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Sustainability assessment of nuclear power: Discourse analysis of IAEA and IPCC frameworks

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ABSTRACT

Sustainability assessments (SAs) are methodologically precarious. Value-based judgments inevitably play a role in setting the scope of the SA, selecting assessment criteria and indicators, collecting adequate data, and developing and using models of considered systems. Discourse analysis can reveal how the meaning and operationalization of sustainability is constructed in and through SAs. Our discourse-analytical approach investigates how sustainability is channeled from 'manifest image' (broad but shallow), to 'vision', to 'policy targets' (specific and practical). This approach is applied on the SA frameworks used by IAEA and IPCC to assess the sustainability of the nuclear power option. The essentially problematic conclusion is that both SA frameworks are constructed in order to obtain answers that do not conflict with prior commitments adopted by the two institutes. For IAEA 'sustainable' equals 'complying with best international practices and standards'. IPCC wrestles with its mission as a provider of "policy-relevant and yet policy-neutral, never policy-prescriptive" knowledge to decision-makers. IPCC avoids the assessment of different visions on the role of nuclear power in a low-carbon energy future, and skips most literature critical of nuclear power. The IAEA framework largely inspires IPCC AR5.

1. Introduction

The past two decades have seen growing acceptance of sustainable development (SD) as an overarching objective for the management of vital functional subsystems of society, such as water, food, shelter and energy. Politicians increasingly recognize that meeting the long-term challenge of SD requires the restructuring of these key subsystems under the guidance by long-term policy designs (Voβ et al., 2006). Climate change and energy are good examples. At the 2009 Copenhagen meeting, the international community agreed to keep global warming in 2050 below 2 °C higher than pre-industrial levels. Addressing climate change means decarbonizing electricity generation as a major change throughout the entire energy system, with a critical role for energy efficiency

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Abbreviations: EC, European Commission; IAEA, International Atomic Energy Agency; IEA, International Energy Agency; INPRO, International Project on Innovative Nuclear Reactors and Fuel Cycles; IPCC, Intergovernmental Panel on Climate Change; SA, sustainability assessment; SD, sustainable development; WCED, World Commission on Environment and Development.

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(IEA, 2014). In 2013, fossil-fueled thermal power (gas, oil, coal and peat) accounted for 67.1% of global electricity generation, with renewables (hydropower, wind, geothermal, biofuels, waste, and sunlight via photovoltaic conversion) (22.1%) and nuclear fission (10.8%) making up the remainder (EnerData, 2014). With CO_2 capture and storage at fossil-fuel power plants facing delayed commercialization (IEA, 2014), renewable energy supplies and nuclear fission are the remaining competitors which could substitute for fossil fuels in electricity generation.

In light of the threat of climate change, the restraints on nuclear power plant construction in the aftermath of the Chernobyl disaster (April 1986) are now being challenged in the 'nuclear renaissance' discourse, sailing under the flag "Nuclear power is not *the* solution, but there is *no* solution without nuclear power" (Nuttall, 2005; Mez, 2012). In the 'Summary for Policymakers' of the 'Fifth Assessment Report', the Intergovernmental Panel on Climate Change (IPCC) also labels nuclear power as a "*mature low-GHG emission source of baseload power*" that "*could make an increasing contribution to low-carbon energy supply*", provided that a "*variety of barriers and risks*" are overcome (IPCC WGIII, 2014, p. 23).

However important, 'low carbon' is but one attribute that power generation options should have in a sustainable energy future. The precise meaning of 'sustainable energy future' is contested, but the (non-)sustainability of energy options depends on their performance in delivering other policy objectives such as alleviating energy poverty, improving equity, reducing air pollution, enhancing energy security and securing economic wellbeing (Hugé et al., 2011). The IPCC explicitly states that "*sustainable development and equity provide a basis for assessing climate policies*" and therefore highlights the need for a comprehensive assessment of climate policies going beyond a focus on mitigation and adaptation policies alone to examine development pathways more broadly (IPCC WGIII, 2014, p. 4).

Sustainability assessment (SA) of energy system options obviously triggers the questions 'What exactly is a sustainability assessment?', and 'How is such an assessment performed?'. We do not attempt to find answers from a normative or theoretical point of view. Rather we investigate actual SAs of nuclear fission power as performed by, or on behalf of, two institutions with acknowledged roles in energy system governance at the international level: the International Atomic Energy Agency (IAEA) and the Intergovernmental Panel on Climate Change (IPCC). A discourse-analytical focus on the IAEA's and IPCC's execution of SA shows how the concept of SD is framed in the context of energy system governance, and subsequently transposed into action-guiding policy prescriptions regarding the role of nuclear power. It is particularly relevant to investigate whether and how a rationalized assessment method like SA can deal with a technology that is profoundly marked by socio-political tensions and polarization within and across countries (Mez et al., 2009; Stirling, 2014). Under conditions of polarization – i.e. socio-political disagreement about both the 'facts' and the 'values' at stake – it is vital to the quality of democratic debate to equally represent all competing perspectives on the contentious issue at stake. The World Commission on Environment and Development (WCED) sees democracy as a central discourse-analytical category and a pivotal normative commitment, as is evident from the statements that SD requires "*a political system that secures effective citizen participation in decision making*" and "*an administrative system that is flexible and has the capacity for self-correction*" (WCED, 1987, p. 65).

