting deforestation, some authors argue that illegal deforestation may occur, as observed in Malaysia and Indonesia with palm oil plantations (Brown et al., 2005). In addition, legally permitted deforestation could follow either as a consequence of sugarcane plantations themselves or most likely from displaced crops or cattle raising. Also, fragmentation and encroachment into areas of important conservation value may ensue, resulting in a negative net effect for the integrity of biodiversity (Feltran-Barbieri, 2009). Potential positive impacts include the restoration of degraded areas, specially riparian vegetation, providing new or better habitats (Gomes et al., 2012).
GHG emissions	Many specialists agree that sugarcane ethanol represents a meaningful reduction in greenhouse gas emissions in comparison with gasoline (Pacca and Moreira, 2009; EPA, 2010; Seabra et al., 2011). However, some argue that replacement of forests can imply losses in the sequestered carbon, taking long periods to offset the gains (Fargione et al., 2008) and also that there are gaps in scientific knowledge about emissions (Macedo et al., 2008; Gnansounou et al., 2009; Cerri et al., 2011; Lisboa et al., 2011).
Air quality	Whilst air quality can improve in cities as a result of substituting ethanol for gasoline (Abrantes et al., 2009; Szwarc, 2010; Borsari and Assunção, 2011), the mills in the rural area do contribute to deteriorating air quality with pollutants emitted by the industrial process, especially NOx. In addition, pre-harvest sugarcane burning in the fields is still employed in some regions, significantly affecting air quality (Costa, 2008; Ferling, 2008; Ribeiro, 2008).
Employment	Regarding employment and income potential, some are optimistic about the high number of *green jobs* that the biofuels industry can create (UNEP et al., 2008; Ragwitz et al., 2010), while others consider that the expectations are too high and the jobs created will be of low quality and poorly paid (Sachs, 2004; von Braun and Pachauri, 2006).
Work safety	The majority of jobs in this industry are for manual cutters. Safety issues are recurrently highlighted owing to both the inherent risks and poor management (Martinelli et al., 2011; Repórter Brasil, 2011; Azadi et al., 2012). A reduction in manual cutting is required for improving the quality of jobs, but at the cost of fewer jobs (Scopinho et al., 1999).

Table 7.1 (continued)

Issue	Description
	(Martinelli et al., 2011; Repórter Brasil, 2011; Azadi et al., 2012). A reduction in manual cutting is required for improving the quality of jobs, but at the cost of fewer jobs (Scopinho et al., 1999).
Agrochemicals	Although the sugarcane industry consumes lower levels of agrochemicals than other large crops such as soya beans, corn and oranges (Arrigoni and Almeida, 2005), the total amount is significant, placing major producers of sugarcane among the major consumers of agrochemicals (IBAMA, 2013). Furthermore, several chemicals banned in other countries are still allowed in the Brazilian market (Schlesinger, 2008; Schiesari and Grillitsch, 2011).
Water consumption	Mills have been reducing the average use of water per mass of processed sugarcane in recent years – from 5.6 m^3/ton in 1990 to 1.85 m^3/ton in 2004 (Elia Neto and Shintaku, 2009). This is largely a consequence of mechanical cutting, which precludes washing, a necessary step when cutting is manual. However, the scarcity of water either observed or predicted in some regions can be a source of conflicts and a harm to the sector (Albuquerque Filho et al., 2012; Goulart et al., 2012). The São Paulo state regulations determine maximum consumption of 0.7 m^3/ton for areas prone to water stress and 1 m^3/ton for other areas.
Water quality	Treatment of wastewater is increasing in the mills, but diffuse pollution is a challenge when it is not controlled. However, few cases of eutrophication are reported (Cantarella and Rossetto, 2010). Land application of wastewater is subject to technical standards, but strict enforcement is a challenge. Erosion from plantation areas can also contribute to the silting of rivers and creeks, but soil conservation techniques have been used in converting pastureland to sugarcane crops, thus resulting in a net reduction in soil losses.
Wastes	The main wastes resulting from ethanol production are: 1) vinasse, a byproduct of fermentation rich in nutrients, which can be used as a fertilizer; 2) bagasse, the sugarcane stalk after industrial processing, which is largely used for steam or electricity production in thermoelectric plants, can be used to protect soil as ground cover after harvesting, and is also the intended raw material for second generation ethanol; 3) filtercake and ashes of bagasse burning, which can also be used as fertilizers (CGEE, 2009; Elia Neto and Shintaku, 2009).

In addition to trade-offs, analyzing sustainability in the ethanol industry calls for considering the land use changes necessary to make room for new plantation areas. Currently, over 90 percent of the ethanol is produced in the Southeast region, the remaining production coming from the Northeast (MAPA, 2013b). The Southeast is characterized by better infrastructure, higher productivity and mechanization (CONAB, 2010), and lower water consumption and burning rates (SMA, 2012). Although new sugarcane plantations are not expanding at the expense of rainforest or savanna, concerns have been expressed that, by displacing other crops and pasturelands, they could result in forest loss as the displaced activities may subsequently migrate to other regions and contribute to deforestation (Miyake et al., 2012; Andrade de Sá et al., 2013).

7.4 ENERGY PLANNING THEORY AND THE BRAZILIAN PRACTICE

In many countries, including Brazil, energy planning is developed by public agencies to be implemented by private companies, with governments playing the role of regulator in a competitive market (Leite, 2009; Pollitt, 2012). This approach is called *indicative planning*, aiming at coordinating private and public investment and output plans through forecasts or targets (Nielsen, 2008). Applied to several sectors in the economy (Black, 1968; Meade, 1970; Miller, 1979), it seeks to balance market and regulation needs.

According to Smil (2005), the objective of indicative planning should not be to carry out a prospective analysis – to find out what could happen – but to identify what is required to achieve a desirable future with some prescribed characteristics. Indicative energy planning should provide economic agents and stakeholders with an appropriate description of the targets to be met as well as the constraints and incentives to achieve them (Perez-Arriaga and Linares, 2008).

In Brazil and in other countries, indicative energy planning emerged as a substitute for determinative planning, a model in which government decides what will be done (FAO, 2010) and implements the means to achieve the goals. Brazilian energy planning departed from determinative planning in the 1990s, when electricity generation and transmission were partly privatized and a Constitutional amendment ended the State monopoly in hydrocarbon exploration and production (Guerreiro, 2005; Leite, 2009). New regulatory agencies were created, namely the National Agency for Electric Energy (ANEEL) in 1996 and the National Agency for Oil, Gas and Biofuels (ANP) in 1997.

When the new Federal government took office in 2002, indicative planning was maintained, and in 2004 a new energy planning unit was created within the Ministry of Mines and Energy, named the Energy Research Company (*Empresa de Pesquisa Energética*, EPE). Despite its name, it is actually an energy planning corporation, as it neither conducts nor sponsors research on the subject. The government transferred electricity planning responsibilities from the State-owned electricity holding company Eletrobrás, which had been playing a central planning role since the 1970s, to EPE, and added fuel planning to its mission.

In 2007, a 30-year long-term plan was launched, the first ever to include different energy sources – electricity, oil, gas and biofuels (EPE, 2008). EPE also started to produce decennial energy plans (*Plano Decenal de Expansão de Energia*, PDE), with the same scope, publishing the first in 2007. These plans have a ten-year time horizon, and one of their main functions is to provide the basis for launching bids to build new power plants and transmission lines. Decennial plans are reviewed and published annually, while there is no commitment to review the long-term plan. Decennial plans present supply and demand studies for electricity, oil, gas and biofuels and include a socio-environmental analysis.

In considering the expansion of sugarcane ethanol, decennial plans refer to agro-ecological zoning, a non-binding land use mapping prepared by the Ministry of Agriculture which indicates areas of potential expansion on the basis of soil types and selected environmental constraints (MAPA and EMBRAPA, 2009). This zoning is used as a criterion for funding – public banks are not allowed to lend money for projects in

areas that are not considered adequate for sugarcane expansion, as in the Amazon and Pantanal regions.

The current energy planning model is largely based on the pre-existing electricity planning model extended to hydrocarbon and biofuels expansion, aiming at an integrated energy planning. However, there are fundamental differences that make any integration initiative difficult. First and foremost is the fact that, to develop hydro potential, any private party has to obtain a concession granted by a regulatory agency, ANEEL. A concession is also needed for hydrocarbon exploration and production, with bids being launched by another agency, ANP. To start a new ethanol plant, however, a private company does not need a concession; an authorization from ANP is all that is required.

On the other hand, for any energy project, an environmental license is required. Differently from other countries, the environmental license is issued by an environmental agency (Sánchez, 2013) unrelated to the sector regulatory agencies. Depending on the type and location of the project, an environmental license may be issued either by the Federal environmental agency Ibama or by its state counterparts. An environmental impact assessment is required for most energy projects.

Hence, there are many steps in the planning process, from the strategic level to the individual project level, and several government and private agents are involved. The biofuel sector is subject to lighter regulation at the strategic level when compared to electricity and fossil fuels. In this context, environmental licensing plays a critical role in embedding sustainability in the biofuels sector.

7.5 HOW IS SUSTAINABILITY CONSIDERED IN ETHANOL PLANNING?

After explaining the history, key sustainability issues and basics of energy planning in Brazil, in this section we explore the extent to which sustainability is incorporated into current energy planning related to ethanol fuel.

As discussed in the previous section, long- and medium-term plans represent the most strategic level of Brazilian energy planning. These plans are similar in their structure, featuring demand and supply studies for fuels followed by a socio-environmental analysis. The environmental and social content in the long-term plan is summarized in no more than four pages, featuring only brief mentions of the main adverse impacts of ethanol production (EPE, 2008; Santos and Souza, 2011). Furthermore, the first long-term energy plan was launched before the 2008 world financial crisis, which affected the sugarcane industry and completely changed the macroeconomic context, so that the long-term projection was not fulfilling its role of providing guidance to the medium-term, decennial plan. Hence, the most important planning documents for analyzing sustainability in ethanol planning are the decennial energy plans. Not only are they supposed to be more influential in decision making, but also a socio-environmental analysis is part of every plan. As decennial plans have been published annually since 2007, with one exception (2009–18), totaling six plans up to the time of writing (EPE, 2007, 2009, 2010, 2011, 2012, 2013b), it is possible to evaluate how sustainability issues related to ethanol are being dealt with in energy planning in Brazil over time.

Three issues pertaining to sustainability assessment were selected for exploration.

Firstly, we jointly evaluated the goals and the fuel supply alternatives presented in the decennial plans, seeking to identify if the desired outcome is aligned with sustainability, and if the alternatives represent the greatest overall benefits while avoiding negative effects (e.g. Gibson et al., 2005; Pope and Dalal-Clayton, 2011). Secondly, we explored the content and role of the socio-environmental analysis, aiming to verify if its scope encompasses the key ethanol sustainability themes featured in section 7.1 and the extent to which it deals with potential trade-offs (e.g. Gibson et al., 2005; Gibson, 2013; Morrison-Saunders and Pope, 2013). Thirdly, we sought to identify the opportunities for participation in plan making (e.g. Gibson et al., 2005; Bond et al., 2012b; Pope and Morrison-Saunders, 2012), as well as the extent to which the plans resulted in recommendations for actions to be implemented by the involved stakeholders.

The analysis presented in this section is based on review of the contents of decennial plans and interviews with selected stakeholders related to energy planning, from government and the sugarcane sector.

7.5.1 Goals and Alternatives

Officially the decennial energy plans present "signals to guide the decisions, focused on the balance between the economic growth projections and the necessary expansion of energy supply, ensuring the supply will have suitable cost, and will be technically feasible and environmentally sustainable" (EPE, 2013b, p. v). In this statement, it is possible to identify energy security as the main objective of the plan, to be reached by supply alternatives that are adequate with respect to cost, technical and environmental aspects. It is interesting to note that the objective is simply to present *signals*, in accordance with indicative planning proposals, as presented in section 7.4. It is worth mentioning that since 2009 decennial plans are officially considered action plans of the National Climate Change Policy, with the mission to provide "comparative advantages to less emission-intensive technologies over more emission-intensive technologies" (UN, 2013, p. 6). Hence, promoting scenarios with lower GHG emissions is also an objective of the decennial plans.

To fulfill their objectives, decennial plans adopt a number of macroeconomic premises to draw a future scenario: projected economic growth, demographic change, sectoral trends in energy consumption for agriculture, industry, services, and residential consumption and vehicle fleets. These aspects have a strong influence on the demand for electricity and fuels, and the figures assumed obviously affect the whole plan.

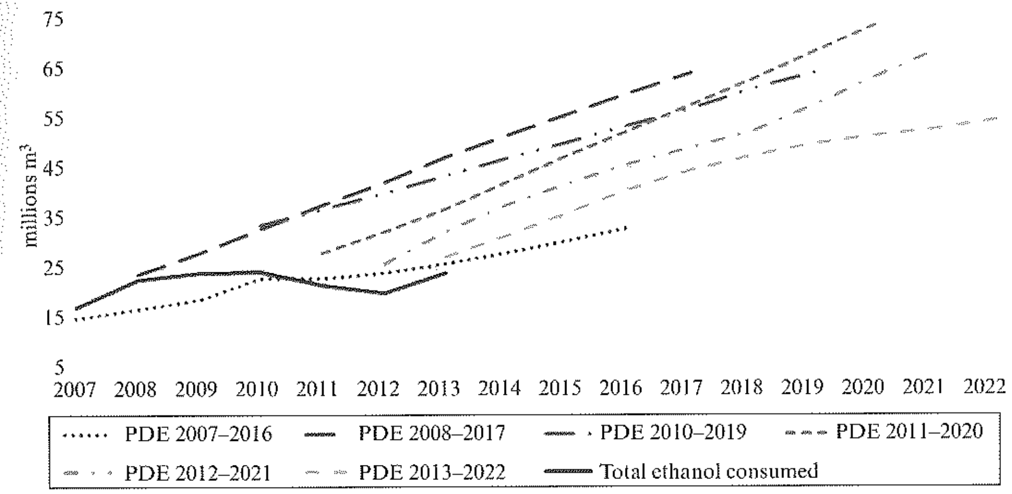
The plans detail projections of the demand growth and supply capacity of the current systems and requirements for meeting the projected demand. Energy efficiency and a socio-environmental analysis can be found at the end of the plans.

