Chapter 9

Sustainability contributions to the energy system: more than one problem to address

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Abstract

Current debates about a more sustainable energy system strongly emphasise the role of CO_2 emissions and climate change. Without denying the urgency of reducing CO_2 emissions, it is important to recognise that this is only one of several categories of requirements for creating a more sustainable energy system. This chapter discusses three of these categories: (1) access and security, (2) climate change and environmental impact, (3) economic and social development. The problem of dealing with three different perspectives is illustrated with reference to the development of concentrated solar power. It is clear that a more sustainable energy system cannot be achieved using the simple creed that renewables reduce CO_2 emissions and are therefore good. Understanding the different issues that need addressing may not in itself resolve disagreement, but will at least create a common understanding of what is involved.

9.1 Introduction

Since any life on earth depends on energy, modern civilisations do so too. Both impacts on and disruptions of the energy system can directly threaten the foundations and futures of societies all around the world. In recent years, much attention has been paid to the problem of global warming. In response to threats posed by global warming, many have advocated increasing the share of renewables in the energy system. Renewables-based electricity is claimed to be more sustainable than conventional fossil fuel because of lower CO_2 emissions. Although this argument is convincing to many, it is important to stress that there are more dimensions to the sustainability problem that need to be taken into account. While a one-dimensional approach may be attractive for its simplicity, it is illusive and even dangerous to use it for making decisions about current and anticipated energy problems.

In this chapter, I give an overview of the main problem dimensions that have been identified in the energy domain. It intends to help sustainability-oriented readers get a better understanding of the complexity that people face when trying to act upon the issues of renewable energy and global warming. Second, I elaborate on one energy technology in particular, to illustrate the complexity of energy-related problems and how they relate to practical dilemmas in decision making and technology development. Concentrated solar power (CSP) is a renewables-based technology that converses solar energy to heat, and then to electricity which can be transported to consumers.

9.2 Challenges to the global energy system

As a rule of thumb, challenges to the energy system can be reduced to three main dimensions. (e.g. Flüeler, Goldblatt, Minsch, & Spreng, 2012):

1. Access and security
2. Climate change and other environmental impacts
3. Economic and social development

Although more detailed classifications do exist, they are not necessarily more inclusive. For the sake of comparison with the above three main challenges, Box 9.1 presents an example of a different classification. The following paragraphs will be used to elaborate upon each of the three challenges.

Box 9.1 Global energy challenges identified by GEA

A more detailed example of the challenges faced by the energy system is given in the Global Energy Assessment (GEA, 2012) . This sizable report proposes seven key global energy challenges:

- "providing **affordable** energy services for the well-being of the 7 billion people today and the **9 billion** people projected by 2050;
- improving living conditions and enhancing economic opportunities, particularly for the 3 billion people who cook with solid fuels today and the 1.4 billion people without **access to electricity**;
- increasing **energy security** for all nations, regions, and communities;
- reducing global energy system greenhouse gas emissions to limit **global warming** to less than 2°C above pre-industrial levels;
- reducing indoor and outdoor **air pollution** from fuel combustion and its impacts on human health; and
- reducing the **adverse effects** and ancillary **risks** associated with some energy systems and to **increase prosperity**."

(GEA, 2012, p. XV) [emphasis added]

Access to energy and energy security may appear mere technical issues in many Western countries, but it definitely is not. Unexpected geopolitical and natural events may influence or even cut off the supply of energy, and even the most technologically advanced countries go to great lengths to diversify their energy sources (Yergin, 2011). The situation is even more problematic in developing countries, as they struggle to keep up with the rising energy demand, and energy poverty is often a real issue here. A stable energy supply supports economic progress and can give social status, and electric power is connected to social power and conflict in many ways (Flüeler, et al., 2012). The introduction of renewables brings new challenges to secure energy access, as in communities depending on fossil fuels and nuclear power, renewables introduce a new source of instability to currently stable electricity grids. In short, a renewable revolution will lead to many challenges related to grid stability, ownership, intermittency, energy storage, transmission, life styles, and so on.

