Integrated design of alternative energy options; a multi-criteria approach

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Abstract

It is long established that for the successful commissioning of a technological project, an extended platform is needed to cover the planning, design, construction and operation phases that will address the complex technical, economic, environmental and social issues involved. In this paper we present a new approach suited for (renewable) energy planning with the aforementioned dimensions integrated in a new platform, together with the necessary decomposition analysis. The whole new framework is based on an analytical multi-criteria methodology and public participation dynamic and will hopefully pave the way towards a new, currently under transition, energy future.

Key words: Energy Systems, Decomposition Analysis, Multi-criteria, Integrated design, Sustainability

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1. Introduction

Energy planning has come a long way during the 20th century from an initially intuitive approach to a full-scale discipline, incorporating technological and economic dimensions. The latter include both the micro- and the macro- policy level, whereas the technological framework covers energy, technology, thermodynamics and thermo-economic approaches under an integrated regional energy planning agenda (Nijkamp, Volwahsen, 1990). It is only during the last two decades that the environmental aspects of energy conversion have started to assume the gravity that it should have been assigned perhaps from the start, with the deterioration of the environment, e.g. acid rain, urban pollution, climate change, etc. and the depletion of natural resources becoming issues of outmost importance. The emergence of the renewable energy technologies as a reliable substitute of conventional fossil fuels gave promises that were only partially fulfilled as they never assumed the role that society had entrusted on them in the beginning. Besides, many scholars claim that it is highly unlikely that renewable energy sources could, on their own, sustain present industrialized societies high levels of energy use (Trainer, 1995).

Alternative energy options, both on the technological and the resource level, revealed the complex nature of energy planning, where energy production and conversion should be addressed in tandem with energy demand and consumption and the particular preferences of the consumers. Today's energy planning requires an integrated approach which includes the technological, economic, environmental and social design, accounting for the multitude of facets that interweave in the analysis and successful implementation of energy policies and projects. The aforementioned four dimensions, i.e. technological, economic, environmental and social must in turn be decomposed in a number of attributes in order for a quantitative and qualitative assessment to proceed (Polatidis, Haralambopoulos, 2005). For the identification of the most appropriate energy solution, a multi-criteria analysis seems to be the logical framework since it allows for a multitude of elements to be incorporated, and at the same time it can include a variety of stakeholders, with conflicting perhaps interests (Beccali et al, 1998; Afgan et al, 2000; Bardouille, Koubsky, 2000).

In this paper we present a new approach for energy planning with the technological, economic, environmental and social design dimensions integrated in a new platform together with the necessary decomposition analysis. The whole new framework is structured around the analytical multi-criteria methodology and public participation and can pave the way towards the new, energy future, which will be based on conventional energy plants, renewable energy penetration and distributed generation.

2. Current situation in (renewable) energy planning and design

The extremely complex nature of energy planning and design, the many different technologies involved and the large number of different, associated aspects (socio-economics, greenhouse gas mitigation, environmental problems,) make this whole topic a multifaceted subject. Particularly for the case of renewable energy sources structural aspects, different actors and a number of diverse dimensions enhance further the complexity of the issue (Figure 1).

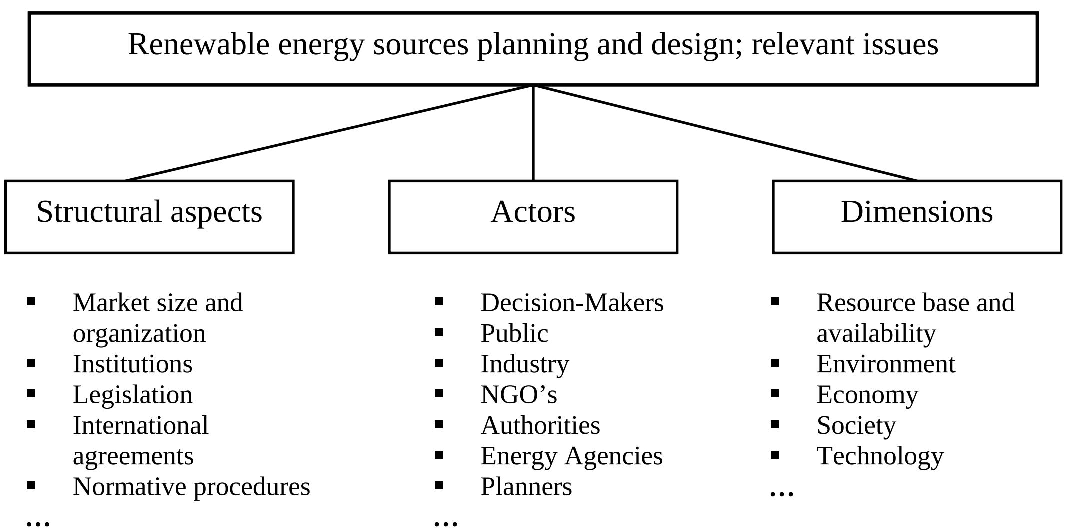

Figure 1. Renewable energy sources planning and design; relevant issues

All these parameters should be analysed and included in the relevant decision-making and design process that take place in the real world under the general spheres of the economy, the resource base, the environmental situation, the particular societal needs and technological options (Figure 2).

