Chapter 2
Framework for the Development of a Long-Term Viable Energy System

In order to realise a long-term viable energy system, various aspects have to be taken into account. On the one hand, overall targets of the society and general aims of the energy system have to be considered in order to define what a desired solution might resemble. On the other hand, the complexity and interweavement of the energy supply system with the society have to be taken into account with regard to recommendations and the design of adequate advisory procedures.

In Sect. 2.1, the general aims of energy supply are discussed, and then further developed in Sects. 2.2 and 2.3, with a clear distinction being made between safety and security. A fitting concept of robustness is derived from this discussion in an effort to clarify the respective demands. Section 2.4 concentrates on the introduction and development of means for developing viable energy systems.

2.1 General Aims of Energy Systems

A very simple definition of a (technical) energy supply system is a practical means for providing the required[1] amount of useful energy to the consumer. Taking this simplified view, the following conditions should prevail:

- The system should fit the purpose, meaning that the use of the tool should lead to the intended effect of providing a usable energy supply in the required amount.
- Unintended negative effects should not outweigh the intended effects.

Taking into account that the realisation of an energy system is one of many competing challenges which a society needs to tackle, the efficient allocation of economic resources plays a crucial role in the evaluation of the various options. Furthermore, the impact of the energy system on the environment, and particularly on natural resources, has to remain within reasonable limits. A third, quite basic,

[1] Useful energy includes such things as the light required to read a book or the electricity needed to use a computer. This shows that the system, as defined above, ends at the consumer.

B. Droste-Franke et al., *Improving Energy Decisions*,
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dimension which is often considered is the reliability of the energy system: the assurance that the demand will always be met. Accordingly, the concrete aims derived from the overall intentions of energy systems are often caught up in the political triangle of the three conflicting targets: economic efficiency, environmental compatibility and supply security. As a fourth target, social acceptance has recently entered respective discussions in some cases.

An additional and more economically based perspective is that of resource allocation and fair distribution. This stems from such concepts as socio-economic efficiency, which seeks to achieve maximal well-being[2] and sustainable development as pre-requisites for the development of a long-term viable energy system. This direction enables alternative indicators in the energy area to be derived, such as environmental protection, resource availability and energy system design with regards to (the needs of) the society (see e.g., Droste-Franke et al. (2012, p. 12), Steger et al. (2005, p. 54)). The first indicator focuses on the unintended negative impacts of energy systems on natural entities while the second highlights the use of resources with respect to the long-term operability of the system. The third aspect summarises all societal aspects including "reliability (end user), openness of options, [and] risk avoidance" (Steger et al. 2005, p. 54).

The design of these typical indicators used to evaluate energy supply systems reflects the yet unsolved challenges related to their adequate and viable long-term design. A detailed examination of the effects of currently realised energy supply systems on resource availability and environmental effects over approximately the past 40 years has revealed that their actual use would potentially lead to major, hardly acceptable or even unacceptable impacts. Furthermore, the limited supply of fossil-fuel energy and raw material resources and the environmental effects of gas emissions that may well lead to a change in Earth's climate by reinforcing the so-called greenhouse effect of the atmosphere have been identified as having the potential of being severely harmful. Overall, a mixture of abatement and preventative measures has been followed in an effort to tackle these challenges. As most fuels being used are of fossil origin, consisting mainly of organic substances containing carbon chains as their primary components, carbon that is removed from the surrounding environment through biological and geological processes is re-entering the atmosphere in the form of carbon oxides. At the same time, carbon dioxide, the main product of reactions of energy efficient processes, is one of the main substances increasing the greenhouse effect. Therefore, this strategy's main focus is on restructuring energy supply processes by switching to technologies with lower carbon dioxide emissions. Switching to the use of a larger portion of renewable sources has become widely accepted and simultaneously tackles the problem of the depletion of limited fossil fuel supplies. According to the assessment of scenarios of future energy systems able to cope with these challenges, a significant change in systems clearly appears necessary (e.g., IEA 2013). With these changes, in

[2] Here, the term *well-being* ideally includes aspects of welfare as well as other utilities which cannot be easily captured in monetary terms.

particular, the increasing share of technologies using renewable sources is giving rise to completely new challenges; in order for these technologies to be adequately implemented into the energy supply, other framework conditions have to be given far more consideration than before. Additional conditions become also relevant, such as changes in local weather conditions and the inherent ability to meet the demand at any given time simply by adjusting the supply respectively.

Therefore, the establishment of a long-term viable energy system, energy security or reliable energy supply as one of the three targets, or as a component of the societal aspects, becomes much more relevant for valuable analyses.

2.2 Conceptual Role of Security and Safety for Energy Systems

As discussed above, security is an explicit target for future energy systems. In one case it was directly mentioned, while in the second case, it was spoken of in terms of supply reliability. Widely interpreted secure supply even includes socially relevant factors as economic efficiency and acceptance. Furthermore, together with the long-term perspective of the targets, the *concepts of security and safety* implicitly include most aspects of all of the discussed indicators. However, there is a noteworthy ambiguity between security and safety which is not explicitly alluded to in the characterisation of systems, but is rather given implicit consideration. First, it should be noted that the two concepts do not always have unambiguous counterparts in other languages. In German they both translate into the same word, *Sicherheit,* while in Norwegian, they translate into *sikkerhet* and *trygghet,* respectively. This could perhaps be interpreted as an implication that the English connotations are somewhat fragile or fleeting. This already indicates that, within the context of risk, the terms seem to imply different perspectives and, in particular, they may imply different perceptions of how potential harm could be expected to arise, and from where.

In English, safety can typically be understood as referring to an inner-system perspective, while security typically refers to an outer-system perspective. Safety measures are called for when it is assumed that the workings of a system to bring about a certain outcome may malfunction, in which case the system would adversely affect its environment, by releasing toxic substances or allowing other dangerous materials to seep out. The typical strategy for addressing these concerns involves optimising the containment of the system to ensure that the effects reaching the outside systems are only those that are supposed to reach the outside.

Security is different. Within this framework, we look at a (production) system from the outside and ask whether (a) the effects that the system is supposed to export to the outside are reliably produced and that they unfailingly reach their endpoints, and (b) only the outside factors (e.g., humans) that are necessary for producing the intended effects of the system actually reach the inside of the system.

Given the difference between these concepts, it also follows that the related social dynamics are also not the same. Questions may arise: Who is targeted by safety measures? Who is targeted by security measures? What is the possible extent of these measures? The claim may be made that safety measures are typically more limited in scope and more directed towards a uniquely defined group of actors. It could be argued, then, that security measures—since they deal with open systems from the outside—are prima facie more extensive. They may even involve a whole society (as is the case with air-travel security, etc.). For the same reason, security easily comes into conflict with other values of an open democratic society, such as the right to privacy. In electricity systems, smart grids may arguably be an important contribution to increasing a society's electrical power security, but they are also suspect with regard to privacy.

It is against this background that we argue that a move from safety considerations to security considerations in an energy supply system requires openness to placing the whole system in a larger socio-cultural framework of basic values. Furthermore, the ethics of new systems should be anchored in societal debate and, hopefully, in societal consensus.

2.3 Robustness as a Basic Aim for Energy System Development

The characterisation schemes cited above and the discussion about the ambiguity of security and safety demonstrate that ensuring a secure and safe energy supply system is a major aim for future energy systems and that this requires a great deal of attention.

Based on the discussion of the above-cited targets, it can be concluded that a central aim of current and future energy systems is to be capable of providing continuously adequate energy services at any given time in future. This aim highlights the aspects of security and safety as major foci of this study, and can be subdivided into two main aspects:

- the provision of sufficient services at all times throughout the system change and
- the long-term adequate usability of the resulting target system.

During the transformation process to the target system, the role of existing elements in the system will change: New elements will be introduced while old elements, already functionally proven, will subsequently lose their relevance for the proper operation of the system. In a practical sense, this results in a gradual exchange of a socio-technical system's functional elements even as the system remains in operation. As argued above, social embedding is a particular challenge with regard to the analysis of security issues. Accordingly, maintaining reliable service can be expected to be a complex issue.

We will now examine the increasing challenges related to the specific concepts of dynamic stability (Sect. 2.3.1) and social robustness (Sect. 2.3.2), so as to identify potential instruments which could be used to reach these basic aims (Sect. 2.4).