A second challenge to the energy system relates to climate change and other environmental impacts. CO_2 emissions from the combustion of fossil fuels are a big part of the total greenhouse gas emissions that are claimed to cause anthropogenic climate change. Other environmental impacts from the energy system include different forms of air pollution, land-use changes, and resource use. Over time many of these problems have grown as the energy system evolved, and affect the entire range from the household to the global level (Flüeler, et al., 2012). Responding to these environmental impacts requires both mitigation and adaptation measures, and both bring along new challenges. In addition, the introduction of renewable energy technologies also entails environmental impacts. While the energy sources themselves may be renewable and non-polluting, the technologies and grid modification needed to use renewable energy certainly are not.

Economic and social development forms the third main challenge identified. The world as we know it has been built by relying on relatively cheap fossil fuels. It should therefore not be surprising that even small changes in global supply may have immediate and far-ranging social and economic impacts. Price increases have led to economic recession, but might also enhance energy conservation measures (Flüeler, et al., 2012). At the same time, political and commercial organisations impose rules to stabilise the impacts of the energy system. In view of the complexity of the system, we must always be prepared for unexpected impacts. Mass introduction of renewables in Germany has led industries to lobby for exemptions from contributing to extra energy taxes, creating wider public dissatisfaction with increasing energy bills. In short, whether one advocates renewables or fossil fuels, energy strongly influences economies and societies. The impacts of changes to the energy system are wide-ranging and often impossible to predict.

A sustainable energy system requires each of these three challenges to be met. Moreover, there is no use in approaching each of them in isolation. Access and security, climate change and other environmental impacts, and economic and social development are interrelated. For example, coal-based electricity may allow for stable access to energy and promote economic development. But when considering the construction of a new coal-fired power plant, such concerns are of little use when social and environmental impacts are so detrimental as to threaten the health and environment of the people involved. In China, a country built on coal, political and business leaders have recognised the need to diversify beyond coal to improve the sustainability of its cities (Yergin, 2011). At the same time, 100-m tall windmills may improve air quality and atmospheric carbon levels, but these green machines also generate opposition based on visual impacts and grid stability. The key is to treat energy problems in a holistic manner. There is no such thing as a perfect solution without negative impact. Instead, it is better to recognise that trade-offs have to be made (Gibson, 2005) in the energy system.

The next section discusses some specific energy issues regarding CSP, a renewable energy technology based on conversion of solar thermal power. Specific attention is paid to the translation of very practical technology-specific issues to the three domains of energy challenges. The section illuminates some of the possible trade-offs that result from this.

9.3 Issues and trade-offs regarding CSP

As a starting point for describing a technology, it is common to refer to a collection or configuration of technological artefacts. At its core, CSP consists of a type of solar collector and a thermal energy storage system (Tian & Zhao, 2013). More detailed descriptions distinguish between a heat transfer system, a cooling system, a transmission system, and so on. For each element there are different possible options, and the selection of the most appropriate configuration depends on the specific location and application (Brown, 1983).

Next to physical artefacts, there are also a number of social aspects that can be included in a technology. For example, CSP-generated electricity is sold on electricity markets, and government agencies need to regulate these markets to maintain stability. In addition, CSP requires engineers to build and maintain the plants, and hence education programmes are needed to train the engineers for their job. Together, these different social and technical aspects are described as a socio-technical system (Geels, 2004). Obviously, these different social and technical elements do not exist in isolation from each other, as it is the whole that we need to consider to form CSP. This makes it possible to say that technical and social elements interact and shape each other (Bijker & Law, 1992).

Just like renewables in general, solar energy is also claimed to be clean and abundant (Kalogirou, 2004). And similarly, collecting, converting, and transporting solar power for future use generates pollution and other side-effects. Like any energy technology, CSP is not free of negative impacts either. This section further elaborates on some practical issues that influence the contribution of CSP to a more sustainable energy system. It also elaborates on some trade-offs that emerge in decision-making about CSP.