For fuel supply alternatives identification, it is assumed that minimizing gasoline consumption is desirable for reducing GHG emissions; hence, maximizing ethanol share is prioritized as a goal, and a strong increase in supply is expected. The future demand for gasoline and ethanol is predicted by using a mathematical model developed by the EPE team. Several parameters are fed into the model, including GDP growth and its reflection in vehicle sales and consumer preference between gasoline and ethanol. To run the model it is assumed that: consumers will prefer ethanol over gasoline; the price of ethanol will

remain competitive in the period; and new technologies, such as electric cars, will not expand in Brazil in the decade. In projecting future supply, the model allows for considering the share of sugarcane to be used either for ethanol or for sugar, and sugarcane productivity.

Despite the many possibilities of parameters for feeding the model, both in the demand and the supply studies, only one alternative is presented in each decennial plan. There are justifications regarding the preferences or choices of the planning team, but no comparison with other alternatives is featured. One possible explanation for this approach, according to one interviewee at EPE, is that the scenario described in the plan represents the government's intention. Hence, presenting other possibilities could raise uncertainties about government intentions.

Figure 7.2 shows the sequence of forecasts for ethanol demand over the six decennial plans, and the actual volume of commercialized and exported ethanol up to 2013. In the first decennial plan, drawn up during 2005 and published in 2007, the expectations for ethanol demand were low and the actual output was higher than projected. In the following plans, however, projections show a sharp increase, roughly doubling production in the decade. The comparison with actual yearly outputs, however, proves that projections are generally overly optimistic.



Source: UNICADATA (2014d).

Figure 7.2 Forecast of ethanol demand in the Brazilian decennial energy plans, from 2007–16 to 2013–22, and the commercialized and exported ethanol

The high expectation about the increase in ethanol demand was reduced in the decennial plan for the period 2013–22, but still indicates that demand will double in a decade. The previous decennial plan (2012–21) states that:

> although the inclusion of biofuels in the energy matrix is considered within the strategic concept of energy security and compliance with targets for reducing greenhouse gases, the use of biofuels targets is being delayed due to the crisis and protectionism in foreign markets. Restrictions on ethanol supply will only be overcome in the medium and long term. (EPE, 2012, p. 310)

However, the forecast featured after this statement does not project slow growth in the short term or stronger growth at the end of the decade.

Ethanol output is highly influenced by other policies, especially macroeconomic and agricultural. However, agriculture policies and plans are focused on the short term (one to two years), and therefore they are difficult to relate to decennial and long-term plans in the energy sector (IICA, 2008).

7.5.2 The Socio-environmental Analysis

Socio-environmental analysis has been included in decennial plans since the first review (2008–17). Regarding ethanol, the objective is broadly defined as the analysis of the social and environmental effects associated with the processing and use of the fuel. In the most recent plan (2013–22), it is stated that "socio-environmental studies . . . were guided by the concept of sustainability, buoyed by reducing the social and environmental impacts in expanding energy supply and by the climate change discussions at the national and international levels" (EPE, 2013b, p. 15).

The EPE team is responsible for selecting the issues to be addressed in the plan. So scoping is not participative and may not reflect the opinion of stakeholders.

The issues included in socio-environmental analysis are shown in Table 7.2, using the same categories as Table 7.1 and identifying the level of detail in approaching them. In comparison to Table 7.1, the only issue that has never been addressed in the decennial plans is water quality.

Six issues pertaining to ethanol were explored in relative detail at least once in the period, while five never received any detailed attention, being just mentioned. The only issue that appears in every edition of the plans is water consumption, albeit at different

Table 7.2 Issues addressed in the decennial plans, from 2007–16 to 2013–22

Decennial plan	1. Food security	2. Family farming	3. Biodiversity	4. GHG emissions	5. Burning (part of air quality)	6. Employment	7. Work safety	8. Agrochemicals	9. Water consumption	10. Water quality	11. Wastes
2007–16											
2008–17		M			M		M		M		M
2010–19	A	M	M	A		A	M		A		M
2011–20	A	M	M	A		A			A		
2012–21	A	M		A	M	A		M	M		M
2013–22	A			A	M	A	M	M	M		M

Notes:
"M" means that the topic is mentioned in the plan, applied to issues that received only a short review in one or two paragraphs, based on general information about sugarcane or secondary data. "A" means analyzed, applied to issues that were addressed using projections, mathematical modeling or spatial analysis.
No plan was prepared for the period 2009–16.

levels of detail. A methodological evolution is noted: the 2010–19 plan features only a review of water use in the sugarcane industry, while in the 2011–20 plan data on average use in the sugarcane industry are compared with regional water availability data. However, in the subsequent years water consumption is only briefly mentioned.

Land use change is addressed under the following topics: food security (or crops replacement in the decennial plan terminology), family farming (participation of medium and small producers) and biodiversity. The level of detail provided in each case varies. Food security is dealt with in relative detail, as the plans present maps predicting where sugarcane could replace pasture or other crops, although there is no mention of which crops could be replaced. The projection shows sugarcane expanding north and west from its current core area in São Paulo state.

Trends regarding family farming and the participation of small and medium properties in sugarcane production are presented, but the plans do not aim at achieving any goal or even at maintaining or increasing participation. Spatial analysis is based on agro-ecological zoning, and it is presented to show that there is enough land availability for expanding sugarcane crops without replacing food crops or forests. However, it is too simplistic to assume that no competition for land will take place – other agriculture sectors also intend to expand in the same indicated regions, notably soy and corn (Sparovek et al., 2009; Castro et al., 2010).

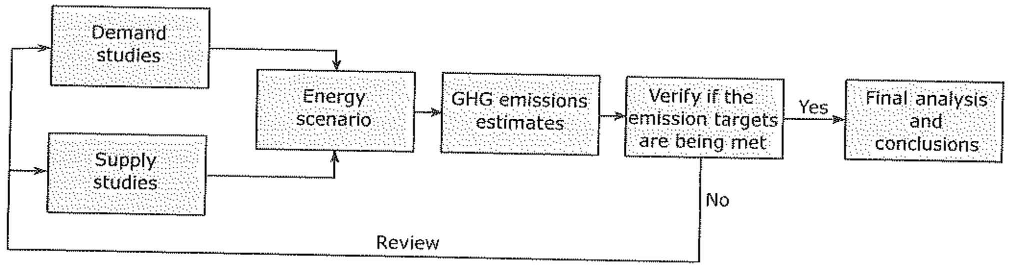
For biodiversity, the decennial plans assume virtually no suppression of native vegetation to make space for sugarcane, as expansion is assumed to occur over planted pasturelands and other crops. Only two decennial plans feature brief mentions of native vegetation, and these do not provide any analysis. On the other hand, large scale sugarcane plantations in São Paulo state have been achieving, albeit to a limited extent, the restoration of native vegetation stands, especially riparian vegetation. Such an opportunity is not mentioned in the plans as a potential enhancement.

Regarding GHG emissions, there are projections for all energy sources starting with the 2010–19 decennial plan, which follows the voluntary targets announced by Brazil in the 2009 United Nations Climate Change Conference of Parties in Copenhagen. GHG emissions are approached in a separate subsection. Different from other issues, there is a target to be met – GHG emissions from the energy sector should not surpass 680 million tons of CO_2 equivalent by 2020.

Sugarcane burning (a practice still adopted by many growers), work safety and agrochemicals are themes not systematically mentioned in the plans. Wastes, despite not being a significant problem in this industry, are mentioned in four out of six plans to highlight technological innovations for reducing vinasse, a high organic load byproduct used as fertilizer in the fields. From a current industry average of 22 liters per liter of ethanol, if a new vacuum fermentation process is fully developed vinasse generation could drop to 3 liters per liter. Finally, employment is a topic dealt with in relative detail in the four most recent plans, featuring projections of the number of jobs that the ethanol industry will provide.

In the two most recent versions of the decennial plans, this analysis is followed by a section named "socio-environmental integrated analysis" for electricity, where all the energy expansion projects are analyzed regarding their interactions with each other and the sensitivity of regions where they are predicted to be implemented. At the end of this section, there is an indication of the environmental management priority issues. For sugarcane mills, included in this analysis owing to their ability to supply bioelectricity for the national grid, the priority issue is air quality. Final recommendations in this section include the importance of the involvement of several institutions and stakeholders able to deal with the proposed agenda and to minimize both the risk of conflicts and decisions that do "not always meet the best social, environmental and economic alternatives" (EPE, 2013b, p. 381).

From this review, we can argue that the role of the socio-environmental analysis in decennial plans is limited to clarifying the potential consequences of the predicted expansion for a number of selected issues. Most of them are addressed superficially, resulting in an analysis that is far from providing decision makers and stakeholders with an adequate picture of the sustainability issues that may arise from sugarcane or ethanol expansion. Only one issue is featured in such a way that it could influence the conclusions of the plan, and that is the forecast of GHG emissions: if the emissions resulting from the combined effect of all energy sources are not predicted to meet the targets, the mix of energy sources should be reviewed, as shown in Figure 7.3.



Source: Adapted from EPE (2013b).

Figure 7.3 Influence of GHG emissions in decennial plans

7.5.3 Participation and Responsibility for Post-plan Actions

There are three opportunities for stakeholder participation and dialogue in the decennial plans development. The first is by invitation for meetings that occur as inputs for developing the draft plans; the second is by submissions during a public consultation period that occurs after the release of the draft plan; and the third is through the National Council of Energy Policy, responsible for the final decision on energy policy issues. The participation of stakeholders in the development of the draft plan is mentioned in the decennial plans in their acknowledgement section, which features a list of those who participated in work groups, meetings and technical seminars coordinated by EPE or provided data and information. The number of acknowledged participants ranges from 126 in the 2007–16 plan and progressively increases to 173 in the 2013–22 plan. The majority of listed organizations are companies and sectoral representatives, with no civil society organization advocating for a social or environmental agenda.

Draft decennial plans are subject to a public consultation period (usually around one month), and open to submissions from citizens, civil society organizations, government agencies, companies and agents in the energy sector. However, the final plans do not describe the contributions received, or provide answers to comments or submissions received. Hence, it is not possible to identify to what extent the contributions were considered in the final plans – there are just generic affirmations such as "we seek to include most of the suggestions" or "embedding, to the extent of the pertinence and opportunity, the suggestions collected in public consultations submitted in earlier plans."

Finally, the responsibility for approving the decennial plans lies with the National Council of Energy Policy, a multi-stakeholder body instituted in 2000, composed of 11 representatives of the Federal government (including the president of EPE), two specialists in energy, one being from civil society and the other from a university, and one person representing the states.

Despite the legal provision, an NGO representative interviewed by the first author affirmed that a legitimate specialist from civil society never occupied a chair, being excluded from the process. The feeling of exclusion is reinforced by a campaign signed by more than 80 NGOs, called Energy for Life, whose first claim is to ensure transparency and the effective participation of Brazilian civil society in decision making on energy planning, including a representative as part of the National Council of Energy Policy. The specialist from a university is also not defined, according to information from the Ministry of Mines and Energy.

As for ethanol matters, according to a spokesperson from a sectoral association interviewed by the first author, industry representatives were not engaged either in the preparation of decennial draft plans or in the final decision. The only formal opportunity for the industry to express its opinions is during the public consultation. In the most recent planning cycle, one of the sectoral associations submitted a letter stating that not only was the expansion forecast excessively optimistic, but so was the estimation of current production capacity (UNICA, 2013). After this submission, they report that only a few adjustments were done, far from addressing what was suggested.

Regarding actions to achieve the goals, unlike the case of the conclusions of the decennial plans for hydroelectricity (where there is an indication of preferred projects to be included in bids), there is no indication of what actions will or should be taken in order to reach the goals for ethanol production. No commitments of other government agencies or ministries are described; only generic assertions on desired improvements or challenges to be faced either by the Federal government or by other agents are featured, such as "reconcile the expansion of energy and the conservation of biodiversity" (EPE, 2013b, p. 380) or "seek to reconcile the interests of different sectors to minimize deforestation" (EPE, 2013b, p. 381).

So, even counting on the involvement of high level decision makers and the opportunity to hold a dialogue with industry representatives, we observe that the decennial plans are still poor in coordinating post-plan actions.

7.6 POTENTIAL CONTRIBUTIONS OF THE SUSTAINABILITY ASSESSMENT APPROACH TO ETHANOL PLANNING

A sustainability assessment approach aims at directing actions and decisions towards sustainability, being applicable to a wide range of initiatives, including strategic level planning (Pope and Dalal-Clayton, 2011; Bond et al., 2012a). We argue that decennial plans, as an essential part of energy planning, could go further if a sustainability assessment approach were adopted. In Table 7.3 we summarize the differences between the current planning approach and how it could be improved if a sustainability assessment approach were adopted. In the remainder of this section this potential is explored.