2.3.1 Dynamic Stability

The development of an energy system is subject to uncertainty. When implementing a new system, it is essential to give heed to dynamic stability, with the goal of continuing along the best possible path without thwarting future prospects through bad decisions taken early on. Indeed, a wrong turn taken at some critical point could put the entire endeavour at risk. Dynamic stability is defined as the act of not undermining one's long-term goals and commitments through bad choices; it means improving the odds for remaining on track. Steering the development of an energy system and adjusting it to significantly different conditions in a dynamically stable fashion is guided by two major requirements: *robustness* and *opportuneness* (Ben-Haim 2006, pp. 3–4). Robustness means staying within an admissible corridor where one is safe against adverse effects (see also Sect. 3.1.2). In this sense, the term robustness is used with regard to the properties of an energy supply system. In Sect. 3.1.2, robustness is discussed as being a specific quality of expert advice. In both cases, the underlying idea is the same: Robust items remain the same despite changes in conditions around them. Opportuneness means that we are able to take advantage of opportunities that open up unexpectedly.

A robust energy system should be structured such that a stable supply of electricity is guaranteed in spite of fluctuating sources and demand. The same requirement of robustness can be brought to bear one level up with respect to technological changes. For instance, the present scenarios for enhancing the supply of renewable energy envisage the long-range transport of wind-generated electricity. Electricity produced by wind turbines in northern Germany, where strong winds are typical, would be transported southward. The underlying idea is that the centralized structure of the present energy distribution system (a few large power plants and a huge number of scattered, small-scale consumers located far away from these plants) should be retained in principle. That is, electricity is produced at a few preferred places and distributed to the consumers over large distances by means of an elaborated grid. An alternative, more decentralised structure, however, needs to be considered. In such a framework, a large amount of electricity would be produced locally by photoelectric cells on myriad roofs and stored on site by using improved batteries or other storage technologies. A technical shift of this type has the potential for providing greater electrical autonomy for single-family households. This shift would bring about a decrease in the demand for large-scale distribution and, accordingly, for a huge supply network.

A robust energy system is safe against natural fluctuations and technological innovations, and aims to prevent the development of a lock-in situation. Such a situation can arise when an energy system is in some respect inferior to its envisaged alternative but when moving to this more suitable state is extremely difficult or even impossible. An elaborate but superfluous electricity supply network would be a prime example of being caught in a lock-in state.

Strategies that may promote robustness include the following: (a) pursuing options in parallel, (b) beginning with measures that are necessary anyway (no-regret actions), (c) postponing decisions. All such measures should be implemented in an iterative fashion, i.e., using a stepwise procedure with phases of reflection and reconsideration. Pursuing options in parallel obviously reduces the impact of adverse influences. This is achieved by providing fallback schemes. Beginning with no-regret actions is different in that it does not shield the system under consideration from distorting influences. Rather, the underlying rationale is to do nothing wrong and to start with what needs to be done in any case. Postponing decisions sometimes helps to prevent manoeuvring oneself into a lock-in state. However, delaying counteraction does not favour robustness under all circumstances and should be used with care and moderation. Sometimes, refraining from making a decision is tantamount to making a decision. If no plans are made to expand the distribution grid, offshore wind electricity is effectively abandoned. In some cases, there is pressure for a decision to be made; fast action is called for in order to deal with oncoming hazards. As a result, robustness is not always enhanced by an attitude of inaction. In order to be on the safe side, hazards and dangers often need to be actively addressed.

It is worthwhile to consider two examples that point in opposite directions. In the early days of atomic energy, no suitable procedures were available for the permanent and safe disposal of nuclear waste. Therefore, experts recommended that the waste be temporarily stored while they waited for new technological solutions to emerge. As it stands, no fundamentally new or better options have been provided, leading to the conclusion that inaction on this issue may well turn out to have been a wrong decision. If a decision about final storage had been made earlier, rather than suspended, the relevant technologies would probably be further developed than they are now. In contrast, uranium residues in the soil of the Erzgebirge, left over from the former East German mining industry, were collected and removed after 1990 by means of chemical processes. Many years later, however, the existence of a cheaper and far more efficient strategy was discovered for extracting uranium residues from the ground, through the use of suitable bacteria and microbes. A number of organisms take up uranium from the ambient soil and incorporate it into their cells (Urban 2014). In contrast to the first example, then, postponing remediation and adopting a wait-and-see attitude in this case would have been beneficial—a bad surprise would have been avoided, thereby making our action more robust against technological change. Such matters will always be afflicted by uncertainty, however, as it is difficult to discern to which category a given case belongs.

Robust energy systems always comprise a variety of elements or options. Each such element tends to work best under different conditions, which results in the fluctuations of these conditions being balanced between the various elements involved. It follows that, in most cases, a robust system will not represent the most efficient or least expensive system at any given point in time. Economic optimisation under certain conditions is typically bought at the expense of flexibility and, hence, robustness. Robustness comes at a price.

Opportuneness is the second requirement for coping with the vagaries of technological change. Dynamic stability not only means staying on the safe side in order to prevent bad surprises, but also being able to take advantage of pleasant surprises, that is, of new and unanticipated technological opportunities. For instance, if a technological breakthrough occurs in a relevant field, it is best to be in a position that allows for an adjustment of the recommended pathway and a switch to a new regime. If, for example, an effective and inexpensive catalyst were discovered with the ability to separate CO_2 from the exhaust emissions of coal-fired power plants, this new technological process would certainly affect the comparative ecological evaluation and hence the public acceptance of such plants. Such a discovery might result in a political decision to increase the portion of fossil fuel-based energy among the sources of a given national energy supply.

There is a desire for politicians to be able to adjust to new opportunities. However, the general pattern is that any implementation of a decision concerning the structure of an energy supply system decreases the leeway for future decisions. Opportuneness, however, requires that options be kept alive as long as possible. Indeed, the three following policies for augmenting robustness also serve to enhance opportuneness: First, pursuing various technological tracks in parallel increases the odds of being able to take advantage of some future technological development. An ideal example is that of the variety of tracks that are followed in the development of future engines for automobiles. With regard to electric drive vehicles, batteries compete with fuel cells; in the case of combustion engines, biofuel competes with methane and hydrogen produced by using green electricity. Robustness and opportuneness are both favoured by simultaneously betting on various alternative options. The second policy involves the adoption of a strategy in which inescapable steps are taken, thereby leaving space for new options to emerge. For example, no matter what a future electricity system may exactly be like, it will definitely include wind energy generated offshore. Accordingly, the construction of a certain transport capacity from offshore wind turbines to the on-shore distribution grid will surely not unduly predetermine how the energy system will develop as a whole. Similarly, dual-use equipment also falls under this category. For instance, battery-powered automobiles could be used as a decentralised storage system for balancing fluctuations in electricity as supplied by unstable renewable resources. This would reduce the need to invest in additional storage systems while remaining more flexible. Third, postponing decisions certainly favours opportuneness. Taking immediate action always tends to reduce the leeway that future opportunities might provide. As argued earlier, suspending action sometimes favours robustness and sometimes does not. However, with regard to opportuneness, no such ambivalence emerges. Opportuneness is in most cases promoted by delaying verdicts and choices and by adopting a wait-and-see attitude with regard to the future of scientific progress.

On the face of it, opportuneness is an opponent to robustness in that the latter seeks stability and safety against adverse effects while the former aims at achieving flexibility and windfall gains. Robustness is a risk-aversive strategy while opportuneness seeks to capitalise on hazards. Certain risks or uncertainties are accepted today so that new and unanticipated options may be taken advantage of once they emerge in the future (Ben-Haim 2006, pp. 37–39; Carrier 2010). However, when it comes to taking actual measures, this opposition between the general goals and attitudes largely evaporates. In particular, robustness and opportuneness are both favoured when it comes to measures that need to be implemented in any event and the pursuing of technological options in parallel. In order to take advantage of unsuspected technological progress, a wide variety of options must be kept in play as long as possible. Differences emerge when it comes to the strategy of postponing decisions. Such a strategy is in harmony with opportuneness: In order to remain open to new technological developments, no potential future countermeasures should be blocked by premature decisions today. In contrast, robustness is typically not enhanced by applying a wait-and-see strategy.