This manuscript is structured as follows. Section 2 provides a brief review of the state of the art of SA (Section 2.1), the tailoring of a layered discourse-analytical framework for understanding how sustainability is interpreted and operationalized in the context of decision making regarding energy technologies (Section 2.2), and the revisit of the sustainability meta-discourse of the WCED report (WCED, 1987) as a benchmark for interpretations and operationalizations (Section 2.3). Section 3 reviews the SA of nuclear fission power as performed by IAEA and by IPCC. Section 4 discusses the overall conclusions and policy implications of the analysis.

2. Sustainability assessment and discourse analysis

2.1. *Sustainability assessment: the state of the art*

Sustainability assessment is a tool to help decision-makers select which actions should (not) be taken in an attempt to make society more sustainable. Pope et al. (2004) reveal that the conceptual roots of SA are embedded in environmental impact assessment practices dating back to the 1970s. Bond et al. (2012) also consider SA to be a 'third generation' impact assessment procedure, following environmental impact assessment and strategic environmental assessment. Similar to these procedures, SA also pursues a more rational form of decision-making, based on 'objective information' about the retrospective (in case of ex-post assessments) or expected (in case of ex-ante assessments) impacts of projects, plans, programs or strategies with SD objectives.

Despite shared roots, SA is more than a mere extension of environmental assessments with economic and social impacts, the so-called 'triple bottom line' (cf. Section 2.3). Gibson et al. (2005, p. 62) attribute to SA a double role: one for "*the general pursuit of sustainability*" and one for "*defining the specifics of sustainability in particular circumstances*". Because SA may range from broad policy strategies to applied policies, or from comprehensive energy systems to individual energy technologies; and because of the contested nature of the notion 'sustainability' itself (Söderbaum, 2007), there exists no one-size-fits-all SA procedure (Jordan, 2008). Every SA is a unique case, and is therefore also methodologically precarious (Grunwald, 2008). Value-based judgments inevitably enter the process of scoping the SA, selecting assessment criteria, collecting adequate data, developing and using models of considered systems, etc. (Latour, 2004). SAs are therefore particularly vulnerable to ideological bias and deliberate misuse, urging special care to safeguard and respect the rational terms of the exercise. In the case of SA, rationality is predicated on the quality of the deliberative process for raising, debating, negotiating and provisionally validating different claims to knowledge (Laes and Verbruggen, 2010; Frame and O'Connor, 2011; Grunwald and Rösch, 2011).

2.2. A discourse-analytical framework for analyzing sustainability assessments

By the construction of meaning and operationalization of sustainability in and through SAs, the latter are clearly objects of discourse analysis (Hugé et al., 2013). Hajer and Versteeg (2005) use discourse analysis to trace how SD emerged as a concept and how it's meaning subsequently evolved as it was molded by institutional settings.

The interpretative debate about the proper meaning of sustainability in a given context becomes especially apparent through a process of increasing specification from general principles to clear, operational policy targets (Laes, 2006). This questions existing SA practices at three discursive levels of sustainability: manifest image, vision, and policy target (Laes, 2006). The three discursive levels merit further explanation.

2.2.1. Sustainability as a 'manifest image'

'Manifest' means accepted at face value, with little reflection, outside of the natural and social context. Something manifest does not have to be uncovered by scientific (philosophical, anthropological, sociological, and so on) inquiry, e.g. in terms of deep-seated cultural structures, ontology, etc. 'Image' evokes the largely metaphorical character of this everyday manifest understanding of sustainability, using phrases such as 'Our Common Future', 'From one Earth to one World', 'Limits to Growth', and 'Spaceship Earth'. Images seem to capture the essence of sustainability in a few simple, basic ideas and mental models (Zaccaï, 2002, pp. 64–70). As an integrated and holistic view, the manifest image of sustainability should easily match very divergent life experiences and contexts; hence it is general and diffuse.

An appeal to sustainability at this level will be too general for policy-making. There is an inherent tension between the manifest image and expert interpretations required for policy guidelines. In real cases it might happen that intensive investigation cannot find the true causes of a signaled unsustainability problem. The true causes might be counter-intuitive, and/or the study of some causes might be restricted, either by principle, or because of the limited mandate of policy actors. Such tensions between manifest images and expert interpretations in SA are, at least partly, irreducible.[1] Policy makers must find ways to deal with them.

2.2.2. Sustainability as a 'vision'

A 'vision' describes sustainability as a positive idea, in terms of criteria, objectives, ultimate goals, etc. Sustainability then refers to a gap between a perceived existing situation and a conception of a desired future situation. Unlike in a manifest image, a direction of change is now implicitly or explicitly included in the problem definition. Visions have two major features: they include a mental image of an attainable future shared by a collection of actors, and they guide the actions and interactions between the actors. Visions are rooted in an actor's assessment of past experiences and expectations of the future, and they delimit a range of possibly attainable futures (Grin and Grunwald, 2000, p. 11).

Visions may also be metaphorical in character, but then metaphors are detailed and precise, making it easier to discuss visions and their implications in a rational way. On the one hand, visions depend on context conditions, such as configurations of actors and historical backgrounds, and must be assessed with respect to these contextual issues (Grin and Grunwald, 2000, p. 49). On the other hand, visions cannot be restricted to specific contexts, because their integrative power overarches different contexts and allows them to integrate. Visions indicate a course without tracing it in detail.

However, as well as opening up certain perspectives, visions may also downplay or obscure others. Hence, an interpretative – and intensely political – debate may evolve. Investigating accustomed visions on sustainability (in our context of SAs of nuclear power) is an effort to identify or construct opportunities for shared understanding and action, as well as areas of contention.

