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"Nuclear Power, Capability Approach and the Developing World"

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Introduction

Sustainable development is fundamentally about improving the well-being of individuals in current and future generations by expanding their valuable choices and opportunities. This chapter evaluates nuclear energy as a potential engine of sustainable development from the prospective of its impact on the well-being of members of current and future generations of a society. The literature on nuclear energy implicitly assumes the context of a developed community. However, the moral and factual questions to consider when evaluating nuclear energy shift when the context becomes that of a developing community. We present in this chapter a theoretical framework for evaluating the promise and peril of nuclear energy for developing countries and for assessing different nuclear technologies that might be available now or in the future. The proposed framework has at its core a concern for individual capabilities. Capabilities refer to the genuine opportunities individuals are free to achieve, such as an opportunity to be educated or adequately nourished. In evaluating the role of nuclear energy in sustainable development, it is critical to consider risks nuclear energy poses; sustainable development promotes opportunities in a secure manner, and risks threaten that security. Our framework considers the costs, benefits, and risks associated with the use of nuclear energy to enhance development.

There are four sections in this paper. The first provides an overview on the general issues influencing the moral justifiability of nuclear energy. The second then discusses why these issues take a different form in developing contexts. The third outlines a capability approach to sustainable development. Finally, the fourth section illustrates how the justifiability of nuclear energy in a given developing society would be approached using that framework.

1. Background

There are a number of subjects of debate in relation to nuclear energy (United Nations Development Program 2007). Three main themes in the literature are sustainability, safety, and security (including weapon proliferation and malicious activity that could impose radiation exposure, such as sabotage and dirty bombs.) Below we summarize how these three subjects are discussed. We then argue in the next section that debates typically assume the context of a developed community. The question of sustainability, safety and weapon proliferation take a different form when the context becomes a developing country.

Sustainability

Since in the 1980s more attention has been paid to the concept of sustainability. The World Commission on Environment and Development (1987) made a special contribution to this increased awareness. Sustainability requires attention to inter- and intra-generational equity, adequate standards of living for all individuals, and concern for the environment (Mileti 1999, 232). In particular, increasing concern is placed on ensuring that ecosystems are able to renew themselves, replacing a general disregard toward ecosystems. Concerns toward the ecosystems stem both from a care for the ecosystems themselves and the belief that well-being can be more prosperous when natural ecosystems also are so.

One subject of ongoing dispute is whether nuclear energy is a sustainable alternative energy source (e.g., Hubbert 1956, 36; Newton-Small 2005, World Nuclear Association 2010, Patterson 2013). Proponents of nuclear energy argue that nuclear energy is sustainable for the following reasons. Using nuclear energy rather than more conventional sources that rely on fossil fuels reduces carbon emissions. Moreover, nuclear energy is not itself a finite resource. Finally, the availability of nuclear energy is more reliable and less sporadic than other forms of alternative energy (like wind and solar.) Opponents of nuclear energy challenge these claims, noting that when one considers the total life cycle emission intensity greenhouse gas emissions per unit of electricity generated is comparable to other sources Shrader-Frechette 2011). Nor is nuclear energy cheap as an electricity source from this perspective (Diesendorf 2007a,b; Kleiner 2008, 130-131).

Safety

A second important source of debate is the degree to which nuclear energy is a safe energy source. Here the central focus is on risks nuclear energy poses to individuals, communities and the environment. One set of risks surrounds the storage of nuclear waste. Opponents argue that the risks associated with processing, transporting and storing nuclear waste are significantly underestimated (Sturgis 2009). Radioactive waste is harmful to living organisms for an extremely long time period (Vandenbosch and Vandenbosch 2007), from 10,000 to literally millions of years. Extremely advanced techniques are needed to successfully isolate nuclear waste permanently and/or transform it into a non-toxic form. Production of nuclear energy also generates a conspicuous amount of waste with low-level of radioactivity including cloth, tools, and general construction material used to build reactors. While the US Nuclear Regulatory Commission has pushed for such waste to be considered as normal waste, a debate remains about whether that would be appropriate.