The conclusion is that opportuneness and robustness are at variance with each another as regards their relationship to hazards and opportunity. At the level of more specific recommendations, however, robustness and opportuneness often coincide. The peaceful coexistence of robustness and opportuneness can break up in some cases, though, as the conceptual tension between the two strategies becomes manifest in opposite recommendations.

Markets provide strong incentives for producing efficient solutions that are fine-tuned to specific conditions. Market solutions are optimising and focused on the prevailing circumstances and expectations. As a result, markets tend not to deliver robust solutions (see above). Only when different market segments are able to operate under different conditions and requirements can a variety of distinct options emerge. The energy market is no exception to this; it conforms to the more general rule that markets on their own do not create an overall system that is resilient to unanticipated intrusions. Left to their own devices, market forces cannot be expected to produce dynamic stability by themselves. Instead, some comprehensive scheme, which is best developed by drawing on foresight and epistemic penetration, is required for building a robust energy supply system. This is why science-based policy advice can prove helpful in exploring the dynamically stable pathway toward a robust energy supply system.

However, once such a scheme has been elaborated and agreed upon, it is best implemented by the introduction of a framework within which market forces can unfold. This involves setting incentives such that the most efficient solutions are developed within a framework that encourages robustness and opportuneness. The reason for preferring markets and avoiding central planning when implementing such a general scheme is that market forces stimulate inventors: They may well take advantage of local niches or specific repositories of knowledge in order to find solutions that precisely match the demand at hand. However, by virtue of only being payable at a later point in time, many future costs are simply unable to influence present-day market choices. Markets will only become sensitive to upcoming challenges if market regimes are introduced that are suitable to transforming such future costs into contemporary debits. In sum, markets produce efficient solutions on their own; foresight and prudence need to be hand-fed.

2.3.2 Social Robustness

The term *social robustness* means that an expert analysis or recommendation is acceptable within a wide spectrum of diverse interests and value commitments (see also the discussion of epistemic values in expert judgments in Sect. 3.1.2). Social robustness articulates both the leeway and the limits of social compatibility. Socially robust expert advice is acceptable to a variety of value attitudes and interests. In other words, social robustness aims to achieve social inclusion.

Participation can be portrayed as a means of tapping sources of knowledge that usually remain hidden from scientific view (see also Sect. 3.1). Yet participation also plays a role in the framework of social robustness. In a political context, social robustness calls upon scientific experts to take the stakeholders' views into account. Participation serves the purpose of encouraging experts to listen to and take up local interests. Ignoring local objectives, goals, or concerns makes experts appear arrogant in the eyes of the public and makes people doubt whether the expertise being offered has anything substantial to contribute to the contentious issue at hand. Brian Wynne (1996) tells of one example of the utter failure of scientific experts in his story of sheep farmers. Here, scientific experts completely failed because they did not take local values and aspirations into consideration when solving the problem (Sect. 3.1.2 provides additional details). One of the reasons behind this was the unwillingness of the experts to listen to the farmers and take their economic interests into due account. Accordingly, social participation is a means for enhancing social robustness. Taking up the views of the lay people and attempting to integrate them into the expert recommendation improves the odds of the recommendation being politically accepted. For instance, the widespread value-based attitudes of the population have been crucial in weakening the prospects of carbon capture and storage (CCS), which was feared to be unsafe, and biofuels, which were perceived in some regions as exacerbating world hunger. Anticipating the impact of such evaluations in expert recommendations plays a large role in increasing social robustness. Another means by which to achieve this effect is epistemic robustness. For instance, the attempt to "play it safe" often helps to pacify conflict and create bridges between opposing factions. Setting strict threshold values shows a compliance with worries among social groups and demonstrates a willingness to meet the critics halfway.

Such moves make it easier for relevant expert advice to be utilised. In a sense, social robustness is a policy for implementing expert recommendations, an attempt to get analyses and recommendations of high epistemic quality politically realised. From an epistemic angle, there is often room left over for resolving an issue of social import. This space is filled by taking social interests and value commitments into consideration.

Furthermore, basing decisions upon socially robust expert advice increases the chances that robust policy strategies will be followed, and not changed with each election.

2.4 Means for Tackling Complex Social Choices

The discussion above demonstrates that the management of structural changes in an energy system requires, on the one hand, that the robustness of the system (the fact that the energy supply is reliable and protects the society from unacceptable adverse effects) is ensured, and, on the other hand, that opportuneness is maintained such that unexpected options may be taken up in order to improve the energy supply system. Furthermore, social robustness should be sought. Participatory processes should be used to align technology policies with the value attitudes of the population and with stakeholders' interests. Thus, participation has the objective of facilitating the implementation of recommended measures derived from expert advice.

This section discusses tools which can be used to deal with complex decision-making situations in the energy area. First, the general role of system analyses is discussed with regard to deciding upon potential alternatives (2.4.1.1). The complexity of the decision-making situation and the resulting areas for system analyses are then outlined through the introduction of a theoretically consistent perception of energy supply systems (2.4.1.2). Section 2.4.2 finally concentrates on tools which can be used to incorporate fundamental ethical aspects into the decision-making situation, thereby allowing for the participation of the relevant stakeholders and the consultation of the relevant system analyses.

2.4.1 Safe and Secure Energy Supply Through System Examination

As mentioned earlier, an energy supply system is a technical system that relies on durable, long-lasting infrastructure. Therefore, initiating a structural change while simultaneously ensuring a robust energy supply at any given point in the future requires not only market mechanisms, but mid- and long-term planning or respective market designs. This change should be based on a sophisticated, reliable plan covering the changes in the energy supply system or its respective framework conditions. Such in-depth planning is necessary, particularly if the change involves more than merely single components, and the structure of the whole system is affected. As discussed above, this is the case with the planned changes in the energy supply system with regard to drastically reducing CO_2 emissions, e.g., in the context of Germany's Energiewende, or energy transition, and similar attempts in other countries.

Considering that sound knowledge about the future can never be made available today, it is impossible to foresee the exact details involved in the concrete technical realisation of a change. Therefore, it should be borne in mind that more generalised, robust advice is more valuable for political decisions than detailed statements about in-depth optimal solutions (see also Sect. 3.1.2).

2.4.1.1 System Descriptions as Tools for Decision Support

Successful planning requires the consideration of framework conditions which influence the success of actions as well as the anticipation of all important causal impacts of the actions. Figure 2.1 illustrates the relevant connections in a simplified way. Neglecting non-linearity and repercussions, a successful action on the part of actor A leads to the intended change in circumstances, shown as X_1, and further impacts (X_i, $i > 1$). Some of the impacts of the action may be desired (green), some may be undesired (red) and some changes have no relevance on the decision (yellow). The causal relations, shown as slim black arrows, are co-determined by framework conditions, shown as broad arrows.

The analysis of relevant framework conditions and the possible impacts of planned actions require the acquisition of insight into causal relationships between both events and actions and changes in relevant circumstances. This is the basic precondition for a rational comparison of various options for action with respect to their potential impacts. More precisely, a reconstruction of regular correlations between circumstances is needed. In the following description, a phenomenon showing such correlations is called a *system*. A *system description* is always carried out with a certain purpose and from a specific perspective.