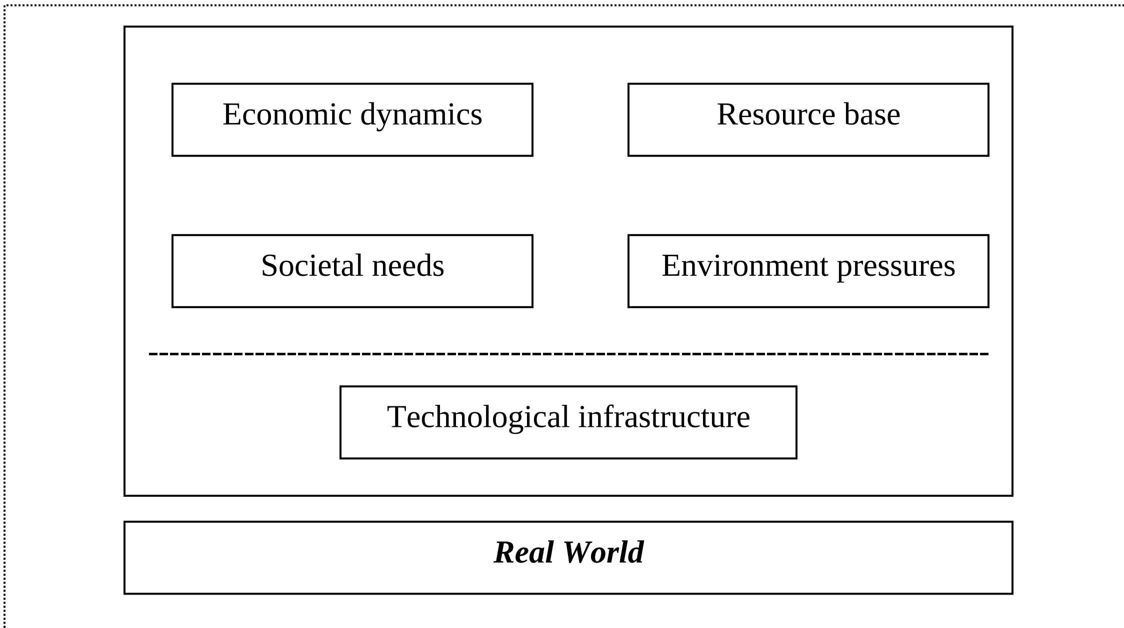

Figure 2. Real world dynamics that should be included in energy decision-making

All these form a new challenge for a science for sustainability and engineering that integrates industrial, social, economic and environmental processes in a global context.

Particularly for energy planning it is generally agreed that conversion to renewables will be 'good' in the long term. Nevertheless, one should have in mind that Renewable Energy Systems (RES) include both the technologies involved and the related decision-making process (Figure 3). This underlines the fact that any managerial approach should take into account the emerging technological regime and social dynamics, in conjunction with different temporal and spatial scales and policy framework (Polatidis et al, 2003).