Proponents of nuclear energy argue that the risks from such storage are sufficiently small as to justify nuclear energy's use. They point to technological advances in nuclear reactors and the safety record of nuclear plants in the developed world to support this point (Cohen 1990). Nuclear waste, they argue, comprises less than 1% of total industrial toxic waste. Hvistendahl (2007) points out that other forms of energy produce radioactive waste. Specifically, burning coal produces toxic and low-radioactive ash. Similarly, Gabbard (2008) in a report from the Oak Ridge National Laboratory stated that coal plants release more radioactive material into the environment per unit energy generated than nuclear power plants in their regular operations. To clarify, fly ash is significantly less radioactive than spent nuclear fuel per unit weight.

However, fly ash is released in large amounts into the environment while spent nuclear fuel is stored (during ideal operations) in, for example, dry cask storage vessels (Montgomery 2010, 137).

Consideration of the risks associated with the ideal operation of nuclear plants is not sufficient because this overlooks possible accidents. There have been a number of notorious nuclear accidents including the Three Mile Island accident (1979), Chernobyl disaster (1986), and the more recent Fukushima Daiichi nuclear disaster (2011), in addition to some, less publicized submarine accidents (Johnston 2007). The most recent, Japan's 2011 Fukushima Daiichi nuclear accident, pushed some countries to reconsider their position toward nuclear energy. Germany, where nuclear energy accounted for 22.4% of the national electricity in 2010, announced plans to phase out nuclear energy by 2022. Similarly Switzerland (where nuclear energy accounts for 39.9% of the country's total production of electricity) decided not to build any more nuclear reactors and not to replace the five reactors at the end of their service life (with plans to decommission the last reactor in the 2034.)

There are a number of debates surrounding how best to calculate the costs of such accidents, and the seriousness of nuclear accidents relative to those stemming from other energy sources. Proponents of nuclear energy point to the fact that there are fewer fatalities per unit of energy generated than the other more popular sources of energy. Some proponents claim that coal, petroleum, natural gas and hydropower produce a higher number of fatalities per unit of energy generated (Markandya and Wilkinson 2007; MacKay 2008; Burgherr and Hirschberg 2008), when deaths from air pollution and energy accidents are calculated. Nuclear energy accidents impose not just costs in terms of lives, but economic and social costs as well, in terms of damaged property, clean-up costs, human and economic costs associated with evacuating populations and lost livelihoods. On this point, US scientist Frank N. von Hippel noted following the 2011 Fukushima nuclear disaster that "fear of ionizing radiation could have long-term psychological effects on a large portion of the population in the contaminated areas" (von Hippel 2011). An accurate assessment of the costs of nuclear accidents relative to the accidents related to other energy sources must consider this broader set of consequences.

Security

Nuclear security refers to the "prevention and detection of, and response to, theft, *sabotage,* unauthorized access, illegal transfer or other *malicious* acts involving *nuclear material,* other *radioactive substances* or their associated facilities" (IAEA 2007, 133). Technologies, knowledge and materials used in nuclear energy programs in many cases have a dual-use capability. Enriched uranium on the one hand and separated plutonium during reprocessing on the other can be used to produce nuclear weapons (Taebi and Kloosterman 2008). Further risks include those posed by the possibility of nuclear weapons proliferation and terrorism.

Scholars engage in the above debates about nuclear energy by subjecting two kinds of claims to critical scrutiny. The first kind of claims is factual. For example, with respect to safety, scholars concentrate on issues that include determining what the actual benefits and risks from nuclear energy are and whether it is empirically accurate to characterize nuclear energy as a sustainable energy source. The second kind of claim is moral. Here conversation will focus, for example, on justifying a particular way of comparing or balancing different kinds of risks and benefits. To illustrate, critics do not believe that new technologies can sufficiently reduce the risks of nuclear energy to justify their imposition on a community.

Resolving these factual and moral disputes is a complex undertaking. In part this is because the factual and moral issues are difficult to resolve in isolation. Moreover, factual and moral questions are interconnected in many cases. For example, determining the factual issue of whether nuclear energy is sustainable depends on first determining how sustainability is best understood. This in turn will be informed by value judgments regarding what about our natural world is fundamentally worth preserving. Many of the chapters in this volume focus on these questions.

2. Contemporary Debates in Developing Contexts

The literature on nuclear energy for the most part implicitly assumes the context of a developed community. However, the moral and factual questions to consider when debating nuclear energy shift when the context becomes that of a developing community. We discuss in this section how the considerations to take into account when evaluating nuclear energy vary when the focus becomes a developing community.