Here, a simple perception of systems is followed, allowing insight into the most important aspects of energy systems. Circumstances can be reconstructed by describing the entities involved and their state: In the case of a system, characterised

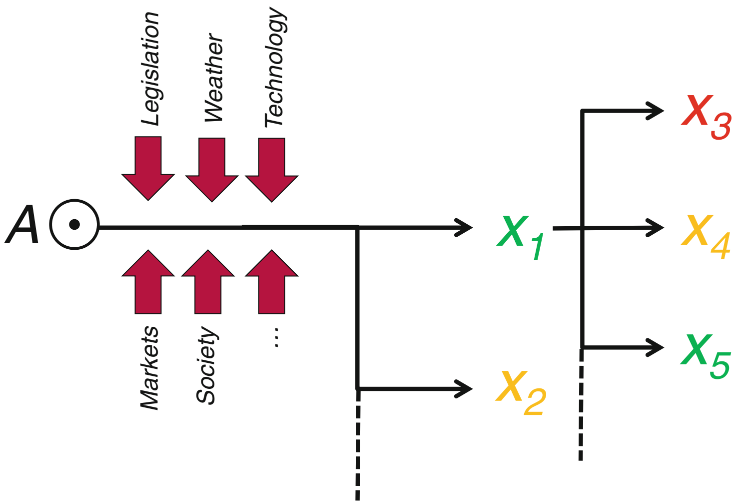

Fig. 2.1 Under the given framework conditions, the action of actor A with the intended impact X_1 leads to the impacts X_i

by regular correlations between circumstances, events and actions (described as *change in states or characteristics of entities*) lead via the correlations to changes in the states of other entities. The correlations between one entity's change of state and the related changes of another entity's state are assigned to an *operation* between both entities. In order to describe the correlation properly, the operation must be specified in its description, particularly with respect to the relevant characteristics of the entities it affects. The changes in characteristics of specific entities and their respective operations automatically span the whole system, and are defined as comprising the operation and all the entities' characteristics the operation affects. In the following description, such a system will be called an *operationally closed system*. This basic idea is closely related to Luhmann's (2009) concept of systems, which claims that a system is clearly defined by its operation.

Such a reconstruction of systems as abstract descriptions of the relationships between entities and operations always has a clear purpose, including a specific perspective or approach that is mostly connected to whole theories. A typical theoretical reconstruction of a system can be described as follows: According to the purpose of the reconstruction, an operation is chosen which best describes the relevant functional relationships between the observed changes in states of entities, fixed at certain changes of characteristics. Depending on the chosen operation and its respective perspective or theory, the description of all relevant characteristics of the entities develops automatically. Entities are connected by means of the described regularities of circumstances.[3]

As an illustration of the way in which systems are perceived here, the following examples of operations and their connected systems prove very helpful:

- Communication as an operation (or more exactly in the wording here: the respective regularities of circumstances described by the operation of communication) which, according to Luhmann, leads to the development of a *social system*. In Luhmann's view, the description of relevant communicative links also provides an account of the fundamentals of social actions and relations.
- Various operations (e.g., energy and momentum transfer, chemical reactions, evolutionary development) in the natural sciences such as biology, chemistry and physics prescribed to regularities of circumstances in nature, develop an overall notion of the *natural system* as the sum of phenomena which are observable as pure events without human action.

Analogous to these examples, all further theoretical descriptions of phenomena in academia correspond to such system descriptions.

Scientific knowledge differs from other knowledge by virtue of the stringent procedures of empirical control and the rules of communicative and argumentative rationality that are applied within the academic system. As a result, after a phase of

[3] The description of a system as a verbal reconstruction and the operation and prescribed characteristics of entities, then, could be interpreted as theoretical constructs or artefacts which are used to formulate statements about correlations of circumstances (Janich 2001).

uncertainty and controversy, a system of knowledge is broadly accepted within a discipline. As long as the proper means are provided, scientific statements can always be verified (*inter-subjective* or intersubjektiv, Janich 2001, p.182) by anyone (*trans-subjective* or transsubjektiv, ibid.), at least in principle. With this understanding, scientific knowledge claims to be universal, therefore making it crucial for the planning and building of technical facilities. In order to make tangible statements regarding specific cases, however, such universal knowledge is not sufficient, and, the specific circumstances must be taken into account. In situations such as these, descriptions involving everyday experience and using specifically derived models could be more successful than descriptions made with universal scientific models. The reasons are often elements which are not taken into consideration in the models, such as non-ascertainable details in the real environment and real framework conditions which influence the results. Therefore, when many additional influences (with their origins in local particulars) creep in and do not share more generic considerations, it could be relevant to develop tailor-made models that do not make a claim to universality. Section 3.1 provides a more detailed discussion of the potentials and limits of expert advice for policy support based on system analyses.

2.4.1.2 Basic Description of the Energy Supply System

One of the fundamental systems in the natural sciences is the (operationally closed) *energy system*. Energy is a fundamental notion because energy content can be ascribed to virtually all entities. Thus, from the operation of energy exchange unfolds a system description containing all observable effects around us. In the case of the *energy supply system*, however, the purpose is to use differences between the energy states of entities as a means to achieve specific purposes. In other words, the aim of the system is to provide so-called *final energy* which can be used by the recipient to produce *useful energy* like light, heat, processing information and mechanical energy. There are multiple variations on such forms of useful energy and the consumer is responsible for providing the necessary machines to convert the supplied final energy, e.g., electricity, gas, coal, oil or wood, into the desired form of useful energy.

The example of the energy supply system shows that, in the case of technically realised systems, operational closure does not help to define the boundaries of this system with regard to its environment. This is because the principles and, thus, the basic operation used to construct the technical system, make up a much larger system. However, technical systems are artefacts, constructed with a certain purpose. Therefore, the energy supply system in all its descriptions can be distinguished from its environment through the operational connections fitting the purpose, or *purpose-fitting operations*. The sub-systems which are developed with the purpose-fitting operation are considered analogous to the concept of operationally closed systems in the following *intentionally closed systems*. The energy supply system is then described as the system arising from the energy transfer operation with the purpose of providing useful energy to the consumer. In physical terms, energy is never lost, but simply converted into other forms. Nonetheless, from the perspective of an intentional system as sub-system, energy fluxes seeping out of the sub-system for energy supply can be interpreted as "energy losses" from the energy supply system. Intentionally closed sub-systems are systems for which the description arises from one specific purpose-fitting operation. Therefore, they are bound to a fixed operation and always part of a larger, operationally closed system. At the same time, intentionally closed (sub)systems in an operationally closed system can be described from other perspectives, relying on other operations as well. In this way, the complete intentionally closed system unfolds as an aggregated web of all the operationally closed sub-systems with the same intention developing from all possible perspectives or all relevant operations. Thus, parts of one intentional sub-system, defined by the underlying intention and operation, could represent parts of sub-systems developing from other operations with the same intention. From this vantage point, intentionally closed systems are also located in more than one operational system. While the perspective of the system description may change according to the chosen operation, the intentionally closed sub-system is still clearly separate from its environment. In this way a web of operational systems can be developed to describe systems with a specific purpose. The more perspectives (operations) are chosen the denser will be the intentionally closed web. This approach developed here, thus, will be called the systems-web approach.

In the case that the final energy has to be converted into useful energy before consumption, the energy supply system must be further subdivided into a *system for the supply of final energy*. This, then, can be used by the consumer and a *system for the production of useful energy from final energy*. From a technical perspective, for the adequate design of an energy supply system, the conversion and distribution processes for the final energy supply must be considered, as well as the processes for the use of final energy. Although other perspectives could be chosen, the physical, or technical, perspective provides the starting point here because it is crucial for the designed system to be technically fully functional. Indeed, this is the most fundamental perspective in the sense that it provides the strongest restrictions with respect to the underlying purpose of energy supply, reflecting absolute technical and, behind them, often natural limits (e.g., the theoretically maximum achievable energy efficiency of a technology). It is the starting point for defining the topic from basic configurations consisting of all the technically possible options.[4] However, certain freedom is given to the choice of technology combinations which then must be further evaluated from other perspectives and, where necessary, be further constrained.

[4] It should be noted that in practice, although it is not necessarily the case, there is a risk involved in starting a reconstruction from technically possible systems: The pre-selection of technologies chosen for analysis is further limited by primarily hidden characteristics such as cultural or social influences and historical developments. Thus, it does not always represent the complete selection of technically feasible solutions. These limitations should always be borne in mind for analyses.

From this simple reconstruction of the systems, diverse yet basic aspects of the energy supply system already arise:

- Final energy has to be produced from energy resources. On the one hand, these represent fuels, e.g., materials with a high energetic content which can be discharged through incineration. On the other hand, energy fluxes from the environment, arising from solar radiation and the heat content of the planet, can also be used. In each case, the energy content corresponds to *primary energy*.
- Over the course of various steps, the primary energy as energy flow must be converted into final energy, and, in the process, pass through numerous entities of the energy supply system. The subsequent steps or operations are also called *processes*.
- Energy passed on to entities in such a way that it can no longer be used to provide final energy is considered a *loss from the energy supply system*. These changes in entities' characteristics are no longer part of the system, but instead belong to the system's environment.
- Final energy must be supplied in a very specific way so that it can be used by the consumer either directly or for the production of useful energy. The conversion of final energy into useful energy again represents a sink of final energy from the perspective of the system and is also called *(final) energy consumption*.
- In order to ensure the proper operation of an energy supply system, the energy supply processes must be controlled in such a way that the final energy is usable (as discussed above). For this to happen, an *exchange of various kinds of information* is necessary. In an optimal stage, the supplied energy flow would equal the energy demand at each point in the system.