Table 7.3 What is being done in the decennial plans for ethanol and what could be done if a sustainability assessment approach were adopted

Aspect	What is being done in the decennial plans	What could be done if a sustainability assessment approach were adopted
Goals and alternatives	Decennial plans attempt to identify demand trends and how supply should expand to meet the demand. The plans present only one alternative for fuel supply, which usually indicates a strong increase in ethanol production. Trends are set aiming to meet goals related to GHG emissions.	A sustainability assessment approach for planning should select a fuel supply alternative that offers the greatest overall benefits while it minimizes negative effects, going beyond the single criterion of meeting GHG emissions targets.
Scope and impact analysis of socio-environmental issues	Socio-environmental analysis is limited to listing some of the consequences of the selected alternative, but does not address the complexity of a rapid expansion of sugarcane crops. Scope is variable in the six plans; impact analysis is featured in little detail and is not always explicit about potential benefits or threats.	Scoping should include the most relevant issues and provide enough detail to ground a trade-offs analysis. The analysis of the consequences should deliver answers about what could be enhanced, avoided or mitigated and what the unavoidable adverse impacts are, and then indicate how to deal with them.
Participation and responsibility for actions	The process counts on invited participants in the plan development period and is open for contributions through public consultation in the final stages. As for actions to implement the plan, recommendations on economic/financial, social and environmental issues are featured; however, no commitment of institutions related to implementation is presented.	More opportunities for stakeholders' participation should be offered, aiming at accommodating different views about Brazil's energy future and the paths to reach a more sustainable energy supply. Broader dialogue is also required to advance the commitment of stakeholders or institutions to the implementation of required actions to achieve the decennial plans' goals.

7.6.1 Goals and Alternatives – Towards a More Sustainable Future

In establishing goals for fuels, decennial plans present only one alternative that prioritizes ethanol over gasoline, with the exception of the first analyzed plan. To address a sustainability assessment approach, decennial plans should seek the greatest overall benefits

from energy sector to society, avoiding and minimizing trade-offs (e.g. Gibson et al., 2005). For achieving such a result, it is fundamental to evaluate the consequences of the plan for every key sustainability issue, in order to guarantee that gains in one agenda will not overshadow losses in other relevant agendas (Pope and Dalal-Clayton, 2011; Morrison-Saunders and Pope, 2013).

Alternatives in the case of fuels planning would include different proportions of gasoline, ethanol and compressed natural gas (which is also available in many fuel stations in Brazil), as well as opportunities represented by electric vehicles (not yet commercialized in Brazil). Alternatives should also be devised for the rate of expansion of ethanol supply owing to its consequences for land use changes and the important trade-offs it can entail. Formulating and comparing these alternatives would be an opportunity to make explicit the most valuable decision criteria for the stakeholders (e.g. Gibson, 2013; Morrison-Saunders and Pope, 2013), and justifying the choices would offer transparency to the process.

Currently, decennial plans are aiming to contribute to climate change strategy by reducing GHG emissions in the energy sector. This is clearly a relevant issue for sustainability, but sugarcane expansion also has to deal with other critical agendas, such as biodiversity protection and water consumption. These issues are not being neglected in the decennial plans, since they are included in the socio-environmental analysis, but it is clear that climate change discussions occupy a strategic position, while other issues receive less attention.

Thus, to ensure a sustainability aim, a broad discussion on alternatives is fundamental, since it allows an early and transparent identification of threats and benefits, at a stage where changes in design can favor better outcomes. Decision making is a complex process, with many contextual variables, subject to a mix of rationalities, and composed of several minor decisions until reaching a final shape (Sabatier, 1991; de Bruijn and ten Heuvelhof, 1999; Lyhne, 2012). The process of formulating alternatives is a very noble task in decision making (Gibson, 2013; Morrison-Saunders and Pope, 2013), and it is not a single moment in time; instead it is an iterative process of adjustments that depends on all the other planning steps.

Bond et al. (2012b) argue that an effective sustainability assessment process must be focused on the sustainability of the outcomes and not only on performing the expected steps, which means that it is necessary to continue an iterative process of design and assessment until the projected outcomes are considered to be suitably sustainable. In this sense, decennial plans should advance in enhancing the preferred alternative, until it meets any agreed-upon desirable features of a sustainability scenario, aiming to maximize the potential benefits and minimize the potential adverse effects.

Therefore it would be fundamental that plans do present a comparison among alternatives, and justifications for the selected one. Such analysis of alternatives could be featured as a technical report appended to the final draft plan for public consultation, detailing advantages and disadvantages of each alternative regarding their consequences and the required resources and actions to implement each one.

7.6.2 Broadening and Deepening the Socio-environmental Analysis

Regarding their scope, the socio-environmental analysis sections of the six decennial plans cover most impacts of sugarcane and ethanol production featured in Table 7.1. However, the coverage tends to be superficial, and it is hard to find any methodological evolution over the years. The scoping of issues to be included in the socio-environmental analysis of the decennial plans is made by the EPE team without any previous consultation or stakeholder input, and over the years there has been no continuity in the scope of the analysis undertaken. The impact pathways are not explained, and the likely future consequences of the expansion considered in the plan are not stated. Other drivers of change are not considered in the analysis; for example, the discussion of the potential impacts of rapid sugarcane expansion on land use does not consider the effects of the expansion of other sectors (e.g. soya or eucalyptus for the pulp and paper industry).

The focus of the plans on meeting GHG emission targets is a first step towards a broader analysis potentially able to balance environmental, economic and technical criteria. Reducing GHG emissions is certainly one recognized goal for sustainability, but, in a scenario of energy supply expansion, increasing ethanol output could be a driver for other unsustainable trends, thus involving trade-offs. Hence, it cannot be the only goal, so multiple objectives must be considered when formulating alternatives for ethanol goals (e.g. Morrison-Saunders and Pope, 2013). Gibson et al. (2005) state that sustainability assessment must be concerned with a broad agenda, adopting multiple objectives to ensure multiple gains. But the issues must be analyzed, ensuring "integrated attention to all of the key intertwined factors that affect our prospects for a desirable and durable future" (Gibson, 2012, p. 13). Thus, beyond mentioning impacts, it is important to push the analysis to the point it delivers answers about what would be the expected effects, considering interrelations and cumulative effects.

In order for the socio-environmental analysis to accomplish a role of enhancing the objectives of the energy plan it is important to include both a broader scope and a more detailed analysis of scoped-in issues.

To advance towards a sustainability assessment approach, it would be desirable to deepen the analysis for the most relevant issues for biofuels sustainability, ensuring continuity and improvement in the analysis over time. The sustainability assessment requirements proposed by Gibson et al. (2005) could be a reference for scoping (i.e. based on issues related to socio-ecological system integrity, livelihood sufficiency, intra- and intergenerational equity, resource maintenance and efficiency, democratic governance, precaution and adaptation, and interrelations among current actions and long-term desirable outcomes). The definition of the most relevant issues can evolve through planning cycles, given learning and knowledge acquired in previous processes. Additionally, documenting and justifying changes in successive plans is relevant both to provide greater transparency to the process and to enable organization learning processes (Sánchez, 2012).

Importantly too, the results of the analysis should influence the definition of limits or thresholds to be respected for ethanol expansion for each of the issues analyzed (e.g. Gibson et al., 2005; Stoeglehner and Neugebauer, 2012; Morrison-Saunders and Pope, 2013). For example, when addressing water consumption in the only decennial plan where water availability is considered, the conclusion of the EPE team was that, even if the most restrictive regulation in force were adopted in all regions, the total consumption

at the end of the decade would still be very "high" (estimates are not provided). The plans bet on the possibility that technological advances could reduce the consumption to zero, favoring the deployment of sugarcane mills in places where water availability is small (EPE, 2013b, p. 365), but there is no suggestion of potential initiatives to stimulate such innovation or any indication for prioritizing areas with adequate water availability. This result may not be acceptable under a sustainability assessment approach.

Discussions on limits are fundamental for trade-off management (Morrison-Saunders and Pope, 2013), offering parameters for discussing which changes are acceptable and which are not or should be subject to some kind of offset. By adopting limits, the socio-environmental analysis would contribute to enhancements in the desirable energy alternative set in the plans, offering conditions to expansion that could limit the speed at which it can happen. Additionally, defining such limits would also enable the selection of indicators that can work both to monitor plan implementation and to design proposed projects, so strengthening the relationship between planning initiatives.

7.6.3 Strengthening Participation and Responsibility for Actions

Despite the three identified participation opportunities and evident efforts to open energy decision making to some degree of discussion, ethanol planning is not conducted with effective participation. Neither industry representatives nor civil society organizations take part in the decisions taken on the desired ethanol production level or on social and environmental criteria for sugarcane expansion. Industry representatives, despite making submissions in the public consultation period, complain that submissions meet with no response from the planning team. Similar concerns are voiced by citizens' organizations.

In dealing with indicative planning, it is fundamental to the success of the plan that regulators and private agents agree on the directions of action – the agents must be convinced and committed to the direction defined (Perez-Arriaga and Linares, 2008). Thus, having a dialogue becomes central for effective indicative ethanol planning; otherwise it is unlikely that the expected results will be reached.

For sustainability assessment, it is fundamental to include the views of different stakeholders in decisions, ensuring the existing diversity is properly considered in the process (Pope and Morrison-Saunders, 2012; Stoeglehner and Neugebauer, 2012). Thus, beyond government and private sector, civil society representatives should also be involved in ethanol planning in Brazil.

The engagement of stakeholders in planning, beyond addressing principles of democracy and transparency in government action, should also provide agreement on what needs to be done in order to achieve the goals proposed in the decennial plans as well as agreed targets, responsibilities and timing for reaching the overall objectives. Currently stakeholders and institutions are not adequately engaged in the decisions that affect themselves later.

As one result, decennial plans feature recommendations on economic/financial, social and environmental issues, but they are not minimally detailed or explained, and there is no clue about how the recommendations could or should be implemented. As an example, actions to reduce water consumption are supposed to be implemented by the states, but there is no dialogue with the responsible organizations, as neither EPE nor the Ministry of Mines and Energy can implement such actions by themselves.

In the *Agroenergy Policy Guidelines 2006–2011*, launched in 2005, the Brazilian Agriculture Ministry recognized that "The achievement of the expansion of bioenergy requires the alignment of various government policies such as tax policy, supply, agricultural, agrarian, credit, fiscal, energy, science and technology, environmental, international trade and foreign affairs" (MAPA et al., 2005, p. 3). So energy planning is central, but it is just one piece in the fuels and biofuels arena, and only a joint effort would be able to guide a sustainable expansion in such a complex context. The National Council of Energy Policy counts on important decision makers, but the opportunity to share responsibility for the implementation of the plan is not being taken, as any commitment is expressed in the plans. Adopting a sustainability assessment approach necessarily would involve integration of all those agendas, by a broad participatory process to connect the different planning efforts.

Currently decennial plans are the main document for fuel planning in Brazil, but the planning process is very limited in engaging stakeholders. Even if no major structural change is introduced in the planning process, the current approach to dealing with ethanol in the decennial plans is in need of much greater opportunities and mechanisms for stakeholder engagement.

7.7 CONCLUSIONS: OPPORTUNITIES FOR BRAZILIAN ETHANOL PLANNING

Sugarcane ethanol is an important part of the current Brazilian energy matrix, a key renewable source that represents a step towards a less carbon intensive economy. But sustainability goes far beyond consideration of renewability alone. Sustainability requires the conciliation of multiple objectives related to ecosystem integrity and human development. Reducing fossil fuels consumption is just part of a more sustainable future.

The decennial energy plans are fundamental tools in Brazilian governmental ethanol planning. In this chapter, the current practice and paths towards sustainability assessment were reviewed in relation to three aspects: their goals and alternatives; the content of socio-environmental analysis; and participation and responsibility for actions.

For the first aspect, decennial plans attempt to identify demand trends and how supply should expand to meet the demand. Among the potential alternatives for fuel supply, decennial plans are maximizing ethanol share, seeking to reduce GHG emissions from the energy sector. We argue that more alternatives should be identified and compared, in order to guarantee that the selected alternative represents the greatest overall benefits while minimizing the negative effects. Specifically for the ethanol context, identification of alternatives must deal with the current crisis that affects the sector, ensuring the connection between the current scenario and the desirable one is really possible.

For the socio-environmental analysis, we found that it is limited to listing some of the consequences of the selected alternative, but does not address the complexity of a rapid expansion of sugarcane crops. Scope is variable in the six plans produced to date; impact analysis is featured in little detail and is not always explicit about potential benefits or threats. To advance towards a sustainability assessment approach, scoping should select and analyze the most relevant issues for ethanol sustainability, indicate limits to be observed in sugarcane expansion, provide for explicit trade-offs consideration and make recommendations or enable commitments from major government actors on actions to enhance, avoid, reduce or compensate for social and environmental impacts.

The process counts on three opportunities for stakeholder participation and dialogue in the development of the decennial plans. Nevertheless, ethanol sector representatives and civil society organizations, especially those advocating a social and environmental agenda, are not part of the discussions that frame the plans. The decennial plans are also poor in defining actions to achieve their goals. To be consistent with a sustainability assessment approach, it would be desirable to strengthen the dialogue with ethanol industry representatives and civil society organizations during the process, and arising from this also to help support advancements in defining responsibilities for post-plan actions.