Consider first the issue of *sustainability*. Developing countries are often not the main users of scare, non-renewable resources, significantly contributing to their depletion and in the process contributing significantly to the concentration of greenhouse gases, which accounts for part of the appeal of nuclear energy. The contribution of most developing countries, with the exception of China, to the depletion of non-renewable resources is minimal. Therefore developing countries are less responsible for threats to sustainability.

Nor is the issue how best to use scarce resources to guarantee to future generations the conditions for a standard of living that is at least as good and prosperous as the present is for us. The core challenge for many developing communities is expanding opportunities and the standard of living for present, as well as future, generations. The *de facto* present standard of living is not taken as a benchmark for what it is reasonable for all people, present as well as future, to accept. Rather, in many contexts *the de facto* standard of living is in need of dire improvement. Not simply maintaining, but rather striving to improve, the standard of living highlights two further complications when it comes to sustainability. Developing countries have many more competing demands on resources, demands which in many cases are for the basic conditions taken for granted as existing in developed contexts (e.g., access to safe drinking water). Not only are demands greater, the available pool of resources with which to try to meet basic demands is typically smaller.

Given the above, the issue of sustainability for developing countries is broader in scope and at its core asks: is nuclear energy the most sensible path to take to achieve sustainable development? Answering this question requires a comprehensive picture of what development is fundamentally about, that is, what the goals of development and practices should be. We turn to this point in greater detail in the next section. It also requires appreciating the significantly greater competing demands which can be met with a more limited pool of resources relative to developed countries.

Similarly, *safety* considerations are different. For one thing, the statistics of the occurrence of accidents are not necessarily a relevant guide for what to expect in developing contexts. Developing nations are often less equipped to deal with accidents and lack the number of experts required to operate reactors. If you do not have the same context for ensuring safety, you cannot use rates from a different context as a guide for what to expect. Moreover, there is a question about the appropriateness of ensuring the same level of safety in a developing as in a developed context. Guaranteeing the same level of safety may effectively price nuclear energy out of the ability of developing countries. In other industries and contexts, different levels of safety are used. Finally, guarding against possible nuclear accidents in the future may seem less pressing relative to other present needs. Why should a developing country be concerned about long-term radiation when children die of hunger each day? Why should a developing country prioritize the storage of radioactive waste when its citizens do not have access to clean water?

In addition, there is a clear issue about who takes the risk and who would pay the associated consequences. While one developing country might be willing to use nuclear energy because the benefits clearly offset the risks for the specific country, this might not be the case of neighbouring (or not too far) countries. For example, if a developing country decides to generate nuclear energy, the possible effects of radiation, in particular in the case of an accident, would often be felt well beyond the boundaries of such country possibly affecting countries who might have decided that nuclear energy is not worth the risks. Whether this counts as a permissible risk imposition is even more vivid in contexts where communities do not have the resources needed to satisfactorily respond to the consequences of a nuclear accident with the resources at their disposal.

Finally, *security* may become even more concerning when such proliferation occurs in countries with unstable and repressive forms of government. In this case, concerns on nuclear weapon proliferation seem to be more acute.

In light of the questions that nuclear energy raises for developing countries, a framework is needed that provides resources for assessing: (1) the relative contribution of nuclear energy to sustainable development; (2) the risks associated with nuclear energy in developing contexts; and (3) the appropriate way to balance the assessments from (1) and (2). We argue in the next two sections that these questions are best considered from a capability perspective. A capability approach evaluates policies and technologies based on how the opportunities of individuals will be impacted. Capability approaches to development and to risk already exist. Such approaches can be combined and used to evaluate nuclear energy in developing contexts, where development and risk are intimately connected. In the next section we outline the capability approaches to development and to risk. The fourth and final section looks at nuclear energy for developing countries from a capability perspective.

3. A Capability Approach to Sustainable Development and Risks

A capability refers to a genuine opportunity to achieve a particular valuable doing or being, such as being educated or being adequately nourished (Sen 1999; Nussbaum

2001). A genuine opportunity to achieve a given doing or being is a function of *what an individual has* and *what she can do with what she has.* "What an individual has" is understood broadly, to include financial resources and other sources of wealth, as well as talents, skills and a support network from family and friends. "What an individual can do with what she has" is conditioned by institutional and environmental factors of different kinds. Legal rules, political processes, and the engineered built environment all influence what we are able to achieve with a given set of resources.