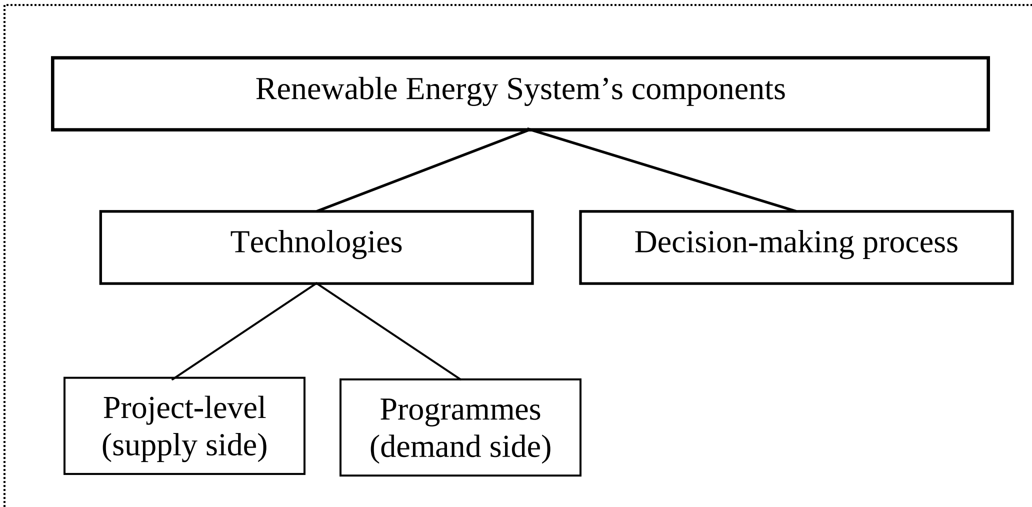

Figure 3. Renewable Energy System’s components

It is prudent, therefore, for a new planning framework for RES to be initiated that could provide for an integrated design of the technological, economic, environmental, and resource base attributes of (renewable) energy projects and programs coupled with the socio-economic aspects of the related decision-making process.

The remainder of this paper attempts to provide a first design agenda for such a framework.

3. The new framework for integrated design of (renewable) energy options

Up to now reactions of the general public towards renewables have been studied on an ad-hoc basis, with a lack of a wider perspective and with short-term focus. It also involved particular technologies and energy management practices, like biomass projects, wind farm installations, rational use of energy and conservation in households, etc., without an integrated framework of analysis (Polatidis, Haralambopoulos, 2005). The associated social processes (e.g., knowledge diffusion, local cultural identities, particular belief systems and the social and behavioural aspects of energy consumption) have not been given their due importance; only implicitly they were included in related decision support tools (Marttunen, Hamalainen, 1995; Polatidis et al, 2005).

A new framework of integrated design of alternative energy options should, therefore, be established that includes the two dimensions: a) at the technological, and b) at the societal level.

This new framework should try to:

- √ understand and incorporate the social characteristics of RES,
- √ match the current conditions of a community with the particular energy requirements and available technological solutions, and
- √ identify the most appropriate and acceptable energy supply system or energy conservation programme

Figure 4 presents the above-mentioned ideas in a schematic form where the various elements have been included in a dynamic fashion into a new, integrated framework of RES design paradigm.