2.2.3. Sustainability as a 'policy target' or 'goal'

At the third level of discursive elaboration, sustainability appears a fully developed concept that can be applied to clear-cut problem fields. This level requires scientific analysis of the causes of unsustainability and of relevant trends, definition of policy targets for achieving desired levels of sustainability in problem fields, intermediary targets, indicators (i.e. measures of progress toward targets), specified policy interventions, etc. This discursive level draws heavily on expert contributions, supported by a broad political consensus: it seems the perfect marriage of knowledge and power. Here the inherent danger is redefining sustainability in terms of what is known and possible to quantify. Our empirical work on SA of nuclear power ponders whether, and to what extent, adopting clearly defined, undisputable policy targets or goals closes and avoids a more fundamental, but uncertain, political debate on sustainability visions.

2.3. The sustainable development meta-discourse

SAs are never developed in splendid isolation, but are influenced by their institutional and cultural context. The SD discourse at the international level evolved after the publication of the seminal WCED report 'Our Common Future' (WCED, 1987). Even this founding document contains compromises that give rise to many different interpretations (Söderbaum, 2007). The WCED discourse links and interlaces two major post-World War II challenges – the worldwide unequal economic and social development (UNCTAD, 1974) and the impact of development on the environment (Meadows et al., 1972). The WCED report points out the need for economic growth to counteract poverty, especially in developing countries. This created room for business-as-usual interpretations such as sustained economic growth and sustained profits in ongoing businesses (Grober, 2015). Gradually, the further articulation of sustainable development concepts and challenges was colonized by neoliberal governance principles (Pestre, 2011), culminating in the 'People-Planet-Profit' (3P) or 'triple bottom line' reduction. Adoption of 3P newspeak in governance for sustainability is pernicious (Norman and

[1] This problem is but one aspect of what philosophers call the 'frame problem' or the 'problem of complete description' (van Brakel, 1998, p. 18).

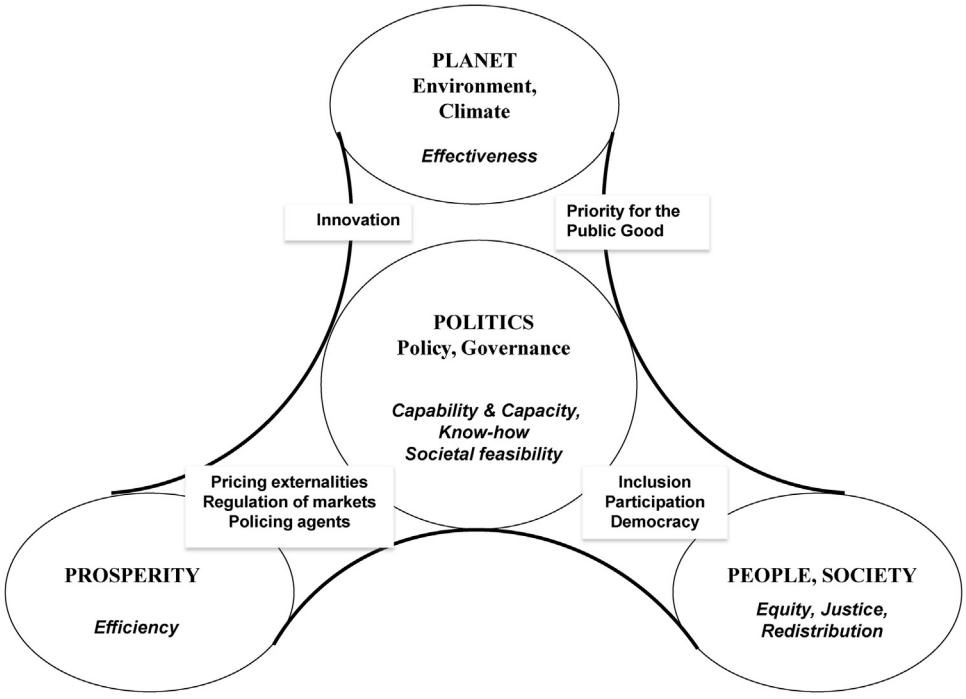

Fig. 1 – Four dimensions and their interactions house the change processes needed for progress in sustainable development (based on WCED, 1987; UNCED, 1992).

MacDonald, 2004). Extending the company's economic-financial bottom line reporting to a 3P bottom line for the whole of society suggests it is feasible to aggregate the economic, environmental and social indicators according to a common, undisputed formula. In practice however, such 3P reports use an eclectic mix of social indicators, rendering the outcomes of 3P assessments vulnerable to manipulation (Norman and MacDonald, 2004). Selective omission of legitimate principles that do not fit with one's ideological outlook, or biased weighing of social sustainability criteria, conceal attempts to reframe the sustainability discourse (Bond and Morrison-Saunders, 2011).

Reframing the SD discourse in 3P terms has no doubt contributed to the discursive success of the concept. Over the past two decades, SD has been seamlessly integrated into the discourse of political, social and business actors on international, national, regional, and local levels.[2] Apart from this discursive success, however, achievements in actual sustainability since 1987 are quite sobering (Zaccaï, 2012). The sustainable growth interpretation has become too far removed from the initial UN propositions. Agenda 21 (UNCED, 1992) puts governance at the center of sustainable development concerns by explicitly calling upon states to elaborate national strategies, plans, policies and processes to make development more sustainable. The conceptual Chapter 2 of Our Common Future (WCED, 1987, pp. 43–65) concludes with the requirement of rebuilding seven societal systems, three of them directly referring to politics, policy-making, and governance, which are omitted by the 3P reductionist approach. Sustainability discourse should place politics centrally in governing and integrating Planet, People, and Prosperity (Fig. 1).