Sugarcane ethanol plays a very important role in the Brazilian energy matrix. However, despite the decennial plans pointing to increased ethanol supply in the short term, industry representatives argue that the sector is facing the hardest crisis of its recent history: an industry that continues to be subject to major ups and downs. Expanding sugarcane ethanol, whilst still considering a sustainability agenda, will require much more effort in modernizing planning practices. In this sense, sustainability assessment can provide the conceptual framework and the necessary tools, and can support the development of a strategy able to organize actions towards a more sustainable energy future for Brazil.

NOTES

1. Energy crops include plants that are sources for biofuels or can be combusted for their energy, such as sugarcane, corn, sweet potatoes, sorghum, miscanthus and firewood.
2. The sugarcane harvest seasons or agriculture years usually start in April and finish in March of the next year, varying between the production regions. In the Southeast–Central region it occurs between April and November, while in the North–Northeast region it is between November and April (EMBRAPA, 2014).
3. Currently, sugarcane ethanol is obtained from the sucrose contained in high concentration in sugarcane through fermentation. The efficiency of the process has increased enormously over the years. It is called first generation ethanol, because the basic process is the fermentation of the must. The waste resulting from crushing the stems, called bagasse, is burned to generate steam and electricity, called bioelectricity. The second generation ethanol is obtained from lignocellulose – the constituent of plant cell walls, composed of cellulose, hemicellulose and lignin polymers (Rubin, 2008); in the case of sugarcane, both bagasse and leaves could be used to produce fuel.

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8. A sustainability assessment framework for energy systems: building an appropriate relationship with energy

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8.1 INTRODUCTION

The purpose of this chapter is to develop a sustainability assessment framework for understanding what a constructive and appropriate relationship with energy entails and what steps are required to achieve the necessary sociotechnical systems change. In order to do so, this chapter poses two general questions:

1. What is the 'energy problem'? This question helps ground energy systems analysis and energy decision making within a sustainability assessment worldview.
2. What are the characteristics of a constructive societal relationship with energy? This second question builds upon the first question by exploring the soft energy path and transition management.

Consideration of these two questions guides the development of the sustainability assessment framework focused on energy systems. In this chapter we propose a set of sustainability criteria for energy systems, variants of which have been applied in different contexts (Gaudreau and Gibson, 2010; Winfield et al., 2010; Duarte et al., 2013).

There are, of course, good reasons to ask why we should be concerned about how we deal with energy issues and options.

Societies today are facing an escalating and interrelated series of challenges and crises at an unprecedented scale. For example, Diamond (2005) describes 12 interdependent biophysical problems facing our world, including those relating to climate change, biodiversity, water availability and quality, overreliance on fossil fuels, and the increasing amount of primary productivity being captured for human purposes.

The challenges societies face are also social and ethical (Schumacher, 1973). There are profound inequalities both within and between countries in terms of resource consumption, material prosperity, power relations, livelihood opportunities, ability to withstand and weather external shocks, and ability to develop equitably within the current world order (Rip and Kemp, 1998; Giampietro and Mayumi, 2009).

Energy is a common thread that connects the various challenges. Energy is fundamental to society, and the implications of humanity's demands for and uses of energy are becoming increasingly evident (e.g. Lovins, 1977; Nuffield, 2011; Nikiforuk, 2012). There is growing agreement that we must change our energy systems profoundly in the coming few decades if we are to avoid socio-economic and ecological system collapse in one form or another (Hall et al., 2008; Rotmans and Loorbach, 2008).

In order to promote constructive change it is helpful, and perhaps necessary, to have a set of guiding principles. This chapter develops a core set of principles as a basis for designing sustainability criteria for planning and evaluating energy undertakings. Further specification of the criteria for application in particular cases and contexts involves a further step, examples of which are documented elsewhere (Gaudreau, 2013).

The outline of this chapter is as follows. Section 8.2 elaborates on three different framings of what the 'energy problem' is. Without at least a general idea of what the problem is, it is difficult to suggest solutions. Following that, section 8.3 describes some basic characteristics of what an appropriate relationship with energy entails. Section 8.4 proposes a basic sustainability criteria set that illustrates how the important themes discussed in this chapter can inform sustainability assessment through the development and application of sustainability criteria. Then section 8.5 briefly reports on a sustainability assessment of cookstoves in Senegal to ground some of the theory in a real world application.

8.2 FRAMING THE ENERGY PROBLEM

We begin by outlining various frames through which the energy problem may be conceptualized. In many instances, especially with regard to energy system trends and effects, there is no clear understanding of even what the problems are, let alone what solutions are feasible or desirable (Robinson, 1982; Bardwell, 1991; Giampietro and Mayumi, 2009).

Problem framing does not necessarily need to be considered negatively (Bardwell, 1991), as an energy problem is typically also an opportunity. This section draws inspiration from Robinson (1982), who noted three broad conceptions of the energy problem that are commonly discussed:

1. the energy problem as a question of supply and conservation;
2. the energy problem as the threat of worsening social-ecological problems; and
3. the energy problem as a deeper critique of modern society.

It is helpful to elaborate on these three different framings, because all three are relevant for energy planning and sustainability assessment.

8.2.1 The Energy Problem as a Question of Supply and Conservation

The first problem is one of developing new supplies and enhanced conservation measures to meet the energy demands of society. This framing recognizes that, as societies develop, they typically use increasing amounts of high quality energy at ever higher levels of throughput (Meadows et al., 1972; Georgescu-Roegen, 1975; Hall and Klitgaard, 2006).

The key theme of this framing is energy security, that is, ensuring the uninterrupted physical availability of energy products on the market at an affordable price for all consumers (Nuffield, 2011). Energy security can be improved through changes to supply and/or demand.

While the focus of energy policy has most often been on increasing supplies, there has been growing recognition that both conservation and efficiency can defer the expansion of energy production, or eliminate its need altogether. Means of reducing demand range

from the simple to the complex, such as adding insulation, taking public transit or developing smart grids.

In the long run, the concern over energy security relates to the overall availability of energy supplies, and the finite nature and declining quality of many of our resources. As societies search for and expand their use of alternative energy sources (e.g. solar PV, wind), we are quickly being forced to consider one crucial question that has often been ignored: can the proposed energy system procure sufficient energy to maintain its own operations as well as have sufficient and durable surplus power to meet current and future societal needs?

One metric often proposed to address this question is that of energy return on investment (EROI). EROI helps inform feasibility by comparing the total amount of energy available to society compared to how much energy was used up by the energy sector itself – in the energy-for-energy cycle – in procuring the supply. Effectively EROI is the surplus left after energy is used to extract energy and make it available for use. As EROI decreases, an increasingly large proportion of total energy throughput is required simply to maintain the energy sector itself, thereby reducing the proportion available to society.

Historically, the EROIs of fossil fuels were so high that no one really considered the amount of energy needed to produce surplus energy. However, as increasingly marginal energy sources are being pursued, the EROIs are dropping and this is becoming relevant for energy security. Giampietro and Mayumi (2009) propose that any energy source with an EROI less than 3 should not be considered a viable option. To put this in perspective, corn-ethanol is considered to have an average EROI of 1.3. It is interesting to note that the EROI of corn-ethanol hinges upon whether or not dried distillers grain (a by-product of corn-ethanol production) is counted as a positive contribution to EROI; without dried distillers grain, the EROI of corn-ethanol would be even lower. What this means is that many modern renewable energy technologies are being subsidized by fossil fuels, an untenable long-term situation (Pimentel et al., 2007).

As EROI declines, the labour, land and resource requirements to produce surplus energy necessarily increase, as more labour, land and resources are required within the energy-for-energy cycle. To provide an idea of the consequences of corn-ethanol production for land and labour in the United States, Giampietro and Mayumi (2009, chap. 7) calculate that simply replacing 3 per cent of total US energy demand with corn-ethanol would require about half of the labour supply in the US workforce (including the unemployed) and more than 30 times the current land under production in the United States.

While the accuracy of EROI numbers can and should be debated, the underlying reasoning is what matters. It is unlikely an energy pathway of low EROI has long-term potential, except as a possible bridging energy source (discussed further in section 8.3.6). The consequences for energy security are significant.

8.2.2 The Energy Problem as the Threat of Worsening Social-ecological Impacts

With its focus primarily on supply and demand, the first problem framing ignores many critical issues facing the world, several of which were mentioned in section 8.1. These issues effectively form a second problem framing relating to energy.

Historically, our understanding of energy has been that increasing energy supply will contribute positively to wealth and wellbeing, both at the individual and the societal level.

To this end, much of the functioning of modern economies, with their productive capacities and conveniences, depends very heavily on the continued and expanding delivery of relatively inexpensive non-human energy.

This understanding of energy is not wholly incorrect. For example, the benefits of modern culture – including modern health care, science and the arts – are all predicated on surplus energy produced with a minimum of human labour (Cottrell, 1955). Likewise, there are still many parts of the world where increasing access to modern energy supplies would have significant positive impacts on health and wellbeing (e.g. reducing the negative health effects of traditional cookstoves).

At the same time, this understanding of energy is misguided and dangerous in several different ways. First, our approach to energy production and consumption has led to or maintained profound inequalities both within and between countries in terms of resource consumption, material prosperity, power relations, livelihood opportunities, ability to withstand and weather external shocks, and ability to develop equitably within the current world order (Rip and Kemp, 1998; Sagar, 2005; Giampietro and Mayumi, 2009). Similarly, our world energy system has contributed to many human rights abuses, such as through the formation of petro-states (Karl, 1999).

Second, energy extraction and use are related to several interdependent biophysical problems facing our world against which our collective corrective measures to date have been unsuccessful. This is in part because we ignore the role of energy in providing basic services that underpin society, and the full lifecycle costs of energy consumption are rarely evident to the consumer (e.g. Lovins, 1976; Williams, 2004; Berl et al., 2010). As well, there is little clear shared understanding of how the use of these technologies shapes and conditions individuals and societies (Winner, 1986).

Third, even in the more affluent countries – where technological innovations have brought almost unimaginable progress in many domains – doubt remains about whether material prosperity and technological progress are delivering a new renaissance or have simply changed the nature of the challenges (e.g. Illich, 1978; Lerner et al., 1999; Marcuse, 2010; Nikiforuk, 2012).

The concerns recognized in this second framing have been addressed in a range of policy and legal initiatives, including assessments of energy-related undertakings. The basic objective associated with the framing is to ensure that any expansions in energy production and consumption – if they are to occur at all – are managed in a way that promotes positive social-ecological outcomes, avoids further damage and begins to restore what has been impaired.

Because the second framing draws from a wider range of concerns than the first (supply-oriented) framing, there are many instances where these framings conflict. Notably, within the second problem framing it is recognized that the basic first framing objective of meeting demand and expanding supply may be considered increasingly undesirable. For example, as Lovins (1977, p. 12) notes, 'we are more endangered by too much energy too soon than by too little too late, for we understand too little the wise use of power'.

8.2.3 The Energy Problem as a Deeper Critique of Modern Society

The second problem framing is more comprehensive than the first. However, at some point, if all the challenges and contradictions related to humanity's relationship with energy are taken together, it becomes reasonable to question whether the problems associated with energy indicate a much more fundamental set of problems (Ellul, 1967; Illich, 1973; Winner, 1977). This leads to a third problem framing, centred on the viability of modern society.

The roots of this third framing run deep, and are often focused on arguments that the underlying assumptions and agenda of modern society are wrong, and no amount of technological and policy development will suffice (Ellul, 1967; Winner, 1977; Marcuse, 2010).

At the minimum, the third problem framing acknowledges the evident needs to revise key assumptions. For example, rather than assuming we can know and manipulate nature effectively and repair any serious damage we do, we need to adopt a deeper appreciation of complexity and favour precaution. Likewise, rather than assuming that economic growth based on ever expanded material and energy use can be maintained and can deliver ever improving wellbeing, we need to recognize planetary limitations, engage in active efficiency and redistribution efforts, and find low material and energy routes to greater wellbeing.

The third problem framing may also encourage consideration of broader system alternatives, such as the replacement or reconceptualization of capitalism with other economic and political options (Bellamy-Foster, 2009; Roman-Alcala, 2010), or the rethinking of property regimes, private and collective rights, and means of recognizing public contributions and achieving status. Some may feel another 'great transformation' (Haberl et al., 2011) is necessary, even if there are competing visions of what that transformation will be (e.g. an agrarian revolution? a deep re-spiritualization?).

In this framing, humanity's relationship to energy is no longer the principal unit of analysis, but rather forms one thread of a deeper critique of modernity (Illich, 1973; Schumacher, 1973; Holt-Gimenez, 2009).

8.2.4 Deciding Which Problem Framing Is Most Relevant

It is notable that the three different problem framings described above generally recognize or anticipate different types of feedback and actions. Changes in the cost of gasoline or electricity (largely first problem framing) have relatively direct and visible implications, which can lead to quick responses. By contrast, the loss of biodiversity due to land fragmentation (which fits better within the second problem framing) is more difficult to measure because it deals with cumulative impacts, time lags, and greater uncertainties, is less visible to consumers and policy makers, and is less likely to spur timely response.

In general, acknowledging and addressing problems from the viewpoint of the second and third framings become consistently more difficult because they are more indirect, abstract, metaphysical, uncertain, complex and ethical; and their solutions rarely relate to any one particular problem, but rather to the totality of problems as conceived by the individual or group. Perhaps more importantly, the second and third problem framings challenge conventional assumptions, institutions, power structures and dependencies.