This rough outline of an energy supply system provides hints to the numerous connections of the energy supply system to its environment (via the operation of energy exchange). These can be distinguished between impacts of the system on the environment and, vice versa, the impacts of the environment on the system which correspond to the system's relevant framework conditions (see Sect. 2.4.1.1). The interdependencies listed below can be identified as a system's connections to its environment, should it be operated normally. The impacts on other systems are marked with arrows. In terms of its description, each system is linked back to its respective overarching scientific discipline:

Some *impacts of the system on its environment in the case of conventional operation* include:

- *Resource usage* results in a change of the energy content and energy flow of the physical environment. Furthermore, materials are often extracted from the environment.

  → Physical system (general energy system), geo-scientific system (material composition of the earth, land use changes), economic system, ecological system

- The *chemical conversion of energy resources* leads to a change in the characteristics of the materials. Both their material state (solid, liquid, gaseous) and their chemical composition change.

  → Chemical and physical system of the earth → natural processes → biological systems (humans, animals, vegetation), physical-chemical system of the environment (inanimate natural elements, man-made environment) → sociological system (society), biological system of humans, health system, economic system

- Final energy is used to *generate useful energy*, depending on the system realisation, more or less *at each location* within an (industrialised) country and exchanged between countries, independently of the locally available energy resources. In comparison to early historical situations in which energy had to be consumed close to its sources, this leads to numerous advantages for society and the economy. Energy is available everywhere up to a technically predefined maximum.

  → Psychology of individuals, sociological system (society), economic system

- A great deal of *personnel* is needed to operate all the necessary facilities in an energy supply system

  → Economic system, sociological system (society).

For a proper *operation of an energy supply system* a number of *framework conditions* are needed. Major preconditions include (with relevant systems shown in brackets, together with the relevant scientific discipline):

- *Energy resources* must be available (geo-scientific system, engineering systems, natural systems, agricultural systems, forestry systems),
- The *technical system,* including the information systems, need to be available (engineering systems),
- The *operation must be approved* by legal or societally legitimated processes (legal system),
- *Sufficient labour resources* must be available (economic systems, social or education system),
- *Rights and duties* which result from the operation as well as business relations must be determined by means of legal regulations (legal system),
- *Earnings of actors in the system* must be possible (economic system, political system (measures), legal system (measures)).

Further *framework conditions* are particularly relevant *for the realisation of the energy supply system*:

- *Knowledge* must be available with regard to the natural scientific basics and technical realisation of the system (natural system, engineering systems)

- The system must be *technically realisable*, and the necessary physical, monetary and personnel resources must be available (economic system (resources, labour, measures), political system, legal system)
- Sufficient and eligible *area and space* must be available (geo-scientific systems, legal system (property law), political system, social system)
- *Adequate approval procedures* must be installed (legal system)
- *Potential earnings* must be secure and high enough over the lifetime of the planned facilities (economic system: markets, measures, etc.)
- *Necessary approvals* must be provided (legal system, political system).

Besides the operation, the realisation also impacts entities in the environment of the system. These impacts may include resource use and environmental impacts as well as economic and social impacts which may occur in the pre-process stages. The following is worth noting:

- Diverse *resources* are needed to build facilities. Besides energy resources, mineral resources are also relevant. Their usage affects the composition and distribution of resources and potentially the landscape as well.

  → Geo-scientific system, *area and space* usage system, economic system (resources), ecological systems

- As a further resource, area and space are needed locally for new facilities.

  → Geo-scientific system, area and space usage system, economic system (land), ecological systems

- Mineral resources are treated by means of chemical processes which are connected to *chemical emissions to the environment*.

  → Chemical or physical system of the earth → natural processes → biological systems (humans, animals, vegetation), physical-chemical system of the environment (inanimate natural elements, man-made environment) → society, biological system of humans, health system, economic system.

In summary, with respect to the realisation and operation of an energy supply system, the following systems (attributed to the disciplines primarily used for their description) are relevant. While the list is incomplete, it should provide indications as to some important correlations which need to be described from different scientific perspectives. Further additions may be made with regard to the different purposes:

- Engineering/technical systems:
  - Framework: realisation of technical systems with desired functionalities
  - Impacts: potential interconnections with other technical systems
- Economic system:
  - Framework: sufficient financial resources, expected revenues, market design, optimal allocation
  - Impacts: structural change of costs and financial circumstances, social benefits

- Political system:
  - Framework: societally desirable energy systems, determination of a regulatory and political organisational framework (approval, participation and acceptance, market design, realisation of long-term reliable framework), discussion and regulation of distributional effects, co-ordination of international strategies, installation of rational planning processes
  - Impacts: decisions regarding societally acceptable impacts, standards and economic measures, influence on the political relevance of actors (decentralised vs. centralised energy conversion)
- Social/sociological system:
  - Framework: acceptance of technologies and individual facilities
  - Impacts: direct and indirect, e.g., changing social structure
- Legal system:
  - Framework: Approval procedures, legal regulation of business relations, rights and duties of operators/users, regulation of economic measures
  - Impacts: legal realisation of maximal burden of measures
- Chemical system:
  - Framework: efficient use of chemically bound energy, avoidance of undesired side-products
  - Impacts: change in chemical concentration in the environment
- Biological systems:
  - Framework: biological energy resources
  - Impacts: change in individual organisms and ecological systems
- Physical systems:
  - Framework: efficient usage of physical processes
  - Impacts: change in physical parameters of the environment
- Geo-scientific systems:
  - Framework: resource availability, appropriate regions/spaces
  - Impacts: change in the earth system, land use changes
- Human scientific/psychological systems:
  - Framework: ways in which to reach acceptance
  - Impacts: psychological and physiological change, on human beings, due to the changes in the environment, increased treatment and medicine requirements.

2.4.2 Ethical Decision Support for Energy Transition

Although the energy supply system is primarily a technical one, the discussion above shows that its realisation and operation affect numerous areas in its environment and, therefore, touch diverse interests. This gives rise to various social conflicts due to impacts and required framework conditions. Therefore, deciding on actions and measures to be taken to change the energy supply system requires that multiple views be considered with respect to societal preconditions and effects.

Even more clearly it can be said that the Energiewende is first and foremost an ethical issue. This was acknowledged by the former German Minister for the Environment, Klaus Töpfer, upon opening the public session of the Ethik-Kommission zur Energiewende, or Energy Transition Ethics Commission. It is a noteworthy statement for multiple reasons.

First, it was both implied and verbally stressed at the deliberations of the Ethik-Kommission that, for the most part, the Energiewende is not a technological issue, despite all the public discussion about the technological feasibility of the various options, e.g., how to replace established energy-producing technologies (like nuclear power stations) with new technologies that rely on renewable (and clean) energy sources. Furthermore, it was claimed that nuclear power was needed as a CO_2-friendly bridge towards renewable energy sources, which, in any case, still lie far in the future. What used to be considered a significant technological challenge with major questions around it, such as energy storage, has now become a seemingly necessary innovative step that will definitely be solved. Other things have moved to the foreground now: ethics.

Second, it is uncommon for a (former) politician to state that an issue is basically characterized by ethical dilemmas, especially an issue that is fundamental to the national economy. In politics, it is typical to balance interests, but what happens when an issue is ethical? Do we appeal to right and wrong outside the democratic practice to follow the majority?

Third, if all the specialists' reports, recommendations and papers are closely examined, it proves difficult to find any written report dealing with the ethical issues of the Energiewende. In these publications, the issues are all highly technical. This begs the question: Who will deal with ethics? The Ethik-Kommission? How will they do that, and with what qualifications? How will they be deemed legitimate? Ethical deliberations are often perceived as rather "soft" when compared to the models drawn up by engineers and economists. The authors of the current study, however, find that engineering and economic models are typically softer than they appear, while ethical deliberations and their implications reveal restrictions which can be firmer than the public typically knows.