The WCED definition of SD is indeed inclusive yet broad and general, and contributes to diverging interpretations in terms of world views and interests of the beholders. Some said that SD is a vague concept; others proposed to dispose of the term. Yet like democracy, SD holds a goal for humankind and contains sets of criteria to assess whether developments advance the goal or set it back. It is helpful to link the SD goal with substantiated elements considered necessary for its advancement (Fig. 2). The standard goal is put forward as "humanity has the ability to make", emphasizing the responsibility of humans, i.e. the ability and necessity to act. SD is advanced in three main action fields: growth control, redistribution, and societal change underpinning the foregoing actions. The clarity of the contents and the actual U-turns implied, make SD an intimidating, concrete and challenging duty for societies, politicians and their constituencies.

3. Sustainability assessment frameworks used by IAEA and IPCC

Section 3 applies our discourse-analytic framework to the SAs of nuclear power developed by IAEA and IPCC. IAEA and IPCC are two influential international organizations with real impact on public energy decision making in many countries.

[2] For example, the World Business Council on Sustainable Development was founded in 1992 to channel the voices of international business leaders in SD discourse and negotiations; while the OECD also regularly publishes thematic and monitoring reports on sustainability.

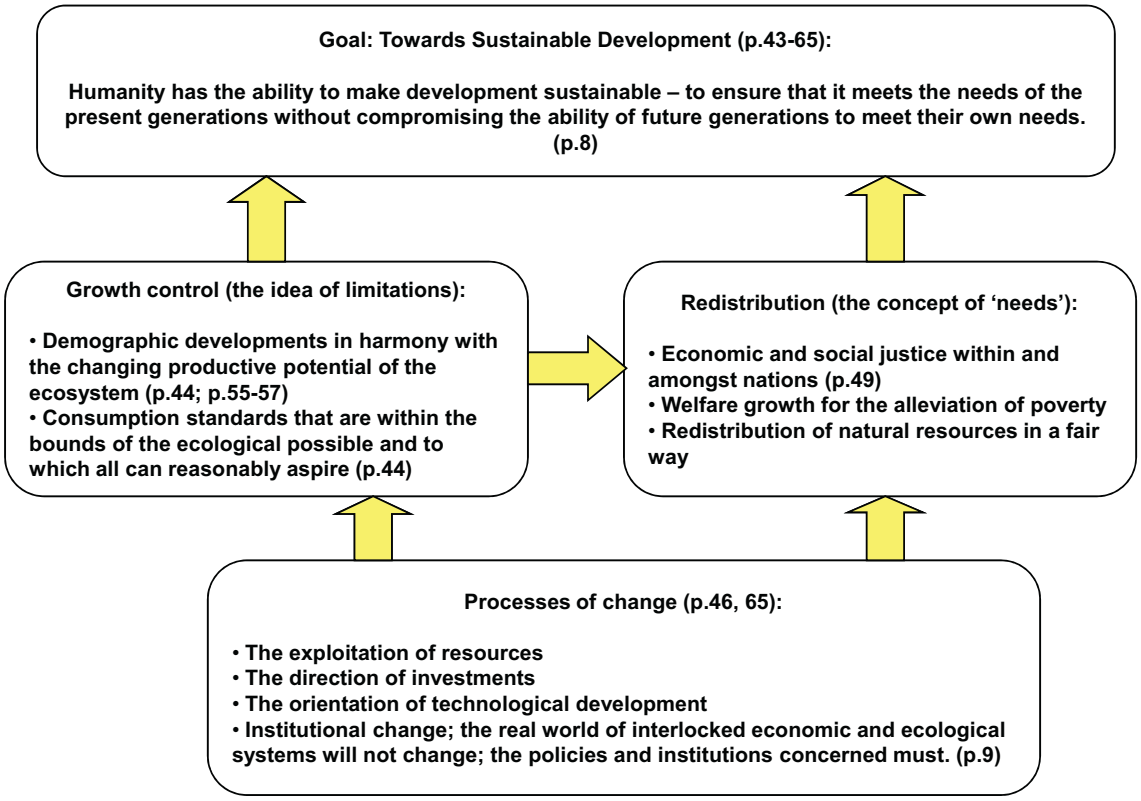

Fig. 2 – Substantiated definition of sustainable development (based on WCED, 1987).

Both organizations have spoken out regarding whether nuclear power can be part of a sustainable energy future.

The International Energy Agency (IEA) also operates at the international level as recognized designer of energy pathways and policies (as published in the yearly World Energy Outlook and since 2006 in the Energy Technology Perspectives (ETP)), but relies on techno-economic assessments for its advice rather than full-blown SAs. Based on a combination of optimization (for energy supply) and simulation modeling (for energy demand), the 2014 ETP edition (IEA, 2014) projects a vision of a 'sustainable energy system' respecting the need to limit global warming to 2 °C in 2050 (2DS scenario). IEA states that nuclear power should play a modest yet still essential role in meeting this target in a cost effective manner, by projecting a contribution of 7% of the needed reductions in greenhouse gas emissions in 2050 (IEA, 2014, p. 30). The IEA nuclear energy technology roadmap (IEA, 2015) lists the 'challenges' standing in the way of the needed nuclear deployment in the 2DS scenario. For Europe, these 'challenges' include "*. . .financing in liberalized markets, developing a 'technology-neutral' policy for low-carbon investments, market distortion (due to subsidized renewables) and decreasing wholesale electricity prices; and public acceptance. . .*" (IEA, 2015, Table 1, p. 14). The 'challenges' identified by IEA broadly correspond to the usual economic, environmental and social dimensions of SD. IEA does not derive these challenges from an explicit discourse on SD; they are mainly directed to clear the way for the 'needed' nuclear power expansion. Therefore it is not meaningful to include IEA in this analysis.