Our actions as a society tend to maintain the current structures of domination and legitimization, at least until something that is sufficiently powerful, visible, visceral and obvious emerges to shake us out of our reverie.

Even if one were to deny the need to overthrow modern society, it is becoming increasingly evident that the energy problem touches upon many issues that extend well beyond supply and demand, and rather force us to question the relationship between energy and the good life.

As an approach to decision making, the sustainability assessment framework we describe here (and variants described in this book) tends to straddle the line between the second and third problem framing. By their nature, sustainability assessment frameworks attempt to address social, ecological and economic considerations. Thus sustainability assessment must address social-ecological challenges and opportunities. However, when you truly and deeply consider and integrate the full suite of social, ecological and economic considerations – particularly over many projects, plans and policies – the assessment at least implicitly becomes a critique of modern society. In other words, even if sustainability assessment is more evolutionary at the level of individual decisions, the emergent outcome should be revolutionary.

In the following section we propose a basic set of principles outlining an appropriate relationship with energy. In doing so, we begin to address the challenges outlined in all three problem framings, and prepare for the sustainability criteria set for energy systems.

8.3 BUILDING TOWARDS AN APPROPRIATE RELATIONSHIP WITH ENERGY

This section considers what an appropriate relationship between society and its energy sources entails, and what the implications are for recognizing key complexities in sustainability assessments of energy systems. In doing so, it provides a basic sketch of how the challenges noted above can be addressed, while accepting that there are unlikely to be any easy solutions.

The story can begin in the 1970s, when the then rarely questioned dominant energy pathway focused on providing more energy to meet ever rising demands, and relied on a small suite of highly powerful and complex technologies with profound geopolitical implications (Lovins, 1977, chap. 2). This was, however, a time of widespread questioning of industrial society's orthodoxies, including in the realm of energy policy.

Grounds for questioning conventional energy options included concerns that: nuclear power brought the threat of nuclear weapon proliferation; the search for oil had led to military uprisings, wars, coups and human rights abuses; and nations and regions were becoming increasingly economically dependent upon and vulnerable to various energy sources (e.g. coal mining) for employment (Lovins, 1977, chap. 2; Meadowcroft, 2009; Nikiforuk, 2012).

In response, Lovins (1977) offered an alternative agenda. The true energy problem, he argued, was not how to satisfy energy demand, but how to meet social goals elegantly with a minimum of energy, while maintaining or strengthening the social fabric and biophysical integrity.

To do this, Lovins proposed an alternative, the soft energy path (SEP), which

featured attention to efficiencies as well as supply, and relied on more diverse, dispersed and smaller-scale options for conservation and generation (Lovins, 1977, chap. 2; Meadowcroft, 2009; Nikiforuk, 2012). The soft path also focused upon energy strategy at the systems level (sometimes called energy 'pathways'), including the design of broader sociotechnical systems and their relationship to societal welfare (discussed further in section 8.3.3).

This new approach, which has been explored and developed significantly over the past 40 years, draws from all three problem framings. The following discussion elaborates on the basic characteristics.

8.3.1 See Energy as a Service and Promote End-use Matching

The basic tenet of the soft energy path is that energy is simply a means to a social end (Lovins, 1977, chap. 1; Bott et al., 1983, chap. 4; Brooks et al., 2009b). People do not want oil or electricity, but rather real things like comfortable rooms, light and food (Lovins, 1976).

When we understand that energy is a means to a social end, we are effectively posing two basic questions:

1. What are the ends we are trying to achieve?
2. What are the best ways to meet those ends?

This questioning is commonly called 'end-use matching' and is key to understanding the soft path, where the usefulness of the task must be considered within its social context (Lovins, 1977, chap. 2; Brooks and Casey, 1979).

End-use matching is one big means of enhancing efficiencies in a way that is likely also to serve other social ends. Proponents of the soft energy path argue that modern societies fared rather poorly in terms of achieving goals in an efficient, effective and elegant manner (Schumacher, 1973, chap. 8). Much useful energy is lost in conversion and transmission, well before it reaches the consumer, and the energy that does reach the consumer is then often mismatched to the purpose of the intended task (Lovins, 1977). For example, electricity is improperly matched when it is used for tasks – such as heating and lighting – that can be provided through lower quality sources (Holtz and Brooks, 2009).

At a broader scale, the capital intensity of large-scale energy systems implies they are unable to benefit from economies of mass production, because there simply aren't enough of the basic components being built (e.g. nuclear plants) (Lovins, 1977). For this reason, end-use matching is seen as a superior means of achieving goals.

Conceiving of energy as a means to a set of ends is obvious, but is easily forgotten with the focus on barrels of oil being refined and shipped worldwide, and megawatts of offshore wind power. Furthermore, at the aggregate level there is – perhaps justifiably – less interest in how people want comfortable homes and proximity to loved ones than in how much electricity and liquid fuel the aggregate lifestyles require.

The rational approach of end-use matching involves working backwards from end goals to energy needs. This approach also works at the societal level for energy planning and visioning using backcasting, whereby positive visions of the future are developed and then steps required to move from the present towards these more desirable futures are determined (Robinson, 2003; Loorbach, 2007, chap. 4; Kern and Smith, 2008).

Compared to forecasting techniques, backcasting provides important benefits for sustainability assessment. First, backcasting helps avoid issues of overstated demand, which have been a traditional concern for energy planners (WCD, 2000, p. 179). Second, because backcasting is an explicitly normative exercise (Robinson, 2003), it promotes reflection and deliberation upon unattractive characteristics of present arrangements and trends, such as the currently inequitable use of resources by modern societies (WCD, 2000, p. 149). This allows for pursuit of futures we want, rather than acceptance of projections from what we have now.

8.3.2 Use Social Change for Energy Conservation and Efficiency

The discussion of end-use matching provided above leads to an important controversy in energy strategy, namely the extent to which energy sustainability can be achieved through efficiency and technological means alone. As Lovins (1976) notes in his seminal *Foreign Affairs* article, there are two ways to approach conservation:

1. purely technical – plug leaks and use thriftier technology while substituting resources; and
2. make changes to our lifestyles, such as smaller cars and mass transit.

In 1976, Lovins argued that studies were showing that, in the long term, using then available purely technical fixes, energy efficiency could be increased by a factor of 4. While acknowledging the tremendous potential for technological improvements, soft path proponents and advocates of other steps to enhance prospects of lasting wellbeing argued for pursuing the technical initiatives in combination with complementary social change efforts (e.g. Robinson, 1982).

One way to promote positive social change is to link energy conservation and efficiency efforts with widespread and longstanding respect for thrift, simplicity, diversity, neighbourliness, humility and craftsmanship. As Lovins (1976) notes: 'We might do this because of changes in personal values, rationing by price or otherwise, mandatory curtailments, or gentler inducements. Such "social changes" include car-pooling, smaller cars, mass transit, bicycles, walking, opening windows, dressing to suit the weather, and extensively recycling materials.' Fortunately, conservatives as well as radicals can embrace the notion that requiring large amounts of energy to accomplish social goals should be taken as an indicator of failure as opposed to success (Lovins, 1977, chaps 1, 2; Lovins, 1978; Franklin, 1990, chap. 6).

As has been well demonstrated in the successes of campaigns to discourage smoking, while major shifts in behaviour and underlying ideas about what is appropriate and healthy are possible and can deliver greater individual and public wellbeing, they often depend on a range of encouragements, dedicated work to foster informed individual and community choice, and initiatives that make it easier for people to act on those choices. If energy strategy ignores the positive roles and potential of these social forces, then much opportunity is lost.

Among the questions that must be addressed regarding social change is how such

changes compare with changes required by other energy paths. Morrison and Lodwick (1981) argue that the basic advantage claimed for the soft energy path is that the social impacts are more desirable in the long term than those of the current energy path. Lovins (1977, p. 23) also weighs in on the question:

> Critics who say a soft energy path is unacceptable because it must change lifestyles are implying that they themselves favour no change in lifestyles, even over fifty years. This implies a static, zero growth economy with no technical or social progress – presumably not what they have in mind. What they probably mean is that they desire no change in certain highly selective patterns and rates of change in lifestyle that they consider agreeable for themselves and appropriate for other people.

Even a well-designed and ably implemented set of social and technical soft energy path initiatives would be only one contribution to what is needed for a transition towards sustainability. However, it is important not to take credit away from the soft energy path as an energy strategy that, unlike the dominant energy regime, explicitly promotes the pursuit of sustainability objectives.

8.3.3 Plan at the Energy Path and System Level

The third consideration of an appropriate relationship with energy is to plan at the system (or path) level. Morrison and Lodwick (1981, p. 365) define an energy path as 'a complex, interacting set of mutually reinforcing, internally consistent features that together constitute an energy system that is, in effect, a sociotechnical system'.

According to Morrison and Lodwick (1981, p. 365), three important features of an energy path are:

(1) a social context consisting of cultural values (e.g. preferences, policies) and associated institutions and organizations (e.g. economic, political, legal) that generate and support;
(2) a set of technological features (e.g. materials, fuels, processes, flows, skills), which produce;
(3) a set of impacts related to social welfare.

The focus on energy paths is important in part because energy paths are self-reflective (or reflexive) in that the choices of technologies and social impacts related to an energy path create the necessary social conditions for that path itself to flourish (Morrison and Lodwick, 1981, p. 365).

The reflexive nature of energy strategy can be understood as a manifestation of Giddens's theory of structuration. As Giddens (1984, p. 2) notes, 'In and through their activities, agents reproduce the conditions that make these activities possible.' For example, nuclear power involves complex and dangerous materials and processes that favour expert management in a large-scale controlled infrastructure, and exclude ordinary citizens from participating. By contrast, soft path proponents argue that soft technologies (e.g. solar and wind) both depend upon and promote public participation in the energy system. The underlying premise is that these dynamics tend to be reinforcing; soft energy systems beget soft societal systems that in turn promote soft energy systems.

An example of the need for systems-level planning is the soft path response to the efficiency paradox, whereby increases in efficiency may ultimately lead to increased consumption. The paradox can arise if decreased per-unit costs of an activity due to efficiency improvements lead to increased aggregate activity, thereby negating the efficiency gains. In energy, the efficiency paradox may mean spending energy efficiency savings on energy consumptive activities (e.g. airline travel), rather than less impactful alternatives (such as music or language lessons).

Lovins's promotion of an ethic grounded in qualities such as thrift would generally discourage such a rebound from occurring. And, combined with sustainability assessment principles, soft path initiatives would aim to ensure that all decisions and savings are increasingly guided to greater efficiencies, fewer adverse ecological effects, and better distribution of the benefits of any gains in growth to those who most need them.

Below the broad level of energy paths, there are also important benefits to thinking in terms of energy systems. Different energy options play different roles in the energy system, and it is difficult, if not impossible, to determine the relative value of an individual technology without considering what position it may occupy in the larger system. What is required then is sustainability assessment of alternative energy (and conservation) portfolios. The ideal assessment of energy portfolios would provide a comparative evaluation of multiple potentially reasonable portfolios to find the package that brings the best suite of mutually supportive and lasting gains and least risk of damage.

Applying a portfolio approach also helps to ensure that different generating options do not unduly detract from one another and rather work in concert. For example, large incremental additions to energy supply have the potential to harm other means of meeting needs, such as conservation and demand-side management, or biomass heating. For instance, some generating options can exclude alternatives owing to long lead times or sunk cost. As noted by the World Commission on Dams (WCD, 2000, p.221):

> Often dams take a long time to come on stream, delaying the delivery of benefits. Because they are high cost investments they divert resources and can exclude other options that may be able to deliver benefits more quickly. These options include demand side management, alternative supply side technologies and improving and expanding the performance of existing systems.

Similarly, as noted by Mahapatra et al. (2007), in Sweden between 1973 and 1986 an abundance of electricity resulting from an expansion of nuclear power led to the promotion of electricity-based heating systems over biomass heating. As a result few housing units in this period were built to accommodate much more efficient biomass heat technologies, and unfortunately it is far more costly to retrofit a house for biomass heating than it is to design for biomass in the first place, which ultimately leads to an exclusion of biomass options for heating.

Adopting a portfolio approach can also help to overcome the relative limitations of individual generating options. For example, hydro dams may help other renewable forms of electricity, such as wind power, by providing a means of overcoming intermittencies. Without a full and fair analysis of options at the system level, the potential for such positive synergy is likely to be lost, and the related design and impacts considerations neglected.

8.3.4 Apply Technology at the Appropriate Scale and Degree of Centralization

Two important and interrelated themes for energy planning relate to scale and centralization, both of which are important considerations in the study of technology. There is no easy formula for determining the correct scale of energy or any other sociotechnical systems. Generally, beginning at the end use and working backwards likely favours a diversity of smaller-scale sources and system resilience, whereas starting from supply and moving forwards tends to favour larger-scale, generation options in less flexible, potentially brittle systems (Lovins, 1978; Lovins and Lovins, 1982).

Soft energy path proponents argue that smaller-scale technologies increase reciprocity, embody a more respectful and constructive approach to work, offer the potential to mobilize the minds and hands of people, allow for democratic control, and provide higher quality employment opportunities where people live and need jobs (Schumacher, 1973, chaps 5, 10; Franklin, 1990). These technologies are generally considered flexible and simple, and can be better understood, used and maintained by individuals (Lovins, 1977, chap. 2).