2.4.2.1 Energy Transition as an Ethical Choice

Mentioning ethics as a basic requirement for decision-making tends to scare people away, especially decision makers who are trying to fulfil their task in a responsible manner. From the standpoint of the decision-maker, there is nothing better than when an issue can be characterised as a scientific issue for which one can call upon the expertise of scientific experts. The more objective an issue presents itself as being, the better it is for the decision-making process: Policy is merely a reaction to *Sachzwänge*, the factual constraints of the outside world.

The problem with calling for ethics is that it is perceived as being deeply subjective. In practice, such issues are dealt with in one of two ways: Either they are left to the market or they are dealt with by counting votes. In the end, neither of these ways of dealing with intrinsically ethical issues proves very satisfactory. Notoriously imperfect markets are rarely good at dealing with non-monetary values. Majorities as the sole justification suffer from populism and the failure to pay due respect to minority rights.

Obviously, there are choices to be made and measures to be decided upon with regard to issues for which ethics undoubtedly play a major role. In this day and age, it seems clear that ethical issues are becoming ever more prominent in many, if not all, fields of science and technology, e.g., the societal debate about biotechnology and, similarly, nuclear power. Even if the assumption is made that various risks related to this technology can somehow be estimated and perhaps even controlled, not all people's concerns are addressed (Gaskell et al. 2005). In the end, the adoption of this new technology and its inherent risks remains an ethical question and has, as an addendum to techno-scientific research, given rise to what is now called ELSI (Ethical, Legal, and Social Issues) research in Europe and North America.

Although researchers have stressed for quite some time that energy policy is raising various ethical questions, policy makers and industry leaders have seldom taken up this challenge. This may partly be due to the fear that, if one addresses an issue as being an ethical issue, all kinds of purely subjective opinions will collide and expert knowledge will no longer play a role, setting aside objective reasoning.

The following chapter shows that

(1) public decision making will most probably benefit from a more explicit societal debate about ethical dilemmas and choices, and
(2) there are methods and tools which can enrich ethical debates by providing useful information, including ethical argumentation, and creating transparency until a final judgement can be made by the appropriate decision-making body (e.g., the Parliament).

2.4.2.2 Ethical Choices in Pluralistic Societies

There are times when individuals face a moral dilemma and must make a seemingly difficult and complex choice that involves thinking through ethical arguments with regard to various strategies. What can be done when things get complicated? One reasonable strategy is to ask a good friend for advice. People seek out trusted friends who are believed to possess a certain moral integrity and experience, since such people are expected to be in a position to provide well-thought-out advice. If the friend is indeed of this sort, he or she will recognize that giving such advice is in and of itself a moral action requiring a certain amount of personal integrity. In other words, even in more private spheres, people cannot expect impersonal, detached ethical advice: In the end, it will involve the advisor's good, value-based judgements.

What happens if the perspective is changed from that of the individual to that of a public body or governmental institution? Obviously, moral dilemmas and ethical uncertainty may arise there as well. The problem lies in the difficulty of finding ethical advice, not because there is a lack of people willing to provide it, but because the standards themselves are problematic with regard to what constitutes "good advice" in public decision-making. In the public arena, there simply is no equivalent to the good friend who is a trusted, skilled and morally competent person. A public body or governmental institution may carry moral responsibility for its decisions, but in modern democracies, it is made accountable to the public at large by its mandate and institutional foundation. For public bodies, advice on ethical issues requires quality assurance to firmly anchor it within both the values of pluralistic democratic societies and within a high level of argumentative backing. In other words, ethical advice to public bodies appeals not only to the moral integrity and co-responsibility of the advisor, but also to the set of standards used both to generate, and eventually evaluate, the advice.

Let us briefly examine the possibilities that the advisor could consider. First, the advisor could turn to existing ethical theories and academic traditions of discourse. Obviously, a variety of choices can be found, from utilitarian traditions of various kinds to deontological traditions (e.g., such as Kantian or Christian ethics) to contractarianism or versions of virtue ethics. Whatever the choice, the definite advantage of such an approach is that, if followed competently, it will provide a thorough and coherent level of argumentation. Spelling out the reasons behind the advice and embedding it in a larger ethical framework or theory opens up the advice to rational critique. Those who disagree may criticise it by pointing out which of the presuppositions they deem problematic and contestable.

In other words, ethical advice based on academic ethical theories meets the ideals of modern society and modern social institutions (e.g., as expressed by Max Weber). Whatever the theoretical foundation, however, serious problems will always face any such approach. For instance, all these theories are in some sense controversial, and using controversial theories to solve controversial social problems does not seem like a good starting point. Each theory will have areas in which the implications of the theory seem to contradict the moral intuitions of a great number of people. Another difficulty is that these theories do not in any straightforward sense of the term have direct applications to the areas being debated. The field of ethics does not have a field of applied ethics in the same sense as, say, the field of mechanical engineering has applied mechanics. In order for these theories to be useful in practice, one must spell out the particular interpretative context and specifications that do not have the same appeal to generality as the more fundamental principles. Providing this context comes across as being ad hoc, at least to those who are sceptical of the theoretical starting point. Furthermore, the context will typically leave out many considerations that others deem ethically relevant. In sum, this approach is met with objections stating that it does not live up to the recognition of value diversity and essential pluralism in modern democracies. In the background lurks the objection of implicit paternalism, or the suspicion that ethics are being used as a smokescreen to hide powerful underlying special interests.

Second, the advisor may try to live up to the ideals of modern deliberative democracies by turning the above approach on its head and basing his or her advice on a truly bottom-up and participatory approach. The art of the advice then consists of setting the advisor's own ethical standpoint to the side and organizing a process that reveals the values and moral judgements of the people, i.e., those that are not deemed experts in ethics but hold important values and convictions with regard to the societal decision in question. Clearly, there is again a variety of approaches to choose from. At first sight, the most democratic approach seems to be a survey method that charts the existing values and attitudes. Apart from the impracticality of conducting large surveys on each and every issue requiring ethical advice, the problem also exists that a survey cannot reveal what ethicists call *considered judgements*, i.e., judgements that are informed by all the relevant facts and considerations. Most people will neither be capable of, nor have interest in, evaluating and weighing all the ethically relevant factors of an issue. Other approaches rectify this shortcoming to some extent. Public hearings with stakeholders, or other such participatory approaches, aim at revealing the various value judgements of stakeholders. By definition, stakeholders can be assumed to have an interest in the issue at stake and thus to bring at least some kind of relevant knowledge and information to the fore (see Sect. 3.1 for the discussion about local knowledge). But again, in democratic societies, stakeholders with some kind of direct interest may not be the only legitimate source of information on relevant moral considerations. Civic society as such may have an overriding interest because of how the issue relates to the general welfare and fundamental principles of society. Thus, such approaches capture not so much the moral judgements of stakeholders, but rather the value-based judgements of a selection of the general public.

The consensus conferences that were first developed in Denmark are a typical example of such an approach. One of the advantages of this approach is that those issuing the recommendation are first offered the best information available on the issue, and their final statement is based on argumentative consensus within the panel. All of these approaches are oriented towards the recognition of pluralism in modern societies and seek to base their advice on the way in which the plurality of ethical viewpoints relates to the issue at hand. They are also bottom-up in their methodological outlook. Yet, they also face some more fundamental objections. One such objection is that, in the long run, recommendations based on participatory approaches are easily targeted as incoherent and lacking reference to more principled considerations, such as universalism, i.e., the identical treatment of ethically similar cases. These recommendations are vulnerable to questions regarding who is consulted when, and the framing of the issue is often decisive for its outcome. From an ethical point of view, one may criticise the fact that participatory approaches of this kind are short on rational ethical arguments, short on coherence over time, but long on admissions to ethical subjectivism or relativism.

Turning back to the initial formulation of the problem, i.e., issuing advice to a public body on ethical issues in policy formation, it can thus be concluded that there is a dilemma: A choice must be made between the Scylla of relying on expert culture in ethics (thereby risking the sacrifice of important aspects of modern deliberative democracies) and the Charybdis of relying on the voice of the people (thereby risking, to some extent, the sacrifice of coherent rational argument). Obviously, the public body seeking advice wants both considerations to be taken into account.