To our knowledge, IAEA and IPCC are the only organizations at the inter- or supranational level engaged in sustainability assessment of nuclear power. We apply the three discourse levels as identified in Section 2.2: manifest image, vision, and policy target.

3.1. *International Atomic Energy Agency (IAEA)*

By way of the ongoing 'International Project on Innovative Nuclear Reactors and Fuel Cycles' (INPRO), the IAEA, in cooperation with the IEA, the European Environmental Agency, EUROSTAT and the UN Department of Economic and Social Affairs, developed the INPRO methodology for the sustainability assessment of nuclear energy systems, encompassing all facilities of the nuclear fuel cycle from mining/milling, uranium conversion, enrichment, fuel fabrication, electricity generation, through to final end states for all wastes and permanent disposal of high level waste, and related institutional measures including legal framework, regulatory bodies, etc. (IAEA, 2008).

As manifest image, INPRO explicitly refers to the WCED report to justify its focus on the four dimensions of sustainable development (IAEA, 2008, p. 11): economic, environmental, social and institutional. Closer scrutiny reveals a marked difference in the importance attached to each of the dimensions. The institutional dimension is assigned a restrained instrumental role of good management of the complicated industrial activities making up the nuclear fuel cycle. At the outset, INPRO confines the environmental

dimension to arguing for the need for an increased use of nuclear power at the global level (IAEA, 2008, p. 2). The IAEA "*recognizes that*

- *A sustainable energy supply for humanity in the 21st century will require the large-scale deployment of nuclear power as well as other energy sources;*
- *Nuclear power is an energy technology that offers practically unlimited energy resources whose deployment can reduce environmental pollution and the volumes of waste needing management, including greenhouse gas emissions.*"

The IAEA apparently considers this statement to be common sense, because no further justification is offered. However, this viewpoint is challenged by detailed analyses showing that the energy service needs of a more heavily populated and equitable world, enjoying radically higher levels of wellbeing, can be cost-effectively met entirely and solely by diverse currently available technological and organizational innovations in wind, solar, biomass, hydro, ocean and geothermal power (ECF, 2010; EREC, 2010; PWC, 2010; IPCC, 2011; Davis and Goldemberg, 2012). Though the comparison of renewable-based pathways with the IAEA's nuclear-based pathway is beyond the scope of the present paper, it is clear from the above-mentioned studies that transformations in global energy services based entirely on renewables merit more attention in a SA than is afforded by the IAEA.

At the vision level, INPRO distinguishes three goals (IAEA, 2008, p. 5):

1. To screen a nuclear energy system to evaluate whether it is compatible with the objective of ensuring that nuclear energy is available to contribute to meeting the energy needs on the 21st century in a sustainable manner;
2. To compare different nuclear energy systems or components thereof to find a preferred or optimum nuclear system consistent with the needs of a given IAEA Member State;
3. To identify research, development and demonstration (RD&D) required to improve the performance of existing components of a nuclear energy system or to develop new components.

The first goal aims to support strategic decision-making in IAEA Member States that want to establish a new nuclear energy program or expand an existing one. Again, it is striking that the actual sustainability assessment of the nuclear energy system comes *after* the acceptance of the need for additional nuclear power in an IAEA Member State. The need is argued as an outcome of power demand and supply modeling over the coming decades, where outputs of models are based on ceteris paribus assumptions about relationships governing energy system developments and assuming only marginal changes. The evaluation of nuclear power as being 'needed' results from estimations of growth in demand (with little electricity efficiency), investment expenses, supportive financing terms, availability factors of the units, etc. The modeling tools proposed by IAEA (2008, pp. 59–69) are run within the bounded rationality of an economic optimization of a nation's energy system within a time frame spanning a few decades, under assumption of manageable doubt and of easy reversibility, sidelining the true challenges of incomprehensible far futures, uncontrollable doubt, and precluded reversibility (Verbruggen, 2013). Gibson et al. (2005) explicitly reject the methodological approaches adopted by IAEA as inappropriate for the assessment of sustainability-oriented policies. Considerations regarding the flexibility or the reversibility of the nuclear power option in the face of large uncertainties are not scoped by IAEA.

In case the modeling analysis recommended by IAEA establishes the need for (additional) nuclear power, the Member State can select a nuclear energy system and further submit it for INPRO assessment. INPRO handles a three-level hierarchy: (1) basic principles; (2) user requirements; (3) criteria based on indicators with corresponding acceptance limits (thresholds). The entire hierarchy covers the areas of nuclear power economics, environmental performance, safety, waste management, proliferation resistance, physical protection and infrastructure (Fig. 3). A basic principle is met when meeting all user requirements related to the principle; a user requirement is met when the performance thresholds for all related criteria are obeyed.