Intermittency

A key issue with solar based technologies is that they have a fluctuating output, depending on the availability of sunshine. Less solar energy will reach a CSP plant when it is cloudy, and none at all at night. This fluctuation in output is called intermittency. Intermittency is greatest with wind energy, but has also been used as an argument against many other renewables, because it would threaten the stability of the energy net, leading to black-outs. As the electricity net cannot store energy itself, a scenario in which renewables become the dominant energy source would require either an amount of energy to be stored somewhere or flexible demand for energy, which in both cases must be able to be used instantly (MacKay, 2008, p. 186). A key advantage of CSP is that it generates heat – thermal energy – which can be stored directly, and more efficiently than alternative storage options, as alternative options such as batteries require an additional conversion step in which energy is lost (Palgrave, 2008). Thermal energy storage allows CSP to supply electricity on demand, thus addressing the problem of the intermittency of solar energy (Guillot et al., 2012). This increases the security of energy access. At the same time, it allows more renewables-based technologies to be connected to the grid, thus lowering average CO_2 emissions. The properties of CSP in terms of dealing with the intermittency of renewables appear to have so far been underemphasised, though it has been argued that these should be taken into account in investment decisions on renewables in the energy system (Kost, Flath, & Möst, 2013).

Resource use

In the second section we have noted that renewable energy based technologies also generate environmental impacts. One of these impacts is related to resource use. An inventory account of all the resources needed to build a large-scale CSP infrastructure has provided evidence for the conclusion that resource scarcity is not expected to become a major issue in future CSP development (Pihl, Kushnir, Sandén, & Johnsson, 2012). At the same time, it is recognised that water usage poses a different and complex problem. Most CSP plants require large amounts of water for cooling purposes at the site of the plant (Damerau, Williges, Patt, & Gauché, 2011). This creates a sustainability challenge, as deployment of CSP is intended for water-scarce desert regions. Dry cooling systems or desalination of salt water have been identified as possible solutions to this problem, but come with an energy penalty (Damerau, et al., 2011). Withdrawing large amounts of water from a water-scarce region will impact on local ecosystems and at the same time risk social unrest.

Conversion efficiencies

The efficiency with which a technology can convert one type of energy into another is called conversion efficiency. In CSP, the thermal energy of the solar power collected is converted to electric energy using a turbine or generator. High conversion efficiencies allow a technology to optimise the use of the energy embodied in the energy source. In principle, higher conversion efficiencies create a competitive advantage for a technology as they enable it to generate electricity at lower prices. Additionally, higher conversion efficiencies decrease the number of power plants and resources required to produce a certain amount of electricity. Unfortunately, increases in conversion efficiency may bring along higher costs as well. A trade-off between conversion efficiencies and investment costs also affects current CSP developments. A distinction can be made here between two types of technologies. Parabolic-trough CSP systems are cheap and proven over time, and operate at relatively low temperatures around 400°C. CSP power towers can generate higher temperatures of up to 1000°C, allowing for higher conversion efficiencies. However, they are more expensive to build than parabolic-trough plants (Taggart, 2008). Trade-offs between conversion efficiency and costs provide a key challenge to decision making on CSP.

9.4 Concluding remarks

This chapter has shown that various concrete technological choices are inherent in a range of socio-technical and environmental debates. As a rule of thumb, there are three main challenges to the energy system: access and security, climate change and environmental impact, and economic and social development. This chapter has elaborated upon the main challenges and illustrated them using examples of solar-based technology. Briefly, the intermittency of renewables challenges the security of the energy system, even though CSP can play a positive role here. Water used in wet cooling of CSP puts an environmental burden on already water-poor areas. Decisions on conversion efficiencies trigger technological development and consequently economic and social development.

Energy issues are not confined within the boundaries of one specific challenge. The choice to use dry cooling technologies comes with an energy penalty, which has an impact on economic growth and might restrict access to energy for the poorest communities. Thermal energy storage may lead to pressures on investment decisions. Conversion efficiencies are not merely a cost issue but also affect the number of electricity plants that need to be built, causing different environmental impacts. The interrelatedness of different types of side-effects adds to the complexity of decision making in the energy domain.

Sustainability scholars interested or involved in decision making in the energy domain should be appreciative of the multiple and interconnected dimensions of the energy question. A more sustainable energy system cannot be achieved using the simple creed that renewables reduce CO_2 and are therefore good. In a sense it should not matter whether one works for Big Oil or supports Greenpeace. Both need to recognise energy security and environmental, economic, and social impacts. Understanding the different issues that need addressing may not in itself resolve disagreement, but will at least create a common understanding of what is involved.

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