The typical response to recurring ethical issues related to the policy work of a public body or governmental institution is to appoint some sort of an ethics committee. This results in the institutionalisation of ethics. In the context of issues relating to developments in science and technology, the European nations have indeed witnessed a significant increase in the number of regional, national or transnational ethics committees over the past 10–15 years.

Some of these committees are specific to certain fields, such as the Ethik-Kommission zur Energiewende or the bioethics committees in the life sciences, while others are more generic, dealing with the sciences in general and turning their attention to a variety of issues. The composition of these committees often reflects many of the same considerations that have been described above. In some countries, these committees are restricted to scientific experts, while in others they also include ethicists and other specialists who have professional qualifications for dealing with the range of issues that the committee must confront. In some places, such as the Scandinavian countries, these experts are typically supplemented by members of the general public.

Whatever their composition, ethics committees face the fundamental problem of democratic legitimacy, transparency and rationality. A certain degree of independence and transparency would normally be expected of such a committee. This, in combination with the fact that they are appointed to provide ethical advice, provides at least some justification for the recommendations they make. Yet this is restricted merely to the formal level of their operations, leaving basically untouched the more substantial level of how they reach their outcome. Indeed, great differences can be found between countries in terms of the way these committees work. Some of these committees can perhaps be described as striving to reach some ideal of discourse ethics (in the Habermasian sense) based on the deliberations within the committee. Some explicitly seek out expert advice from ethicists in order to provide a coherent string of arguments. Still others seek to initiate public discourse by means of some of the participatory measures described above. And perhaps the majority of them do not have a clear philosophy that guides how they operate, or even a clear sense of what an ethical issue or a moral judgement even is or what it demands. From the perspective of the advice-seeking public body, then, the resulting recommendation may seem to emerge from a black box. Quality assurance of the advice seems to be limited and mainly restricted to the assumed trust that the committee is operating in line with its task. Typically, though, even if the public body may trust that the committee is operating professionally, the public at large may not share this view (see also 2.3.2). They may simply open up the issue again, and be unimpressed by the fact that a committee has come to a conclusion on the matter. The underlying problem is that no consensus exists on exactly what methodology a competent ethics committee should use when dealing with an ethical issue. The installation of such quality-evaluation mechanisms would serve as a basis for achieving social robustness (see 2.3.2).

Medical ethics, for example, is an area in which experience has been acquired with regard to practical ethics. It can be argued that, within the field of medicine and medical research, important ethical problems are now handled, by and large, rather competently. This is due to a combination of factors: First, ethics committees have been established on several levels and have been integrated into the workings of medical research. Second, guidelines such as the Helsinki Declaration provide a checklist of issues that are to be dealt with by those issuing ethical advice, and these guidelines are also supported by a majority of actors. Third, practical approaches have been defined that essentially sidestep the controversies of ethical theory and provide for a variety of broad considerations that, as a whole, seem to cover all the major ethical intuitions. This is basically the principlism that was first propagated by Beauchamp and Childress (2001). Together, these factors seem to work rather well for ethical issues that involve medical research vis à vis patient considerations. For more complex issues however, this framework seems to meet with some limitations, e.g., xenotransplantation, involving such overarching social issues as the risk of infection. The challenge is to draw lessons from this for other techno-scientific issues.

2.4.2.3 Basic Ethical Principles and Values

The term ethics is used here in a wide and non-technical sense. The classical notion of ethics is that of normatively delineating one's vision of the good life. In more recent philosophic literature, the term *ethics* has typically been conceived as the systematic study of the totality of our moral judgements and beliefs. Ethics is then seen as the theory of morality, and *morality* is the sum of moral judgements. There are basically three versions of moral judgements: morally right, morally wrong and morally neutral. Moral judgements and beliefs are seen as guided by our moral values. Moral values, again, are seen as those values that "give voice to the needs and legitimate expectations of others as well as ourselves" (Weston 2001). Although values, attitudes and preferences are very often used synonymously, we see values as something connected to, but distinct from, attitudes and preferences. *Attitudes* refer to a tendency to evaluate things in a particular way. To have a *preference* is to have a greater liking for one alternative than for another. We attribute more importance and meaning to values and can use them to evaluate attitudes and preferences. Values have a prescriptive dimension that is lacking in mere preferences. When we affirm something as a value we want others to see it as a value too. The EU project Value Isobars defined *values* in the following way (European Commission 2012):

> Values are reference points for evaluating things as good or bad. Values are rationally and emotionally binding and provide long-term orientation and motivation for actions.

In an informal sense, ethics are based on values and have to do with what might be termed *pro-social attitudes*. The non-technical meaning of ethics as it is used here refers to all issues concerning deeply embedded values and value conflicts, where the values at stake hinge upon our notions of the good life.

Values do not directly dictate what a person should do, as is the case with norms. Values provide a motivation and rationale for action without demanding a specific (course of) action.

Unlike meta-ethics or the more theoretical parts of ethics, which, by and large, thrived sheltered within the halls of academia, practical ethics was discovered as a promising tool to manage our complex social and technological realities. Medical ethics was the first to be taken on as an instrument with which to address imminent practical needs and concrete dilemmas of our social and technological life. Beauchamp and Childress (2001) set a new, influential standard with their textbook, *The Principles of Biomedical Ethics*. They saw the need to develop a specific methodological tool which could be helpful in solving practical medical dilemmas. This resulted in the well-known *Four Principles*, or *Georgetown Mantra*, as it is also called: non-maleficance, beneficence, autonomy, and justice.

Ethical principles occupy a special place. While they typically emerge from some ethical theory, this is not necessarily the case. They can be a common denominator across various ethical theories. *Principles* can be roughly characterised in the following way:

Principles are normative statements that are meant to guide action without prescribing specific actions. All applications of principles need to be contextually embedded and interpreted.

Principles are often present in legal contexts, e.g., the Precautionary Principle (discussed below). A prominent example of an ethical principle is the principle of due respect for autonomy and human dignity. This principle is a core element of the *Universal Declaration of Human Rights* (UN 1948), and in fact most constitutions. *Dignity* is the innate right to moral respect and asserts a number of basic liberties that must be granted to individuals. For instance, the freedom of religion, freedom of speech, freedom of movement, freedom to found a family, etc., are all part of the basic autonomy that is granted an individual. Restrictions on these freedoms need to be grounded in well-founded evidence, e.g., children do not enjoy full autonomy, mentally impaired or mentally ill people can have their autonomy restricted, etc. *Autonomy* is thus the freedom of choice with regard to certain basic qualities of life, and respect for human dignity is the widest possible ascription of this autonomy to other humans.

Whenever it is felt that issues concerning widely pronounced principles such as equity, fairness/justice, or integrity (of persons, animals or nature) are at stake, it should be assumed that the issue is of an ethical nature. The presupposition exists that any ethical issue can be made subject to, and constrained by, rational argument. When an attempt is made to survey, analyse and weigh the ethical arguments for and against a specific course of action, e.g., applying a technology, without necessarily adopting a specific theory of ethics, this effort is described as an *exercise in practical ethics*.

2.4.2.4 Ethical Matrix

One method for ethical evaluation originates in principle-based ethics, or principlism, as mentioned above. It starts not with ethical theory, but with a selection of principles that can find a broad degree of support from various ethical theories or cultural beliefs. The principles are selected in such manner as to be seen as roughly representative of families of values. This method finds its origins in the approach developed by Beauchamps and Childress (2001) with regard to medical ethics. Inspired by medical ethics, Ben Mepham, from the University of Nottingham, was the first to transfer the principles of this approach, modifying them slightly, to a practical approach for addressing broader policy-related problems. Mepham's work was then termed an *ethical matrix*.

The challenge of this approach consists in moving from the general level of the principles down to the practical level of the questions.

The first stage of the method involves setting up a two-dimensional ethical matrix where chosen ethical principles are specified in regard to the stakeholders' constellation of interests. The relevant stakeholders must be determined beforehand. As in other settings, the principles of welfare (utility, or maleficence/harm and beneficence), dignity/fairness/justice and freedom/autonomy could be used. The principle of respect for dignity, rather than autonomy, seems more appropriate when dealing with animal stakeholders or the environment. As the former refers to constraints when dealing with others, and the latter refers to the assertion of one's right to freely decide one's own course of action, dignity and autonomy will be considered separately here. Differentiating between negative and positive utility, instead of only considering their aggregate net result, is a practical way of enabling the discussion of the individual impacts in greater detail and, thus, facilitating the identification of individual drawbacks and benefits as well as the potential conflicts and remedies that may result.