The criteria, with their respective indicators and thresholds or acceptance limits, reveal how sustainability is constructed by IAEA at the third discourse level (sustainability as a policy target or goal) (IAEA, 2008, pp. 75–109). If a nuclear energy system meets all thresholds or acceptance limits, the system is called 'sustainable' (IAEA, 2008, p. 50). But closer scrutiny of the thresholds or acceptance limits shows that for IAEA, 'sustainable' is that which is in accordance with the current dominant energy supply thinking and practice. This is strikingly obvious from several acceptance limits on assessment criteria, e.g. (our italics): "information provided to the public [which is] *sufficient according to best international practice*" (on infrastructure); "lower consequences *compared to existing facilities*" (on environmental protection); "generation of waste shall be kept to *a practicable minimum*", and "waste shall be managed in such a way that *undue burdens* are not imposed on future generations" (on waste management). However, a diffusion of nuclear best practices cannot provide proof that best practices obey the standards of sustainable development. Countries heralded as exemplary cannot address the consequences of nuclear misfortune (e.g., Japan). Furthermore, the IAEA discourse on acceptance limits and thresholds for sustainability criteria precludes more fundamental ethical debates on the use of nuclear power. A few examples (further elaboration in Verbruggen et al., 2014) of ethical questions include:

- Is it morally acceptable to impose intricate burdens on future generations who will not benefit from the power generated by the nuclear energy system?
- Does relying on a 'low-probability/catastrophic-consequence' type of technology such as nuclear power lie in accordance with the precautionary principle?
- Can a continued reliance on nuclear power be justified from the point of view of intra-generational equity given that a

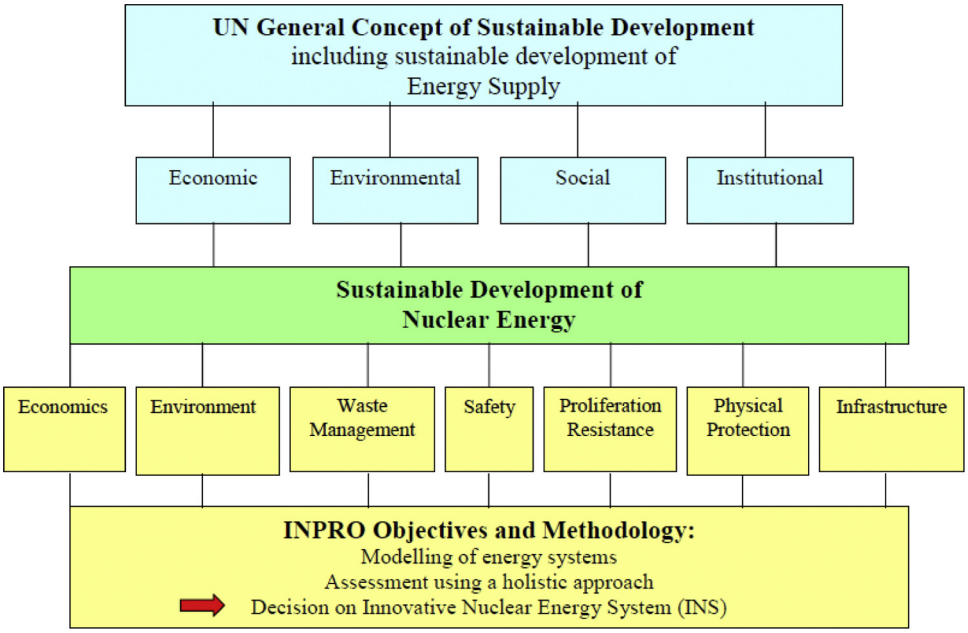

Fig. 3 – Interrelationship of the IAEA's INPRO methodology with the WCED concept of sustainable development according to the IAEA (IAEA, 2008, p. 14).

majority of countries cannot attain the 'best practices' of wealthy and experienced countries?

To sum up: the extensive assessment structures elaborated by IAEA fail to address the most fundamental question of the role of nuclear power in a sustainable energy future. For IAEA, 'sustainable' equates to responsible deployment of nuclear power in those countries that are able to comply with current best international practices and standards, in order to meet an (according to IAEA) indisputable need for more nuclear power at a global level.

3.2. *Intergovernmental Panel on Climate Change (IPCC)*

According to its mission and background, the IPCC is receptive to prevailing manifest images of SD. However, the IPCC is barred from policy-target discourses as the watershed between that and policy-prescriptive discourses is considered too fine. Hence, the main contribution of IPCC WGIII is in identifying and analyzing the various policy-relevant visions in a rigorous and balanced way by assessing the available literature regarding the main policy options, as well as the contentious ones such as nuclear power. We will hereby check to what extent IPCC WGIII performed a sustainability assessment of nuclear power in the fifth assessment (IPCC, 2014).

The Fifth Assessment Report addresses nuclear power mainly in subsections of WGIII Chapter 7 on Energy Systems (IPCC, 2014). First, nuclear power is called one of the three major low-carbon electricity supply options, after renewables and ahead of fossil fuel conversion with carbon capture. Promoting this trinity reveals the predominance of low-carbon electricity supply as a decisive attribute in the assessment. It neglects and covers up important contradictions and incompatibilities between full deployment of renewable electricity and the extension of nuclear supplies (Verbruggen, 2008). Second, one subsection (7.5.4) and separate paragraphs in other sections assess nuclear power as an electricity supply source. Nuclear power being contentious, the IPCC is expected to provide and discuss the various visions on this technology and on its eventual role in a low-carbon future. However, Chapter 7 fully conforms to the IAEA vision, with a few extensions to peer-reviewed literature accepting this vision and leaving out the literature which is critical of the IAEA vision. For example, subsection 7.5.4 contains 52 references: 37 to mainly nuclear-dedicated institutes (e.g. 16 to IAEA) and 15 to authored, mainly technical nuclear, publications (six non-peer reviewed).

The IPCC's Table 7.3 shows how 'nuclear replacing coal power' would perform on 'Economic, Social, Environmental objectives/concerns'. This 3P discourse is further reduced by a narrow interpretation of the dimensions. For example, economic performance is expressed by (1) 'Energy security (reduced exposure to fuel price volatility)', (2) 'Local employment impact (uncertain net effect)', (3) 'Legacy cost of waste and abandoned reactors'. IPCC rates 'nuclear replacing coal power' as positive for the first two points, and negative for the third. Construction and generation cost information (IPCC, 2014, Chapter 7, p. 39) comes from IEA and NEA (Nuclear Energy Agency, OECD), which obtain their data mostly from nuclear plant owners, viz. operators. This closed loop from data source to data use creates circular referencing, and IPCC does not balance it with peer-reviewed publications that offer other information on nuclear power costs (e.g. Grübler, 2010; Bradford, 2012).