Small-scale technologies, or at least certain manifestations of them, can foster enhancement of the experience through the promotion of character-building work and the development of greater autonomy (Schumacher, 1973, chap. 2). At the same time, some terrible human rights abuses take place in sweatshops that operate with small-scale technologies as well, and there is the risk of becoming nostalgic (Winner, 1986, chap. 4; Bauchspies et al., 2006).

It is important to note that even renewable energy technologies can be inappropriately scaled. For example, the increasingly large renewable energy systems (such as large hydro dams and 10 MW wind turbines) do not necessarily fit into the soft path worldview. These approaches do little to change the socio-political structure of the energy system, and nor do they promote better end-use matching.

Closely coupled to scale is centrality, and the general trend in alternative energy strategy appears to be towards promoting greater decentralization than is common in current practice (Brooks et al., 2009b). For example, Lovins (1977, chap. 2) calls for energy systems that are matched in scale and in geographic distribution to their ultimate uses.

Historically, decentralization has been seen as a means of promoting smaller scales of social organization, and reducing the rural exodus (Schumacher, 1973, chap. 2; Lovins, 1978; Morrison and Lodwick, 1981). Decentralized production could be localized and promote local self-sufficiency, with better use of local resources and more equitable distribution of benefits and risks (Lovins, 1978; Morrison and Lodwick, 1981; Franklin, 1990). However, as Winner (1986, chap. 5) notes, some big questions remain, for example concerning what to centralize and decentralize to how many centres, to reduce which specific problems or capture which specific opportunities.

What this means for the purposes of energy strategy is that (de)centralization options must be elaborated and evaluated in their context, an approach generally required in sustainability assessment. However, the argument remains that current energy system design tends to be overly centralized and large-scale, and there are benefits associated with moving in the opposite direction.

8.3.5 Promote Long-term Energy System Resilience and Integrity

The fifth characteristic of the soft path relates to promoting long-term energy system resilience and integrity.

At a practical level, promoting resilience and integrity involves reducing vulnerability to and the cost of failure (Lovins, 1978; Morrison and Lodwick, 1981). Soft energy path practitioners promote safe-fail technologies, which can stop working without causing undue hardship to people, the environment or the economy (Lovins, 1978). By contrast, many large-scale technologies must be designed to be fail-safe so as to avoid catastrophic failure (Winfield et al., 2010). A nuclear plant explosion could release radiation to its surrounding environment, and failure of a centralized electricity grid could cripple the economy as well as bring hardship for those depending on electricity for needed services (e.g. heating and cooling).

Some argue that, while many traditional supply technologies must be fail-safe, their scale and complexity make them vulnerable to failure in a way that is not applicable to soft technologies. For example, large energy systems are vulnerable to shocks, disruptions, malfunctions and malice (Lovins, 1978; Homer-Dixon, 2006). By contrast, Lovins argues that the technological diversity of soft path portfolios with many smaller supply technologies increases resilience, and even demands a lower reserve margin, because they are unlikely to all fail at the same time (Lovins, 1978).

The discussions above touch upon reliability. With its focus on meeting all needs with electricity and liquid fuels, the dominant current approach to energy strategy forces the same level of reliability on all forms of energy usage (Lovins, 1978; Farrell et al., 2004). Indeed, as Lovins noted long ago, it is a diseconomy that those using coffee grinders must pay for the same reliability necessary for subways and hospitals (Lovins, 1978).

Promoting long-term resilience and integrity also requires focusing upon the economics of permanence (Brooks et al., 2009b). As Schumacher (1973, chap. 2) argues, nothing makes economic sense unless its continuance can be projected many years into the future without becoming absurd.

The focus on permanence requires that the energy-for-energy loop be closed – such that fossil fuels and resources are not used to subsidize renewable energy production. As noted in section 8.2.1, without a sufficiently high EROI it is effectively impossible for an energy source to provide sufficient surplus for society in the long term. Efforts are ongoing to determine accurately the EROI of various renewable energy sources (e.g. Gupta and Hall, 2011).

In part to achieve permanence, energy systems must ultimately rely on renewable energy flows and drawing from income rather than natural capital (Lovins, 1977, chap. 2; Holtz and Brooks, 2009). This will require bridging in the short to medium term, which is discussed next.

8.3.6 Develop Energy Bridges for the Necessary Transition

The discussion above covers the basic principles of an energy path and a society that is more desirable than what is offered by the status quo. How, then, can we achieve the necessary systems change to move towards a more desirable and lasting future?

In planning for change to a more sustainable society, it is important to recognize that change takes time: infrastructure must turn over, attitudes must change, and the natural world must heal. Because of this, it is generally helpful to consider system changes in terms of bridges which may help ease the transition from our current overconsumption of non-renewable resources to socially and ecologically viable reliance on renewable supplies (Brooks and Casey, 1979; Morrison and Lodwick, 1981).

For Lovins, the general time scale for bridging is in the order of 50 years, and in that time period both the current and the desired future energy path would co-exist (Lovins, 1978). Keeping in line with the soft energy path ethic, the transition would be broadly democratic and with a concern for equity (Morrison and Lodwick, 1981). At some point a critical mass would be reached and a threshold would be crossed (Morrison and Lodwick, 1981).

In 1976, Lovins proposed coal as a suitable bridging energy source for the United States, owing to its availability and scalability, and the apparently promising short-term horizon of new clean technologies (e.g. coal-bed gasification). Given the concerns of climate change today, and the still distant promises of 'clean coal', it is doubtful that coal remains a potentially viable bridge fuel. In recent years there has been increasing discussion of natural gas as a possible bridging fuel, although it is unclear the extent to which the discussion is influencing long-term energy strategy.

While the concept of energy bridges – and energy transition more generally – is simple in principle, it comes up against two interrelated types of challenges, described by Collingridge (Rip and Kemp, 1998, p. 378):

(1) an information problem – the impacts of the adoption of a technology cannot easily be predicted and important effects may not be revealed until the technology is extensively developed and widely used; and,
(2) a power problem – control over or change to a technology and its associated technological structure is difficult when the technology has become locked-in.

To expand on the second challenge, Table 8.1 provides a non-exhaustive list of ways in which lock-in may be manifest.

Lock-in is not always undesirable; the stability provided by lock-in can help reduce complexity and uncertainty and increase efficiency (Rip and Kemp, 1998). However, it is not well suited to a world of significant, potentially rapid and minimally predictable change, where flexibility and other characteristics of adaptive capacity are needed. Lock-in is especially problematic where it helps to entrench dependency on social, economic and/or biophysical behaviours and trends that are unsustainable and for other reasons undesirable.

Effectively, the challenges described by Collingridge leave decision makers to choose between making early choices about whether and how to develop and apply new technologies, when information about potential effects is poor but flexibility is great, and leaving the key decisions until later, when the actual effects of application are more evident but the technology is entrenched and a change of direction is at best difficult (Collingridge, 1980).

Addressing the Collingridge dilemma requires a multifaceted approach. First, the dilemma provides an example of the need for prudence and precaution in the face of great uncertainty and the potential for great harm. Proceeding with precaution may be appropriate in the face of potentially significant adverse effects (plausible effects with substantial possible damage) if:

Table 8.1 Some manifestations of lock-in

Financial reasons
Economies of scale
Sunk investments in machines, infrastructure and skills
Ease in obtaining financing and insurance
Vertical integration within sectors
Improper pricing signals
Psychological reasons
Cognitive routines that ignore relevant outside developments
Organizational commitments, vested interests and political influence
Adaptation of lifestyles to technical systems that increase social dependence on new technologies
Familiarity by customers
Co-evolutionary reasons
Success breeds imitation
Tight fit with existing regulatory approaches developed around original technology
Technologies create their own needs
Dependence of social and institutional structures (e.g. design of cities, infrastructure)

Source: Adapted from: Idenburg and Faber (2008); Verbong and Geels (2008); Arthur (2009); Jordaan et al. (2009); Meadowcroft (2009).

- the potential benefits are significant (i.e. meet important needs, are fairly distributed, are likely to be lasting, etc.);
- steps along the path are reversible;
- the technology is flexible and adjustable; and
- capacities are in place to monitor the effects and ensure appropriate responses.

Second, it is possible to promote flexible technologies (or technological plasticity), which are a basic tenet of the soft energy path. For example, technologies such as solar PV are modular and easily scalable, and may be developed in a wide variety of ways (centralized, dispersed, public, private). Other technologies, such as nuclear generation, are more capital intensive and less flexible and characteristically involve large incremental increases in supply and centralized control.

Third, there are benefits to promoting a wide variety of options and avoiding selecting winners too early. In order for this to occur there must be a safe space for innovations to develop, and a level playing field that provides competing innovations with a fair chance of succeeding (Kern and Smith, 2008; Rotmans and Loorbach, 2008; van den Bergh and Oosterhuis, 2008; Loorbach, 2010).

Finally, there is a great need for political and social leadership that allows stakeholders to deliberate on these questions and make informed choices. As Funtowicz and Ravetz (1993, p. 752–753) note:

> When problems lack neat solutions, when environmental and ethical aspects of the issues are prominent, when the phenomena themselves are ambiguous, and when all research techniques are open to methodological criticism, then the debates on quality are not enhanced by the exclusion of all but the specialist researchers and official experts. The extension of the peer community is then not merely an ethical or political act; it can positively enrich the processes of scientific investigation.

8.3.7 Summary

This section elaborated on six basic characteristics of a constructive relationship with energy based on the soft path approach, namely:

1. See energy as a service and promote end-use matching.
2. Develop a constructive energy ethic.
3. Plan at the energy path and system level.
4. Apply technology at the appropriate scale and degree of centralization.
5. Promote long-term energy system resilience and integrity.
6. Develop energy bridges for the needed transition.

The soft energy path provides a means of conceptualizing energy systems and incorporates an ethic. The principles described above focus on energy but are more widely relevant, with implication for water planning and governance, for example (Brooks et al., 2009a). Likewise, the focus on moving from supply to end uses, to services and ultimately to human needs promotes a critical reassessment of what it is we desire and what is the most efficient, effective, ethical and elegant way to achieve the goals.

We are now at a point where it is desirable to summarize the various energy system principles and guidelines that have been discussed thus far in this chapter (Table 8.2).

This concludes the discussion of the soft energy path. The following section proposes one means of integrating the insights from the soft path into a sustainability assessment framework.

8.4 TOWARDS THE SUSTAINABILITY ASSESSMENT OF ENERGY SYSTEMS

The discussion of the soft energy path provided above concluded with a set of principles for how society can develop a more appropriate relationship with energy. These principles are relevant for energy planning, as well as more broadly in society. The question that remains, however, is how these principles can be included in a sustainability assessment framework.

There are two general means by which the insights from the soft energy path can be incorporated into sustainability assessment. First, the soft path principles can inform the decision-making process, in so far as they promote a broadly democratic approach to decision making that begins with positive visions of the future and works backwards to determine how those visions can be achieved. Even at the instrumental level, end-use matching describes the same backwards reasoning approach, whereby desired end uses are determined and then the appropriate means are designed.

Table 8.2 General guidelines for achieving a constructive relationship with energy

Promote end-use matching
Match the scale and quality of the energy supply to the scale and quality of its final use. Seek opportunities for multiple uses of energy inputs (e.g. cogeneration).

Prioritize energy services in the pursuit of worthwhile ends
Use energy as a means for social ends that is valued for the services that it provides (e.g. comfortable rooms, light). Use energy policy as a vehicle for meeting end-use demands for those services in the most efficient, effective, ethical and elegant manner possible. Promote constructive discussions about means and ends in society, both with regard to energy policy and beyond.

Design energy bridges that aim to close the energy-for-energy loop
Design systems as bridges to more sustainable social structures, recognizing there is no ultimate energy or social end state. Bridging mechanisms should be minimally disruptive but will require societal and technical change and require seeking and developing means of production and consumption that do not (or minimally) rely on fossil fuels. Non-renewable goods must be used only if they are indispensable, and then only with the greatest care.

Use energy policy to catalyse broader change in social values
Recognize that energy strategy has implications far beyond energy supply and demand, and rather affects a wide variety of sectors (e.g. public health, food sovereignty). Design energy systems as a democratic means of constructively re-patterning society (e.g. promoting urban agriculture, fostering social learning). Ground quantitative calculations within qualitative narratives of desired future states.

Maintain rate and scale of production and consumption within local limits
Control the pace and rate of change of energy production and consumption to ensure that they remain within local capacity for system management and for change. Recognize that having too much energy too fast is as harmful as too little energy too late, and rapid expansion is harmful both to producing nations (e.g. resource curse and petro-states) and to consuming nations (fuel security).

Promote soft societal and political systems
Seek structures and dynamics in society that reinforce and are reinforced by the feasibility and desirability of the soft energy path, including appropriately decentralized decision making and energy production, and local self-reliance. Favour energy systems that promote sovereignty and minimize geopolitical risk.

Promote reciprocity, responsibility and fairness in production and consumption
Design energy systems that promote intrinsic responsibility, and foster greater reciprocity so as to allow people to become more involved in and aware of the production, consumption and operation of their energy technologies. Encourage the fair sharing of benefits and risks.

Prioritize democratic participation to benefit both the individual and the public interest
Favour energy technologies, employment opportunities and decision-making processes that promote informed and participatory decision making and citizen engagement. Prioritize basic virtues, rights and the public good (e.g. liberty, justice, equality, fairness, self-realization).

Plan for the cumulative and emergent consequences of mass adoption
Recognize that many of the important benefits and drawbacks of energy technologies emerge during mass adoption. To the extent possible, anticipate such cumulative and emergent effects and plan accordingly. Seek positive cumulative and synergistic impacts in energy systems.