After setting up the matrix, it must be determined how the technology at stake—here, the energy production and supply system—will affect the values described in the ethical matrix. This state of affairs can be structured within a consequence matrix, consisting of the same cells as the ethical matrix. The *consequence matrix* gives a brief description of the anticipated or potential consequences of a decision upon every affected value as specified in the ethical matrix. To fill the consequence matrix, both scientific expertise and system analyses play an important role.

Table 2.1 demonstrates the ethical matrix as used to evaluate some important general issues with respect to the design of a country's future energy supply. Following the ethical matrix approach, the determination of the relevant stakeholders is the first step, e.g., large- and small-scale producers as well as consumers. The potential effects on the environment must also be agreed on, and are mentioned quite unspecifically in Table 2.1 as "environment, near and far". The contents of the

Table 2.1 Simplified ethical matrix for energy supply (see also Kaiser et al. 2007)

Ethical matrix energy supply:	Harm	Beneficence	Freedom/autonomy (options for action)	Dignity/justice/fairness (limits of action)
Small producers	Dependencies on local conditions, tariff regulations/market, grid access, credit conditions	Increase in revenues dependent on opportunities	Freedom in production technologies, autonomy to a certain extent, increase in economic and social power	Fair treatment in the realisation of revenues/trade, unequally distributed possibilities to contribute (e.g., single family homeowners vs. tenants)
Large producers	Higher dependencies on regulations (e.g., market, subventions/taxes, obligations due to system relevance of plants), decrease in planned revenues	Increase in revenues dependent on opportunities	Decrease in freedom of technology choice, decrease in economic and societal power	Challenges of enforced structural change dependent on existing energy mix
Consumers	Lower-quality of electricity, blackouts, higher prices	Options of environmental friendly products available	Freedom in choice of electricity products	Fairness of cost distribution, affordability
Environment, near and far	Potential known and unknown effects on well-being, human health, produced assets, ecological systems, resource availability and other societal aspects	Reduced fossil fuel depletion, fewer known negative environmental effects (particularly climate change), positive societal effects	Local restrictions on land use, change in societal and power structure	Fairness of shared burden

table show that it takes into account much more than just the natural environment, including the man-made environment and society itself. A proper set of ethical principles then needs to be established, e.g., dignity/justice/fairness, freedom/autonomy, and the obligation to do no harm and the goal of doing good. Once a common understanding of these principles has been is determined, it is important for the principles to be specified with regard to each interest perspective. The result is an ethical matrix comparable to Table 2.1 that represents the starting point of the ethical assessment. It is clear that many of the cells in the table relate directly to the scientific system analyses and respective assessments dealing with security or safety issues. Scientific data will provide information as to how the technology relates to the qualities described in the various cells of the matrix. The consequence matrix then enables the determination of whether specific consequences of the new technology promote, inhibit or have a neutral impact on each of the specifications in the cells. At the same time, the significant uncertainties must also be noted in the matrix. After completing this task, recommendations can be made that take into account all of the future energy supply's ethical considerations and conflicts.

Of course, the matrix shown in Table 2.1 is in need of greater detail and still must be adapted and extended to fit the context of the specific decision-making situation for which it will be used. However, even in this simplified form, it provides a solid overview of some important aspects which prove relevant for the decision-making situation.

Once the ethical matrix and consequence matrix have been completed, it becomes possible to see whether the different consequences amount to a violation of certain specified norms (e.g., expressed as a minus sign) or whether they seem to be in accordance with the values (e.g., expressed as a plus sign). These relationships between consequences and specified norms are noted in an *evaluation matrix*. An evaluation matrix, then, is a matrix that provides an overall picture of the ethical status of the issue at stake. The correct ethical answer is not deducted from the evaluation matrix since weighing will be essential; the best ethical solution is essentially a moral judgment on the sum of considerations expressed in the matrix. Several applications of the ethical matrix have been conducted and analysed by research groups in Nottingham (Mepham, Millar) and Norway (Kaiser, Forsberg, Bremer). Other studies have followed or are currently being conducted.

The ethical matrix is an instrument for structuring and facilitating decisions regarding alternative options. Decision-making in multi-criteria situations can be facilitated by relying solely on the matrix or on various multi-criteria decision aid (MCDA) methods, which have been discussed and applied since the 1990s. Before selecting one of the predefined methods for specific applications, the strengths and weaknesses of each should be considered (see e.g., De Montis et al. 2003, 2005).

As already stated in Sect. 2.3.2, involving stakeholders in the decision-making process provides several advantages and represents a prerequisite for reaching social robustness. This is especially the case with respect to which energy supply is needed, particularly with large structural changes such as the implementation of new technologies in new and different locations. Furthermore, ethical issues are a major motivational factor for behavioural change. Therefore, a practical tool like the ethical matrix, which can bring the most salient ethical considerations to the fore, will prospectively support a rational, robust development of a country's energy supply. Such formalized ethical frameworks hinder accusations of ad-hoc behaviour or bias in the ethical evaluation, provide transparency with regard to the process involved, and facilitate international comparison and mutual learning. In this sense, the ethical matrix can be seen as a potential tool for facilitating quality assurance in practical ethics. Among other things, it could also have been a useful tool for Germany's Ethik-Kommission für eine sichere Energieversorgung (Ethics Commission for a Safe Energy Supply) which was established in 2011 after the Fukushima disaster.

In conclusion, the authors of the present study argue that when ethical assessments need to be made in a practical setting, or when an issue of public policy raises ethical challenges and dilemmas, an explicit framework or tool should be employed to assist with this task, thereby allowing greater transparency and quality control. The ethical matrix is one such tool that could facilitate decision making.

2.5 Summary and Conclusions

By defining a (technical) energy supply system as a practical means for providing the required amount of useful energy to the consumer, it becomes clear that any tool used to realise such a system must fit the purpose in such a way that the intended effects can be produced and the unintended effects remain acceptable. Evaluation indicators of two major approaches—the triangle of economic efficiency, environmental compatibility, and supply security as well as welfare or wellbeing optimisation together with the assurance of sustainable development—show that energy security and reliable energy supply are major issues for future energy supply systems switching to the use of a higher share of renewable energy sources. However, the differences between safety and security aspects must be defined. While the assessment of conventional energy supply systems mainly focuses on the impacts of the energy supply system on the outside (safety), security aspects dealing with the reliable provision of the intended effects—independently of external factors and even if the production is done in a distributed way—become more important with a new supply system. An energy supply system that is so much more integrated into society should also be integrated into a larger socio-cultural framework of basic values. The ethics of new systems, therefore, should be better anchored in societal debate.

This study shows robustness to be a major aim in the establishment of a framework for future energy system development. Robustness is further subdivided into dynamic stability, a characteristic of the resulting energy system that includes being robust against external influences and opportuneness, or being open for new options which may occur in the future. Furthermore, recommendations regarding the relevant framework conditions should be socially robust, meaning they should be widely acceptable within society, taking into consideration various interests and value commitments. Social robustness encourages the increased longevity of decisions being made. However, a robust system development requires that both relevant expertise and participatory elements be used in order to improve the societal inclusion of the process.

The final section of this chapter included the introduction, development and discussion of instruments which can be used to tackle the complex decision-making situation so as to foster the robust development of a future energy supply. While the theoretical examination of the energy supply system revealed various relevant disciplinary aspects, the ethical matrix showed how basic ethical values can be used to structure a problem. Drawing up such a matrix can enable, in an issue-related manner, the discussion of solutions to the diverse aspects. Ethical commissions are seen as preferable settings for the advisory procedure. However, such commissions require a certain amount of standardisation in order to be effective and acceptable to the public at large. Drawing lessons from ethical committees in the medical area could be a helpful first step.

Finally, some initial approaches could be developed for the design of the advisory procedures, how this complex field could be better structured, and what tools could be introduced for use in such processes.

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Droste-Franke, B.; Carrier, M.; Kaiser, M.; Schreurs, M.; Weber, C.; Ziesemer, Th.

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