The executive summary of Chapter 7 contains two paragraphs on nuclear power, although not equally endorsed in the Summary for Policymakers by the IPCC plenary meeting in Berlin (April 7–12, 2014). For example, the view that "*barriers*

to an increasing use of nuclear energy include concerns[3] *about operational safety and (nuclear weapon) proliferation risks, unresolved waste management issues as well as financial and regulatory risks*'' echoes IEA's position (IEA, 2014) that not the risks as such, but rather the non-acceptance of risks, would be the real problem for nuclear breakthrough. The plenary adjusted the phrasing by putting the real risks and problems first and risk perception second, as barriers for nuclear deployment.

The evidence is that in its Fifth Assessment Report, IPCC WGIII did not probe a sustainable assessment framework to evaluate nuclear fission power and find out whether nuclear power can form part of a sustainable energy future. Assessment reports now include a chapter on SD in their WGIII volumes, but policy actions and programs are not assessed with clear sustainability frameworks, and SD often receives no more than the obligated lip service. The IPCC accepts mostly the IAEA vision, and neglects its task of identifying and assessing alternative visions in the peer-reviewed literature. Our findings on the generally supportive attitude toward nuclear power in the IPCC's Fifth Assessment Report are in line with the findings of Waldman's (2015) analysis of the IPCC's shifting position on nuclear over the period 1990–2014. In particular, Waldman notices a remarkable shift between the 2011 ''Special Report on Renewable Energy Sources and Climate Change Mitigation'' (IPCC, 2011), where the reliance on nuclear power is to be 'minimized'; and the 2014 Fifth Assessment Report, where nuclear power is once again grouped with renewable energy as the key elements of a low-carbon energy system.

4. Conclusions and policy implications

Table 1 summarizes our findings on the SA frameworks used by IAEA and IPCC. Both organizations make ample use of the sustainability discourse's 'constructive ambiguity' to further their agenda.

IAEA was established in 1957 to promote civil nuclear power and to supervise accounts of nuclear materials for avoiding its use for military purposes. The promotional mission of IAEA is also evidenced by its sustainability discourse, which essentially boils down to a plea for a 'responsible' deployment (i.e. one in accordance with current best international standards) of nuclear fuel cycle technologies.

IPCC, in accordance with its institutional mission as a provider of ''policy-relevant and yet policy-neutral, never policy-prescriptive'' knowledge to decision-makers and its emphasis on SD as the overarching framework for assessing climate mitigation and adaptation options, is a prime candidate to develop a comprehensive SA of nuclear power. But IPCC avoids the discussion and assessment of different visions on the role of nuclear power in a low-carbon energy future, and skips the literature that is critical of nuclear power. IPCC may act so because of fear of being policy-prescriptive,

Table 1 – Overview of IAEA and IPCC discourse elements by sustainability discourse stages 'manifest image', 'vision', and 'policy target'.

Manifest image	
IAEA	Self-proclaimed adherence to 4 dimensions of SD (economic, social, environmental and institutional). Environmental dimension (resource use and GHG emissions) are stressed as a 'common sense' argument for the continued need for nuclear power on a global scale. Institutional dimension takes on the limited (instrumental) role of 'good governance' of nuclear fuel cycle activities.
IPCC	Chapter 4 of the Fifth Assessment Report advocates a three-pillar model of sustainable development (economic, environmental and social pillar). Sustainable development is presented as the overarching framework for assessing the impact of climate mitigation options on each of these pillars with special attention to the distributional aspects of the impacts (equity dimension).
Vision	
IAEA	The INPRO methodology can be used to create a common vision on • The contribution of nuclear power to the development of a sustainable energy system in a Member State; • The comparison of different nuclear energy systems; • The comparison of components of a single nuclear energy system. Need for nuclear power for a Member State predicated on narrow techno-economic modeling, implying that these techno-economic parameters have a privileged status in the sustainability assessment
IPCC	Nuclear power is named as one of the three major low-carbon energy supply options. Narrow 3P discourse in Chapter 7 on ''Energy Systems'': nuclear compared to coal on 3 dimensions (energy security; local employment impact; and legacy cost of waste and abandoned reactors). Ambiguous discourse on nuclear risks: sometimes presented as 'real' barriers to nuclear energy deployment (Summary for policy makers), sometimes presented as a problem of 'public acceptance' (Chapter 7 on energy systems).
Policy target	
IAEA	Elaborate system of basic principles, user requirements and criteria based on indicators with corresponding acceptance limits (thresholds). Acceptance limits are defined so that 'sustainability' in practice means complying with the best international standards currently in use. Fundamental ethical debates are avoided.
IPCC	Policy target discourse is avoided because the watershed with policy-prescriptive discourses is considered too thin. Fundamental ethical debates are avoided.

[3] Stronger wording is used in IPCC subsection 7.9.4 on Public perception, e.g. ''For nuclear power, anxieties often focus on health and safety (...) and proliferation (...). Further, perceptions are dependent on how the debate around nuclear is framed...''. This observation is not followed by a broad range of references that represent the various visions on the issue of perceptions. IPCC (2014) Chapter 4 (sustainable development and equity), p. 26 is more balanced than chapter 7. Chapter 7 also skips the argument that risk-averse citizens are equally as rational as the multinational underwriting companies that reject full indemnity insurance for nuclear power plants (e.g. Verbruggen, 2008).

but the exclusion of a critical perspective implies a strong policy-prescriptive stand.