Table 8.2 (continued)

Foster an economics of permanence and non-violence
Prioritize sociotechnical and energy systems that may be considered permanent, while recognizing the need for bridging technologies and practices. Favour energy technologies that are non-violent with respect to people and the environment. Favour technologies and technological systems that can fail safely and do not unduly depend on human infallibility.

Design diverse, redundant and modular energy pathways
Favour sociotechnical systems that ensure the ability of future generations to determine their own desirable futures. Promote energy technologies that are modular, incremental, diverse, redundant and with short lead times, so as to improve resilience and responsiveness. Favour precaution (e.g. safe-fail versus fail-safe).

The second means by which the soft path principles can inform sustainability assessment is through the design of sustainability decision and evaluation criteria. This is the approach that will be discussed in the remainder of this chapter. While there is not sufficient space to provide a full criteria set, we will provide references to the necessary resources for further reading.

8.4.1 From Principles to Criteria

Every important decision we make is based on some set of criteria for evaluation and decision making. The criteria are not always explicitly stated or applied in a consistent manner. They may not even be mutually compatible. But they are always present.

For the purpose of sustainability assessment and proper decision making, the goal is to have a coherent set of explicitly identified and consistently applied criteria. These criteria clarify how to pursue the general goal of contributing to sustainability in a given case and context.

The generic sustainability assessment framework that we are most familiar with is Gibson's framework (Gibson et al., 2005, chap. 5). Gibson's framework represents a synthesis of the main requirements for progress towards sustainability presented in the literature and tested in practice in sustainability implementation initiatives (including early sustainability assessments) over the past few decades (Gibson et al., 2005, chap. 5). For practical application, however, the generic criteria must be specified for the case and context.

Table 8.3 proposes a criteria set that illustrates how the energy considerations discussed above can inform sustainability assessment. These more specific considerations are integrated into Gibson's eight categories of progress towards sustainability. The criteria include a mix of universal requirements for progress towards sustainability (e.g. promotion of intragenerational equity) as well as our current social-ecological context (e.g. considering the challenges elucidated in the discussion of the 'energy problem').

Variations of this criteria set have been developed and applied for generic energy applications (Gaudreau, 2013), applied energy issues research (Gaudreau and Gibson, 2010; Duarte et al., 2013; Gaudreau and Gibson, 2015) and consulting (Gibson, 2006b; Gibson et al., 2008; Winfield et al., 2010; Gaudreau et al., 2013; Gaudreau and Gibson, 2014).

Table 8.3 *Illustrative sustainability evaluation and decision criteria for energy applications*

Socio-ecological system integrity
Build human-ecological relations to establish and maintain the long-term integrity of socio-biophysical systems and protect the irreplaceable life support functions upon which human as well as ecological wellbeing depends.

Maintaining foundations for life support services:
- Maintain critical ecological services (e.g. water purification).
- Maintain and promote ecological life support systems (e.g. pollination, nutrient cycling).

Anticipating and adapting to systems effects and thresholds:
- Recognize that the most important positive and adverse effects are typically the cumulative and interactive ones.
- Respect the complex system characteristics of ecosystems and socio-ecological systems, including multi-scale interactions, dynamic cycling and potential for crossing thresholds to changes structures and functions to move through necessary cycles including growth, development, collapse and renewal (e.g. fire regimes).
- Avoid unwanted feedback cycles (e.g. overharvesting forests to meet current energy needs for cooking).

Living within the capacity of our planet:
- Ensure the energy system helps reduce local appropriation of global bio-capacity.
- Seek productive uses for wastes (e.g. energy cascading).
- Ensure the energy system contributes to substantial reduction of net greenhouse gas emissions.
- Avoid the production of persistent toxic wastes.

Livelihood sufficiency and opportunity
Ensure that everyone, and every community, has enough for a decent life and that everyone has opportunities to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity.

Promoting meaningful employment opportunities and self-actualization:
- Promote respectful and fulfilling employment that respects workers' rights and fosters their ability to self-actualize.
- Provide fair opportunities to all those seeking gainful employment.

Fostering local economic development and capacity building:
- Support economic systems able to accommodate changing labour allocation due to the increase in renewable energy production and generally ecologically friendly practices.
- Ensure pace of energy production remains within local capacity for management and avoids boom and bust effects.
- Promote local employment and capacity building (e.g. economic spin-offs) of both urban and rural regions in an appropriately decentralized economy.
- Favour reliance on locally available resources and avoid resource conflicts.

Facilitating energy transitions:
- Plan for transition to renewable energy and resources for communities and sectors currently relying on fossil-based electricity.
- Strengthen economic and energy self-sufficiency.
- Promote small-scale and local energy production to improve resilience and counter current dynamics of centralization.

Table 8.3 (continued)

Intragenerational equity
Ensure that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, etc.) between the rich and the poor.

Fostering equality:
- Promote equality broadly in society.
- Ensure equitable energy pricing, while respecting that some groups have lower capacity to pay the true cost of goods and services.
- Enhance equity through initiatives to retain energy and resource consumption within ecological limits.

Promoting fair distribution of benefits and risks:
- Enhance fairness in the distribution of wealth, influence and income-generating opportunities.
- Enhance fairness in the distribution of risks within local communities.
- Promote equitable distribution of resources and opportunities.
- Ensure fair and full-cost energy pricing.

Promoting international equity:
- Encourage responsible and equitable practices by the international community (e.g. fair trade).
- Promote policies and consumption patterns that do not harm other nations.

Intergenerational equity
Favour present options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably.

Avoiding lock-in and perverse effects:
- Avoid energy undertakings with long-term legacy costs (e.g. nuclear wastes).
- Maintain sufficient options for future generations to avoid lock-in.
- Avoid rebound effects that may cause long-term social-ecological harm.

Ensuring fairness for the future:
- Plan to leave the local communities, regions and provinces with resources and opportunities at least as great and desirable as those available today.

Resource maintenance and efficiency
Provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste and cutting overall material and energy use per unit of benefit.

Managing at the whole-system level:
- Minimize whole-system costs (e.g. GHG emissions, resource extraction) of energy systems by optimizing conservation resources and demand-management opportunities.
- Promote resilient energy supply systems with sufficient diversity, modularity and redundancy of energy pathways.
- Seek opportunities for multiple uses of energy inputs (e.g. cogeneration) and for energy cascading.

Promoting end-use matching:
- Match the quality of the energy supplied to the quality required for the end use (e.g. promotion of biomass or passive solar for heating purposes).

Table 8.3 (continued)

Developing renewable and adaptable energy systems:
- Minimize the use of non-renewable resources along the entire lifecycle, and avoid unsustainable uses of renewable resources (e.g. water mining).
- Promote energy systems that promise increasingly positive energy returns on investment.

Socio-ecological civility and democratic governance
Build the capacity, motivation and habitual inclination of individuals, communities and other collective decision-making bodies to apply sustainability requirements through more open and better-informed deliberations, greater attention to fostering reciprocal awareness and collective responsibility, and more integrated use of administrative, market, customary and personal decision-making practices.

Promoting good governance:
- Promote local decision making and more broadly participative and decentralized local multi-stakeholder governance.
- Favour policy and decision-making processes that are inclusive, transparent, accountable and linked closely to bodies of representative democracy.
- Ensure participation early in decision cycles.

Respecting basic rights:
- Uphold basic rights (e.g. those recognized by the UN Declaration of Human Rights).
- Promote respect for marginal members of society.
- Ensure attention to the interests of the most vulnerable.

Developing an awareness of means and ends:
- Promote open deliberation on the means and ends of energy initiatives (e.g. through forecasting and backcasting).
- Foster a culture of conservation and resilience, and seek to delink wellbeing from energy and resource consumption.
- Promote energy systems that encourage people to become more involved with and aware of the operation of their energy systems and the impacts of their lifestyles.

Fostering individual and collective learning and understanding:
- Use energy policy as a means of catalysing broader constructive social change (e.g. public transport and urban agriculture).
- Use energy-related conflicts (e.g. wind turbine siting) as openings to explore broader ethical concerns in society.

Precaution and adaptation
Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, plan to learn, design for surprise, and manage for adaptation.

Fostering resilience, reliability and adaptive capacity:
- Favour system options designed with adaptive capacity for response to potential and unexpected changes (accidents, technological advances, etc.).
- Promote diversity, flexibility, modularity, reversibility, fallback options, and safe-fail characteristics.

Avoiding lock-in
- Avoid lock-in (e.g. one type of energy system) by favouring energy investments that are flexible, incremental, and with comparatively short lead times and appropriate lifetimes.
- Favour energy options that minimize geopolitical risk (e.g. nuclear proliferation).

Table 8.3 (continued)

Developing anticipatory planning and managing for uncertainty and complexity:
- Acknowledge and address key areas of uncertainty.
- Provide the capacity for monitoring changes in complex situations.

Minimizing energy systems risks:
- Favour technological systems that are relatively insensitive to human error, and with low cost of technological failure and accidents.
- Avoid rebound effects (efficiency gains facilitating more consumption in ways that add to sustainability problems).

Minimizing energy systems risks:
- Minimize risks of increasing supply in a manner that requires increased demand.
- Anticipate and plan for technological development (recognizing uncertainty over the long-term control of technology).

Immediate and long-term integration
Apply all principles of sustainability at once, seeking mutually supportive benefits and multiple gains.

Promoting constructive co-evolution:
- Encourage cultural-technological co-evolution favouring sustainability objectives.
- Facilitate positive indirect effects within the social-ecological system (e.g. public health, education).
- Promote bottom-up and top-down change for sustainability at all levels.

Using key windows and harnessing key players for change:
- Favour peaceful and constructive means to achieve meaningful change.
- Take advantage of avenues for rapid change and seek leverage points to obtain maximum net gains.

Developing energy bridges:
- Plan for the transition to more sustainable energy within longer cycles of change (e.g. economic cycles).
- Direct non-renewable resource use to developing energy bridges to renewable and equitable energy systems.

Aside from the generic criteria set, all other criteria considerations have been specific for the given case and context. The process of criteria specification is described in Gibson (2006a) and Gaudreau (2013).

The transposition of energy principles into sustainability criteria is not a simple linear process. In certain instances the principles can be transposed directly and easily into sustainability criteria, but often the principles must be interpreted and reworked to integrate other overlapping considerations. A single principle may inform several criteria, and likewise a single criterion may be informed by multiple principles. The overlaps among criteria reflect both the complexity of the task being undertaken and the interrelations among the various theories that inform understanding of desirable energy futures.

The set of evaluation and decision criteria presented in Table 8.3 illustrates how the energy principles discussed above can be integrated into a broader sustainability assessment framework, in this case the one from Gibson et al. (2005). This criteria set would need to be elaborated further for application in the identification and comparative evaluation of options in a particular case and context. For a similar criteria set that cross-references the criteria to the soft energy path principles, the interested reader is directed towards Gaudreau (2013, chap. 4).

8.4.2 Comments on the Sustainability Criteria

There are six characteristics of the criteria set in Table 8.3 that merit particular attention. First, the criteria set is designed as a package of intertwined components. Individual criteria cannot be taken as non-overlapping, and equivalently weighted. Important themes are double counted, and in specific contexts some criteria will be more important than others. This does not preclude the possibility of organizing the criteria to make them minimally overlapping or of applying weights or other means to recognize that some criteria are more or less important.

Second, the criteria set, presented as a package in Table 8.3, is demanding, both in specific substance and in broad intent. The substance is daunting enough by itself. Table 8.3 has eight criteria categories and over 60 criteria, many of which are themselves broad. Moreover, further specification of these criteria is needed for applications in particular cases and contexts.

Not much can or should be done about this. The Table 8.3 criteria lists can be shortened only by leaving out some considerations and/or collapsing the current material into fewer and fuzzier criteria. Shortening the list will have no effect on the number of issues that deserve attention. It will only impair their prospects for adequate attention. In any event, many of these criteria topics already get fragmentary attention somewhere in the planning and approving of new energy undertakings. It is clearly sensible to treat them openly and realistically as interactive issues that ought to be addressed together.

Third, the criteria set combines principles and goals into requirements for progress towards sustainability. A cursory analysis of the sustainability criteria set reveals a mix of principles and goals. In some instances there are benefits to proposing a criteria set that is either uniquely a set of principles or a set of goals, but not both. However, in practical application it is difficult if not impossible to isolate the criteria set as only principles or only goals, since neither should be neglected in decision making. Furthermore, in so far as the principles are not yet met – for example, the principle of proper end-use matching is rarely applied – they remain goals as well.

Fourth, the criteria set outlines desirable system attributes and actions for achieving *progress* towards sustainability, rather than defining an acceptability threshold. Conventional assessment practice often assumes an acceptability threshold whereby, if a proposed project meets the minimum requirement, it may proceed. Many of the concerns with environmental assessment – including ignoring cumulative and synergistic effects, and focusing on harm mitigation rather than demanding positive contributions to sustainability – are due in part to the acceptability threshold approach. While there are obvious cases where a proposed project is unacceptable, defensible delineation of an acceptability threshold is rarely possible, and comparative evaluation of alternatives is more likely to reveal what will best serve the long-term public interest.

Fifth, while the criteria set was informed by considerable research and case experience, it is a work in progress that will continue to evolve as we learn from our successes and mistakes. Further enrichment will come through diverse applications with people

who have different experiences and worldviews, face different perils and opportunities, and consequently have different understandings of what is most important for progress towards sustainability.