To illustrate, consider mobility and the conditions that must be in place for an individual to have a genuine opportunity to be mobile. A personal resource like a car can contribute to mobility, but possession of a car is not sufficient for mobility. An individual must know how to drive a car. She must be legally permitted to drive, in virtue of satisfying conditions laid out in law (e.g., being of a certain minimum age, possessing car insurance, not having received a certain number of tickets in the previous years). In addition, an individual must in the usual case have extra financial resources to pay for gas and repairs of a car when needed. Finally, the built infrastructure must be present, in terms of roads and bridges, to enable an individual who knows how to drive a car, has the financial wherewithal to support a car, and the legal permission to use a car to be effectively free to drive.

In a capability approach, the standard of living or quality of life of individuals is defined in terms of the genuine opportunities individuals have to do and become things of value. Measuring the standard of living of individuals requires making a set of choices. The first choice concerns which opportunities are sufficiently important and definitive of the standard of living to consider in an analysis. The second choice surrounds how those capabilities or opportunities will be measured. Capabilities are not themselves directly measurable. Indicators are needed that provide proxy information about the kind of opportunities individuals enjoy. For example, one indicator of the ability to live a long and healthy life is life expectancy at birth.

Complicating the question of measurement further is the issue of opportunity versus achievements. Capabilities capture the *opportunity* an individual has to do or become something of value. Underpinning many analyses of capabilities is a general commitment to liberalism, according to which the purpose of government and public policy is not to require or force individuals to live a certain kind of life, but rather to provide a framework within which individuals are free to pursue a life they have reason to value. One challenge in implementing the capability approach is determining which range of opportunities should be left open to individuals to pursue.

Another challenge for any implementation of the capability framework then becomes determining which indicators or use of indicators tell you the opportunities available to individuals, which can be broader than the doings and beings he or she in fact chooses to achieve. Opportunities do not track achievements because there can be opportunities an individual enjoys that h/she does not choose to take. An individual may have the talents and skills, grades, family support, and financial wherewithal to attend college, but lack the desire to do so. Moreover opportunities are interdependent. In the abstract and absent any choice an individual may be genuinely free to be educated, have a demanding career, and become a parent. However, in practice certain choices may foreclose others and/or make choices available. Choosing to raise a family may limit certain especially demanding careers, or the possibility of demanding careers for both parents (on this point see Robeyns 2005). In contexts of poverty, a set amount of resources may be sufficient for buying enough food to satisfy nutritional needs or for paying rent, but not both.[1]

Tabandeh *et al.* (2014) developed a reliability-based capability approach (RCA) using a system reliability formulation. In a system reliability formulation you establish the probability not by considering the threshold for each single capability, but rather by considering a system of capabilities interacting simultaneously. The RCA has several benefits both conceptual and toward the implementation of a capability approach. It uses a system reliability method to compute the probability that the levels of achievement in a specified subset of capabilities are not adequate. The RCA also explicitly models the interactions between indicators when computing the probability of a change in the level of the indicators. Instead of considering an aggregate measure, it translates in a transparent way the performance in individual indicators into a system performance

Sustainable Development from a Capability Approach

In a capability approach, development is defined as a process for enhancing the quality of life of its individuals. The goal of development is more specifically to work towards ensuring a decent "standard of living" for individuals, which puts them in a position to pursue a life they have reason to value. Development policies aim not simply to provide individuals with a genuine opportunity to achieve a decent standard of living at a discrete moment, but rather in a durable, sustainable manner. Development is sustainable when emphasis is placed on maintaining in a secure manner a certain level of opportunities. When secure, achievements in doings and beings like being nourished or sheltered are not temporary or require the undue assumption of risks to other important doings and beings in order to be maintained.

Sustainable development from a capability perspective has three key features. (1) There is emphasis placed on *social equity* or *intra-generational justice* such that the key opportunities defining the standard of living are available to individuals in a given generation in the present and future in a secure manner (World Commission on Environment and Development 1987, 188). (2) *Intergenerational justice* is also important. The promotion of opportunities of the current generations should not compromise the possibilities of future generations to have a quality of life that is at least as good as the one of the current generations. (3) Sustainability requires attention to the *environmental impacts* of development's pursuit.