The essentially problematic conclusion is that both SA frameworks of nuclear power investigated here are constructed in order to obtain answers that do not conflict with prior commitments adopted by the institutes. These findings on the essentially 'precarious' nature of SAs of nuclear power most likely extend to SAs performed on behalf of nation states – cf. the conflicting positions on nuclear power taken by the German government (a phase-out policy supported by the advice of an Ethics Commission) (Ethics Commission on a Safe Energy Supply, 2011) and the UK government (a new build policy conditionally supported by the advice of the SPRIng consortium) (SPRIng, 2011) – though specific analysis is requested to verify this assumption.

A comprehensive framework for the proper assessment of nuclear power's suitability for sustainable development is lacking, as is the institutional embedding of comprehensive SA procedures and implementations. Our analysis demonstrates the need for a critical and reflexive approach in SAs of nuclear power and for being sensitive to the ideological (re)production that plagues politically contested concepts such as sustainability. Language and discourse are powerful ways of reproducing ideology and maintaining hegemonic institutional positions. These positions may conflict with more transformative visions of sustainability.

We therefore revisit the need for a global independent agency to review nuclear power issues independently, using sustainability as the guiding principle. The SD paradigm as developed by the WCED radically surpasses the trivial general claim of compromising between social, economic, and environmental policy. With this proviso, a new agency should accomplish the following tasks:

- Provide the normative foundations of a sustainability discourse on nuclear power; and based on these foundations, specify the discourse according to clearly defined sustainability criteria (attributes to be included, results to be obtained);
- Provide a descriptive analysis (informed by the criteria) of how nuclear power programs currently perform according to the criteria;
- Tackle the descriptive question of which external hindrances and motives have so far obstructed the progress toward sustainability;
- Discuss to what extent sustainability is required from a moral point of view, when balanced with competing interests, e.g. short-term economic growth, questions of employment, etc. including questions about which institutes could resolve this issue and within which margin of discretion;
- Give advice on policy means to effectively increase performance in accordance with the sustainability criteria.

Table 2 refers to a comprehensive framework based on the sustainability vision of the WCED report. It may contribute to a

Table 2 – 19 criteria for the sustainability assessment of nuclear fission power.

Dimensions	Criteria [attributes to own; results to obtain]
Environmental/ecological Planet	1. Climate change problems are relieved (mitigation and adaptation) 2. Ecological resilience of the energy system's embedding environment is preserved 3. Exhaustible finite resources are managed in light of future substitutes Electricity use efficiency and deployment of renewable electricity potentials are stimulated
Economics Prosperity	1. All costs of the nuclear system are identified, measured (or properly assessed), and billed to end-users of nuclear power 2. Technology evolves to higher economic efficiency: more output at reduced costs 3. Capital investments are affordable for most countries in the world The electricity supply industry resulting from generation technology choices, is secure and reliable [of low vulnerability]
Risks	1. Risks are fully insurable, also catastrophic risks 2. Nuclear plant owners and operators are fully liable for risks, including long-term effects and impacts Proliferation of technologies and know-how that can be used for nuclear weaponry is limited and reduced
Social People	1. Electricity bills are affordable (match expectations of constituencies) 2. External and future costs are allocated according the polluter pays principle and precluding displacement of problems and risks to the poor, to developing countries, and to future generations 3. Exposure to harmful pressures is low, with proper information on safety and health impacts Global redistribution of access to natural resources and of economic wealth growth is stimulated
Governance/policy Politics	1. A global, independent agency studies nuclear power issues and choices in light of its longevity, uncertainties, and irreversible impacts 2. Independent and accountable nuclear regulatory institutions and processes are established and publicly monitored 3. At national-regional levels, public interest prevails over private profit, and democratic institutions prevail over technocracy At local levels, citizens can deliberatively commit in energy system governance, and participate in deployment of local energy systems

rational – i.e. transparent, comprehensive and reflexive – SA procedure for the nuclear power option.

The conclusions, while arrived at in the context of SAs of nuclear power, have a broader validity also to the practice of SA in other domains. Our findings are in line with Grunwald's (2015) conception of SA as 'theory-in-practice', meaning that SAs through their operationalization of a particular conception of sustainability have an effect on policy-making practice, which should in turn be reflected on. Therefore, the practice of developing SAs should include an explicit deliberation on the conception of sustainability applicable to the question at hand (including a further specification in criteria and indicators), as well as the practical consequences of this conception in terms of implementation advice. These practical consequences in turn have to be monitored and taken in account to assess the adequacy of the proposed sustainability conception in a policy-learning loop. Particularly, if the proposed conception of 'sustainability' does not deviate significantly from the historically observed 'business-as-usual' (as is the case for the SAs by IAEA and IPCC), historical investigations on the consequences of previously adopted (technological) pathways are imperative.

Many more aspects of the discourse on sustainable development and nuclear power could be explored in further research. For example, it would be interesting to analyze SAs on nuclear power performed in different countries all over the world in support of national energy strategies, and the influence of the IAEA or IPCC on the discourse embedded in these SAs. It would also be interesting to trace the emergence of a discourse on the relationship between nuclear power and sustainable development in such SAs as the result of a compromise between different perspectives of actors involved in drawing up the SA. Our article may be a stimulus for broadening and deepening the much needed debate on the future role of nuclear power in a sustainable energy system with more discourse-analytic contributions.

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