Finally, the criteria set is focused on evaluations and decision making on energy undertakings but is more broadly relevant. Many of the considerations incorporated in the Table 8.3 criteria set are suitable for applications that are not centred on energy systems. Moreover, energy and other undertakings inevitably affect as well as are affected by the broader socio-ecological context in which they are undertaken. Deliberations informed by explicit sustainability-based criteria are tools of broader social change.

8.5 APPLYING SUSTAINABILITY ASSESSMENT – PEANUT-SHELL COOKSTOVES IN SENEGAL

In this section we briefly report on an application of sustainability assessment relating to the combustion of peanut shells in Senegal. This section focuses on the relationship between the agricultural and energy systems of Senegal, as this relationship is necessary to specify the sustainability criteria set, as well as to start sketching out pathways, projects and plans that can be assessed by the criteria set. A longer description of the case is available in Gaudreau (2013, chap. 8) and Gaudreau and Gibson (2015), including the case- and context-specific criteria set.

The application adopted Gibson's (2006a) sustainability assessment framework, versions of which have been applied in several energy systems cases at both the strategic and the project levels (JRP, 2009; Gaudreau and Gibson, 2010; Winfield et al., 2010; Duarte et al., 2013).

In many parts of the world, agricultural residues are seen as a viable energy supply for cooking, as they may reduce pressure on forests, eliminate the hazards related to collecting fuelwood, and – with properly designed cookstoves – reduce the adverse health impacts related to cooking with traditional stoves (Rehfuess, 2006; GIZ, 2011; Hrubesch, 2011; REAP-Canada, 2011). Furthermore, given that Senegal has lost almost half of its forest cover since the 1960s (Tappan et al., 2004; Mbow et al., 2008), the need to provide the forests with some respite is all too apparent.

Within the context set out above, we endeavoured to determine whether, and under what conditions, cookstoves burning peanut-shell residues could promote progress towards sustainability. For this case study we applied Gibson's (2006a) sustainability assessment framework, and began with the generic energy criteria set provided above. We chose a case study approach guided by Yin (2009), and drew from a variety of methods, including document analysis, literature reviews, key stakeholder interviews, and participant observation.

This sustainability assessment application focused on the intersection of the energy and agricultural systems, both of which are facing a general crisis, one that is tied in with broader considerations, including gender equity, livelihood opportunities, and social-ecological resilience. It is instructive to briefly describe the energy and agricultural systems, recognizing that these descriptions represent a Western interpretation of the context.

8.5.1 The Senegalese Context

Senegal's energy system (both modern and traditional) is facing various challenges. The electricity system is composed of largely inefficient fossil-fuelled infrastructure that is unable to meet demand and suffers from increasingly frequent power outages, which discourages economic growth and fuels public discontent (CRSE, 2008; Diop, 2009; *African Bulletin*, 2010; Callimachi, 2011). Oil imports were consuming almost half of export earnings by 2007 (MDE, 2007).

One consequence of the weakness of Senegal's energy system is that the country remains heavily reliant upon traditional bioenergy, primarily fuelwood and charcoal for cooking, and is overexploiting its forest resource base (MDE, 2007). The overuse of wood and charcoal for cooking has worsened deforestation and desertification, and – when coupled with overgrazing and agricultural expansion – has led to an almost 50 per cent reduction in forest cover since 1965 (Tappan et al., 2004; Mbow et al., 2008).

Similar to the energy system, Senegal's agricultural system is also facing a crisis. Senegalese agriculture is primarily rainfed, and based on small farms growing peanuts, millet and sorghum (OECD, 2008), although peanuts have been the primary cash crop for decades. Despite its extensive agricultural base, Senegal suffers from food insecurity, which is expected to worsen in coming years.

The main component of Senegal's agricultural crisis relates to peanut farming. Peanuts are a focal point in Senegal, in large part because of years of government and colonial promotion, and the history of peanuts being an economic engine of Senegal. Over time, the percentage of export earnings related to peanuts has dropped approximately sevenfold, from 80 to 12 per cent, since the 1960s (Hathie and Lopez, 2002; UNDP, 2010), in part owing to competition from other oils, reduced yields and increased foreign trade barriers (e.g. regulations on aflatoxin contamination). The production of peanuts is very difficult on the soil and is a major driver of dropping soil fertility. Farmers tend to produce only peanuts until soil fertility drops to a point at which they are forced to rotate with millet.

During the same time period, Senegal has become increasingly food insecure owing to reduced earnings from peanut products and increased costs of importing staple foods (Elberling et al., 2003; Brown, 2008; Diaz-Chavez et al., 2010; UNDP, 2010). Although the government has been promoting agricultural diversification in order to improve food security (OECD, 2008; Diaz-Chavez et al., 2010), no viable alternatives have yet taken root.

Through the assessment process, it became clear that deforestation is intimately connected to problems in Senegal's agricultural system. As a result of decreased soil fertility and productivity, many farmers have abandoned their fields and cleared forests in the south-east in order to renew farming (Tappan et al., 2004). Initiatives to maintain or recover soil fertility would therefore also help to protect the remaining forests, and using peanut shells and other agricultural residues for soil enhancement is one possibility. What this means is that burning agricultural residues as a fuel source removes their potential use as a soil amendment, and may ultimately lead to deforestation, the very outcome their use was designed to prevent. To complicate matters, the magnitudes of these two drivers of deforestation are uncertain.

8.5.2 A Soft Energy Path in Senegal

The context provided above describes a situation in crisis, one where there is likely no single best solution for moving forward. Fortunately, both the soft energy path and sustainability assessment can guide decision making forwards. This section briefly describes a possible energy bridge and a potential end state.

One energy bridge deserving attention in Senegal is liquefied petroleum gas (LPG, or 'cooking gas'). LPG helps decouple energy from agriculture in that it is fossil fuel derived. LPG stoves are clean burning and culturally appropriate for cooking, and already present in Senegal. In fact, the Senegalese government has subsidized LPG since 1988, but has been phasing it out in recent years owing to a balance of payments crisis (Youm et al., 2000; CRSE, 2008; Fall et al., 2008; Laan et al., 2010). The original impetus for the LPG subsidy – and one that is no less relevant today – is that it provides a means of reducing forest pressure by providing an alternative fuel source.

The LPG subsidy has been criticized for various reasons, including its cost and equity effects (the rich tended to benefit the most), and the long-term implications of promoting reliance on fossil fuels (Laan et al., 2010). While the criticisms seem justified, no present option is likely to be problem-free.

An improved version of the LPG subsidy is not a permanent solution. Rather, it could serve as an energy bridge in the transition to more sustainable energy systems, effectively buying time for the forests to replenish and alternative energy solutions to develop.

A seemingly strong candidate for a future energy system is biocharcoal, which is biochar with an added binder, such as clay, that allows it to be burned in a stove. Biochar, produced by the pyrolysis of biomass, is gaining popularity as a means to regenerate soils by increasing soil carbon storage and nutrient holding capacity, often more effectively than the original biomass could do as a soil amendment (Whitman and Lehmann, 2009).

Biocharcoal shows many possible benefits in Senegal. It allows for locally appropriate energy production at various scales, and does not lock Senegal into one specific type of biomass or agricultural residue. Rather, biocharcoal may be produced using various feedstocks (e.g. Typha, an invasive riparian weed), although it is likely only feasible under commercial production. Second, the German Development Agency GIZ is promoting biocharcoal in Senegal as a means of encouraging youth employment for both men and women, indicating that mutually reinforcing gains are being sought.

At present, the long-term success of biocharcoal is not guaranteed. The extent to which it could feasibly replace charcoal depends on the scale of production (artisanal versus commercial scale) and the availability of biomass, both of which require further analysis (e.g. Hrubesch, 2011). Likewise, the energy return on investment of biocharcoal is unknown and likely context dependent (e.g. affected by manual or machine production), indicating that a degree of precaution is necessary. Ultimately, time is needed to allow the technology to mature, ensure its benefits are as anticipated, and develop a means of disseminating it more broadly in the country.

Ultimately, through developing the case and context, we determined that the development and large-scale use of cookstoves that burn agriculture residues, notably peanuts, for fuel appear generally undesirable. Some possibilities that appear worth exploring included coupling biocharcoal (a potential long-term solution) with LPG (an immediate energy bridge) to develop a preliminary energy strategy. This strategy and others should be assessed by a comprehensive sustainability criteria set, such as that generically proposed in Table 8.3 and specified for the case and context (e.g. Gaudreau, 2013, chap. 8).

8.6 CONCLUSION – THE (SOFT) PATH AHEAD

The nature of energy use and associated energy systems has probably always been a fundamental determinant as well as product of societies' economic behaviour, institutional structure and ecological impact. Today, the importance of energy systems and energy decisions is greater than ever. In a world of deeply unsustainable trends, huge unmet needs, pervasive uncertainties and great potential, decision making on energy policy and project options can and should play a key role not only in maintaining the current quality of life but also in supporting steps to more desirable futures.

If energy decision making is to play this role well, open and effective integration of sustainability considerations into deliberations on energy system options is needed everywhere. This should be obvious. It does not follow, however, that the task can be easy.

This chapter has outlined the fundamentals of an approach that begins by reframing the 'energy problem' in light of the challenges to be faced and identifying the basic principles for building an appropriate energy system. These energy foundations are then integrated with generic sustainability criteria to deliver a set of sustainability assessment criteria specially designed for evaluation of energy policy and project options.

The bigger challenge is in winning acceptance for the underlying agenda. Like other sustainability assessment frameworks, the energy package rests on a critique of business-as-usual approaches that reinforce unsustainable trajectories. Accordingly, the Table 8.3 criteria are meant to foster and guide changes towards more sustainable energy systems and more sustainable societies. The intent is to have far-reaching consequences – on livelihood opportunities, biophysical integrity, fair distribution of benefits, and so on – now and in the future. But, while the critique is compelling and the goal of a more sustainable future is attractive, advocacy of the significant changes needed to get there will provoke resistance, especially from institutions and individuals most wedded to or dependent on the old ways.

Serious concerns are involved here. Resistance to progressive change rests on legitimate fears as well as entrenched habit and interest. Even the most promising change is disruptive and risky. Overconfident and impatient imposition has probably wrecked as many shining opportunities as narrow and self-serving opposition. It is useful but not enough to argue that the changes required for a transition to sustainability in energy and society will be less dramatic and onerous than the changes we will face if the direction of current practices is allowed to continue (more GHG emissions, more degradation of ecosystem services, more conflict over depleting fresh water and other resources, more dangerous gaps between rich and poor, and so on). Also needed is persuasive evidence that the transition can and will be pursued with care and sensitivity.

Much of the necessary guidance for transition efforts is already incorporated in the Table 8.3 criteria, which emphasize openness, participatory process and broad engagement, precautionary bias, anticipation of potential risks, preference for reversibility, and special care to protect the interests of the most vulnerable. It will be important to recognize that these criteria apply not only to energy options but also to transition steps.

Any successful transition must be gradual, flexible, responsive to its effects and able to learn from error. Because of the slow but now considerable penetration of soft energy path ideas and practices into the energy sector, especially in electric power system planning, over the past four decades, there is an existing foundation of understanding and credibility for serious applications of sustainability assessment.

The tides are forever changing, and maybe now is the time for the next generation to develop a new narrative, grounded in the requirements for progress towards sustainability explored in this chapter and book.

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9. Cities and sustainability assessment: resilience and sustainability thinking about the future of cities

Maria R. Partidário and Pedro Pereira

9.1 INTRODUCTION

Urban planning is still mostly driven by population and economic growth forecasts to justify the need for new or expanded infrastructures. Concerns with urban environmental and social issues are certainly increasing on the agenda, but economic growth is still largely seen as the enabler of well-being. Increasing sustainability concerns with this model of city development have led over the last few years to emerging city sustainability approaches, both in developed and in developing countries, albeit their priorities being different.

In the regions of the world that still experience high demographic growth rates, we observe the continuing expansion of the size of cities, accommodating high fertility rates and incoming rural populations, with arguably insufficient physical infrastructures and limited social inclusiveness. Where fertility rates have slowed down, or even reversed, cities get more focused on rehabilitation to increase competitiveness, while still planning to accommodate a growing culturally diverse incoming migrant population, with large social and economic gaps, and social inclusiveness becoming even more acute (Florida, 2009; Stiglitz, 2013). In western world cities where basic water quality and supply, sanitation and waste disposal are problems under management control, the effects of climate change, as well as income distribution, poverty and social stresses, become the major problems.

The question could then be asked: to what extent is cities' sustainability actually being realized? The recent concept of smart cities development[1] (Naphade, 2011; Neirotti et al., 2014), an innovative dimension enabled by digital technology, was developed in Europe to combine competitiveness and sustainable urban development, and has now extended into other parts of the world (Angelidou, 2014; Lee et al., 2014). The purpose was to have an impact on issues of urban quality such as housing, the economy, culture, and social and environmental conditions, but so far it has been designing sustainability concerns largely around information technology, social networks, services, security, energy and transport-related issues.

More than creating sustainable lifestyles and livelihoods, the driving force in cities development seems to be the creation of space for people, as needed to respond to a growing demand for economic growth. Conversely smart cities development is much driven by systems engineering in smaller size cities, and is encouraging connections and networks, but mainly of materialized infrastructures, including information and communications technologies, energy and transport, and water and waste management infrastructures, often expressed as urban metabolism (Niza and Ferrão, 2006; Niza et al., 2009; Pinho et al., 2013). Both ecological and social dimensions, and in particular