There are two important sources of uncertainties that make it hard to determine whether a development plan achieves intra- and inter-generational justice. The first source of uncertainty is in the impact that a development plan will actually have (which is not necessarily the same impact as the desired or foreseen one.) The second source of uncertainty is related to the actual conditions that are needed for maintaining the current level of well-being in the future. There is uncertainty in what future generations will

[1] For a detailed description on how to measure capabilities see Murphy and Gardoni (2010) and Tabandeh (2014).

need to fulfil their needs. In Robert Goodin's words, "Allowing for substitutability, future generations might be as well off as present ones in terms of all the functional tasks performed, albeit using a different array of material items to perform those functions" (Goodin, 1999).

Because we cannot assume that future generations will simply continue to need the same resources that are available now, it is difficult to determine which resources, and how much of such resources, must be left to future generations. Future generations will inevitably develop new engineering solutions and make new scientific discoveries that might create new opportunities, making conserving current resources unnecessary. If for example, in the future a new non-fossil fuel based source of energy becomes the foundation for most economies, there would not be the same pressing need to be concerned about the relative scarcity of fossil fuel. In addition, future generations might discover that some technologies, materials and general engineering solutions are worse than other alternatives. For example, at the time of the Roman Empire lead was ubiquitous. It was used as a component in a number of cosmetics including face powders and mascaras, a pigment in paints, a spermicide, a condiment for food, a wine preservative, an easy to work with and inexpensive metal for kitchen utensils and tableware, as a key metal in coins, and a piping material for water supply. Lead was later found to be highly poisonous.

Risk from a Capability Approach

Whether and to what extent nuclear energy promotes sustainable development is only one factor to consider in its adoption. Nuclear energy poses risks, which must also be taken into account. In this section we describe a capability approach to risk analysis. We then use this framework to evaluate nuclear energy in developing contexts in the next section.

Murphy and Gardoni (2006, 2007, 2008, 2010, 2011, 2012), and Gardoni and Murphy (2008, 2009, 2010, 2013a,b) proposed a Capability-based Risk Analysis (CRA) for risk determination, risk evaluation and risk management for natural and human-made hazards, and disaster response and recovery. The CRA uses changes in capabilities to quantify the impact of hazards and past disasters. More specifically, in CRA the possible consequences of hazardous scenarios are defined in terms of capabilities. Risk analysis considers the change in capabilities that result from such a scenario. Risk is the probability that capabilities are reduced.

Which capabilities should be considered is hazard-dependent. That is, the relevant capabilities to consider depend on which doings and beings are characteristically affected by a given hazard. As with development policies, CRA uses indicators to track changes in capabilities. The prediction of the impact of a hazard on capabilities requires a method of prediction for this purpose. The CRA proposed by Tabandeh et al. (2014) is ideally suited for this. In the context of risk analysis specifically, the RCA translates the performance in individual indicators into a system performance so that the system performance can be evaluated for its acceptability or tolerability based on the definitions in Murphy and Gardoni (2007). Evaluation of the impact of a given disaster can be based on the same basic framework. The impact of a nuclear accident, for example, would be the function of the reduction of selected capabilities, as measured by changes in certain indicators of the requisite capabilities.

This way of analysing the consequences of a given hazardous scenario is different than common methods in risk analysis. Often engineers and social scientists consider specific resource losses when determining the risk from a given hazard (Rowe 1980; Vose 2000; Bedford and Cooke 2001). Consequences analysed include market resources lost (e.g., time through construction delays, money, structures). As the capability approach recognizes, such resource losses do not translate automatically or uniformly into impacts on individual lives. A lost structure may have little impact if abandoned or underutilized, or if it is one of many buildings a given individual owns. In such cases, the opportunities open to an individual who owns the building may not be constricted in any meaningful sense. Conversely, the loss of a home can be devastating for individuals who lack resources to rebuild what was lost or to relocate to another home. When many individuals or a community are vulnerable to a hazard, CRA assesses the overall impact as a function of a sum of the impacts on individual.

The evaluation of risks from a capability perspective involves asking two kinds of questions. One is evaluative in an absolute sense and queries: "are risks associated to, for example, nuclear energy the kind of risks individuals and/or communities should at all permit?" The second kind of evaluation is comparative, answering the question "are those risks preferable compared with the risks associated to alternative options, including the option of not doing anything?"

To address the first question, Murphy and Gardoni (2008) argue that risks should be compared against two basic thresholds. The starting point for risk evaluation from a capability approach is the idea that there is a certain threshold minimum level of capabilities that individuals should enjoy and should be in a position to continue to enjoy with a specified degree of confidence. The inclusion of a 'threshold degree of confidence' reflects the fact that principles of justice should be understood probabilistically. It is impossible to guarantee with certainty that capabilities will be maintained by any given policy or action; for instance we do not know with absolute certainty if efforts to mitigate risks will be successful should a particular hazardous scenario be realized. So any requirement concerning the protection of capabilities must demand that it is sufficiently likely that capabilities will be maintained at or above a required level. A necessary condition for a risk to be acceptable is that the probability that such risk threaten the ability of individuals to maintain a threshold level of capabilities is sufficiently small. Murphy and Gardoni (2008) recognize that it could be tolerable that the level of capabilities falls below the acceptable level under temporary and reversible conditions. To deal with such situations they introduce the concept of tolerable risk. The tolerable threshold is lower than the acceptable threshold and specifies the absolute minimum below which nobody should go irrespective of whether the situation is temporary and reversible. A risk is tolerable, though not acceptable, when the probability that capabilities will fall below the less demanding tolerable threshold is sufficiently small.

The comparative judgment evaluates potential risk policy alternatives in the following manner. Combining a concern for the promotion of development with a concern for risk yields the overall objective of maximizing capability expansion while minimizing the impact of risks. Any given policy should satisfy a target risk, which the acceptable risk threshold provides.

4. Nuclear Energy in the Developing World

How should we think about nuclear energy in developing contexts using a capability approach? In this section we outline the considerations that should inform such an analysis. The overall judgment about the use of nuclear energy in any particular context would of course need to be based on the specific empirical facts pertaining to that context.

The first step in evaluating the possible adoption and use of nuclear energy in any particular context is to determine whether the risks associated with nuclear energy satisfy the threshold of acceptability. This follows from the overarching objective of CRA, protecting and furthering individuals' capabilities (Murphy and Gardoni 2007). Because the tolerability threshold requires the consequences to be temporary and reversible, they might not apply to risks associated to nuclear energy, which tend to be extremely long - term. To some degree, the specification of the standards for acceptable risk might be society-specific. As with human rights, the international community may come to identify broad principles that a threshold for acceptable risk must satisfy in terms of the probability and magnitude of impact on capabilities for a given hazard. However, there are reasons to support a role for democratic decision-making in terms of how those broad principles will be satisfied in a given context. There can be variation among communities in the precise specification for the threshold for acceptable risk. Communities may vary in the particular impact on general capabilities, such as an opportunity for education or mobility, which they are concerned to guard against. There may be a range of values for the target probability that a set of thresholds for acceptable risk could permit. As mentioned earlier, the target probability would also require a comparative risk analysis where there is a direct comparison with the risk associated to nuclear energy with the risks already faced by a community (Gardoni and Murphy 2014).

In developing contexts there is one additional challenge to specifying the threshold of acceptable risk. Within many developing communities capability levels may be below an acceptable, and even tolerable, level initially. For the billions of individuals subsisting on less than $2/day this will almost certainly be the case. Thus, the introduction of risks associated with a technology like nuclear energy may not always threaten to bring capability levels to an unacceptable level; they are already there. In these contexts the question then becomes when, and under what conditions, it is permissible to potentially worsen the already unjustified level of capabilities individuals enjoy for the sake of a possible increase in the present level of capabilities. Ruling out the introduction of any further risk to capabilities levels is not necessarily justified; this could foreclose important avenues for enhancing the capabilities of individuals. At the same time, caution must be taken so as to not exploit or unnecessarily harm an already vulnerable population. There may be reason to pursue a policy that economizes threats to the further erosion of the capabilities of individuals, identifying the pathways for a given source of development that pose the minimum risk to the possibilities that individuals further fall below the acceptable threshold. In the case of nuclear energy, a number of different kinds of risks must be considered when making this judgment, importantly security and short- and long-term safety risks for both current and future generations (Taebi 2011). Dealing with this tension is best dealt with through dialogue among the various actors working for sustainable societies in different ways. Such dialogue would serve as a corrective to the relatively little interaction and communication between advocates of sustainable development and risk analysts.

If nuclear energy passes the acceptable threshold, the second step is to assess the contribution of nuclear energy to the goals of development relative to the costs that the pursuit of nuclear energy entails and sustainability considerations, and then compare that contribution against alternative energy paths that a developing country might pursue. For the second comparative evaluation, we ask of nuclear energy: "are the risks associated with it preferable compared to other risks associated to alternative options, including the option of not doing anything?"

Benefits include the provision of electricity for a given population, in many cases in developing contexts this may be available for the first time. In 2011, 59.6% of the population of Bangladesh 26% and of the Democratic Republic of Korea had access to electricity.[2] Electricity contributes in fundamental ways to education, allowing individuals to study longer and learn more each day. It can be crucial for the functioning of businesses, whose flourishing in turn increases the economic resources generated by a community. It allows for food refrigeration which is essential for a healthy diet. Precisely what gains in capabilities result from the introduction or increase in nuclear power in any given society will depend on how many individuals are effectively able to access nuclear power, given, for example, the extent to which it is produced, the reliability of its supply, and the costs for consumers of using it relative to their income level and their other competing expenses.

Consideration of the costs of nuclear energy in developing contexts must begin with the recognition that nuclear power currently plays a much smaller role in developing countries than in developed ones. Though comprising 17% of the global electricity generation, 346 reactors in OCED contain 80% of this capacity (United Nations Development Program 2007). For example, while the EU derives 30% of its electricity from nuclear energy, in many developing countries nuclear energy is not used at all.

Given the relative small reliance on nuclear energy in developing contexts, for the vast majority of developing countries the question is not: what are the costs associated with continuing to use or expand reliance on nuclear energy? Rather, the question is: what are the entry costs associated with nuclear energy, to determine whether they are worthwhile to incur. The entry costs for nuclear energy are significant. Nuclear energy requires a substantial upfront and ongoing investment in engineering knowhow and nuclear structures and infrastructure. The infrastructure and expertise required for nuclear energy production is characteristically not present in many developing contexts. The infrastructure needed to produce and sustain nuclear energy must be created, including an electricity grid size and structure. "In many developing countries, this is an important factor limiting the introduction of nuclear power: the grid is often too small and fragmented to permit introduction of the fairly large nuclear power plants which are

[2] World Bank database,
http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS/countries/1W?display=default

available" (Laue et al. 1977, 8). Other components of the requisite infrastructure include qualified manpower to absorb the technology transfer from a developed country (the typical case), as well as the resources and knowledge needed to construct and to run facilities needed for nuclear energy production. These conditions are also frequently absent. Facilities once constructed must also be maintained, with the requisite support and surveillance structures in place. Developing countries are among the most vulnerable to rising sea levels and increased flooding due to climate change, which increases safety risks. In this context, developing countries might or might not have the relevant resources to invest in nuclear energy as a long-term solution to the provision for and satisfaction of energy needs, either as a matter of upfront investment in preparing the infrastructure and possessing the expertise needed for the construction and maintenance of nuclear facilities or as a matter of ongoing maintenance.

Even if the resources are available, developing countries must consider whether it is worth devoting a significant amount of the scarce resources available towards this purpose, relative to the other pressing needs that might be served with the same set of resources and the costs associated with other alternative forms of energy. Other forms of energy might increase capabilities more quickly because they do not require the same significant upfront investment. They may also pose fewer risks. However, alternative energy sources may also prove less reliable. Developing countries must then decide how to best try to maximize capabilities now and for future generations given the realistic options available.

Going beyond the individual country considering nuclear energy, one final consideration for the international community is related to the distinction between *voluntary* or *involuntary* risk (Murphy and Gardoni 2011; Gardoni and Murphy 2014). Because the consequences of a nuclear accident, for example, would typically cross state boundaries, while a single country might decide to pursue nuclear energy, we believe that the international community should have a clear role in determining whether safety conditions are met or not.

Conclusions

This chapter takes up the question: "should developing countries produce nuclear energy?" The chapter proposes a framework for conceptualizing and evaluating the risks and opportunities that nuclear energy might bring to developing countries. Opportunities and risks, we argue, should be assessed using a capability approach to development and to risk. A capability approach to development can be used to quantify the opportunities brought by the production of nuclear energy and gauge the possible impact of hazards in term of changes in capabilities. Our chapter highlights the ways in which consideration of the risks and opportunities created by nuclear energy must be different when looking at developing, as opposed to developed, countries. In particular, in developing contexts the entry costs and pressing other basic needs to which a country may devote its resources must be taken into account.

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