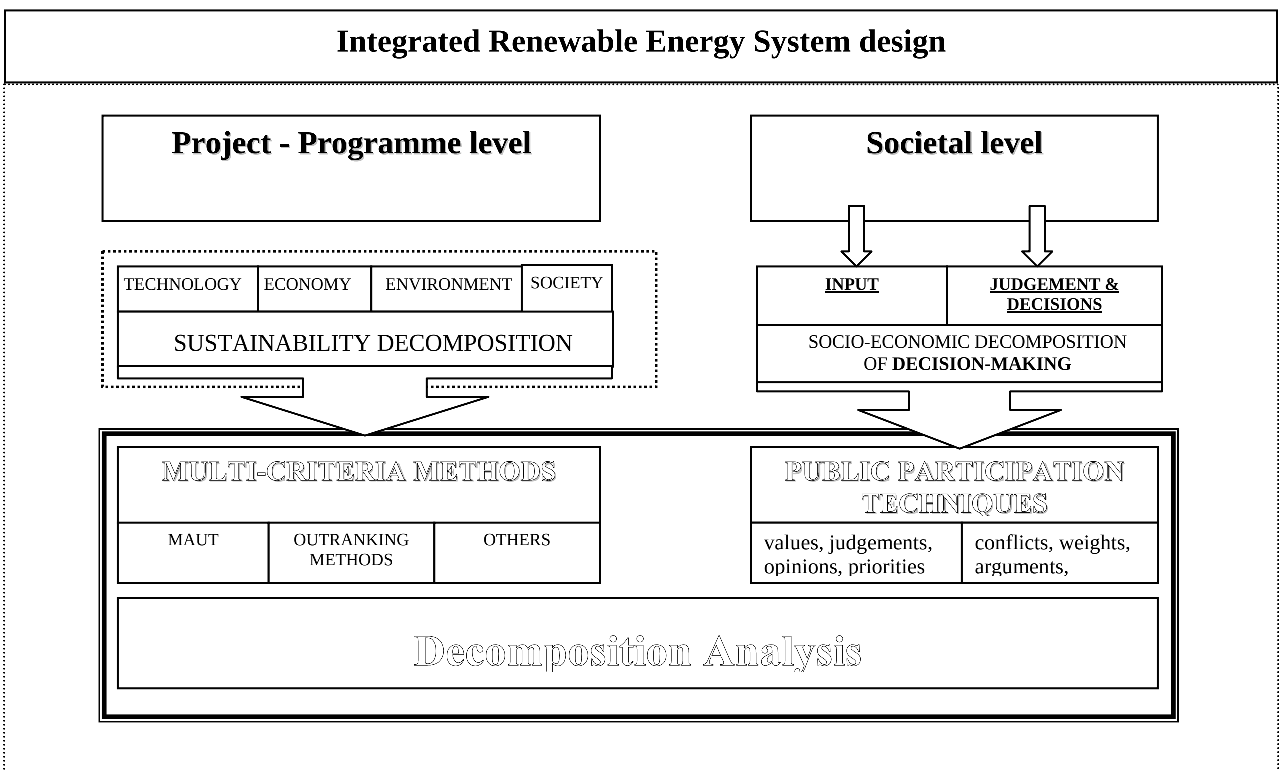

Figure 4. Schematic diagram for the integrated RES design

This integrated design of sustainable RES encompasses two modules:

A. an innovative project/programme Sustainability Decomposition module which will feed into the Multi-Criteria methods, and
B. a Socio-Economic Decomposition of Decision-Making module that would elicit inputs, judgements and decisions from public and actors (stakeholders, decision-makers) through the public participation techniques.

Such an integrated design frame for energy options could possibly:

- establish the data collection and organisation for the decomposition of sustainable RES
- involve existing multi-criteria methods, available for social acceptance measurements, and public participation techniques
- decompose, on a sustainability basis, the contents of renewables projects and programmes
- provide the socio-economic decomposition of the relevant decision-making process
- map the emergent institutional and legislative regimes

The multi-criteria methods could be used as models and tools for (indirect) social acceptance measurements and could encompass a variety of differing techniques like Multi Attribute Utility Theory – MAUT (Keeney, Raiffa, 1976; von Winterfeldt, Edwards, 1986), Outranking methods – PROMETHEE family (Brans, Vincke, 1985; Brans et al, 1986), ELECTREE family (Roy, Vincke, 1981; Roy, Hugonnard, 1982; Roy et al, 1986), etc., (Interactive) Programming methods (Zeleny, 1982; Steuer, 1986; Vincke, 1992), Analytic Hierarchy Process – AHP (Saaty, 1980), and other methods – NAIADE (Munda, 1995), REGIME (Nijkamp et al, 1990), FLAG (Nijkamp, Vreeker, 2000), SMAA (Lahdelma et al, 1998), etc. (Figure 5).

MULTI-CRITERIA METHODS		
MAUT	OUTRANKING methods	PROGRAMMING methods
AHP	NAIADE, REGIME, FLAG, SMAA	OTHER…

Figure 5. Multi-criteria methods as models and tools for (indirect) social acceptance measurements

The public participation techniques may include methods like preference-weights elicitation, opinion surveys, community advisory boards, focus groups, citizen juries, etc. (Rowe, Frewer, 2000; Halvorsen 2001; Hisschemoller et al, 2001) and their particular applications in energy and environmental planning and decision-making (Hobbs, Horn, 1997; Alvarez-Farizo, Hanley, 2002) (Figure 6).

PUBLIC PARTICIPATION TECHNIQUES		
WEIGHTS ELICITATION	OPINION SURVEYS	ADVISORY BOARDS
FOCUS GROUPS	CITIZEN JURIES	OTHERS…

Figure 6. Public participation methods for RES planning

The overall socio-economic and institutional context in which RES are deployed may well be addressed by the proposed framework for integrated design in a synergistic approach, taking under consideration energy, environmental, economic and other related policies; modifications of past policies and formulation of new ones, where necessary, could also stem from this framework. Taken as a whole, the decomposition of sustainable projects and programmes provides for an identification, and categorization of relevant economic, environmental, social, technological, and resource based data of RES.

Furthermore, the integrated framework for energy projects design developed in this work could provide for a common yardstick to measure parameters that are, most of the times, difficult to quantify and taken into account from the early stages of a scheme. Factors to be taken into account include public perception of RES, environmental pressures, employment creation, aesthetic attitudes, life-cycle costs, externalities, etc. An illustrative example is presented as follows in Box 1 concerning the siting of a new power plant in the island of Lesvos –Greece. With such an integrated framework it is expected that the unsustainable patterns of development characterised by growing dependence on conventional fossil fuels and rising energy demand could be decelerated and an initiative towards a more sustainable energy system can be materialised without hampering economic growth.

BOX 1. A case-study of the siting of energy facilities in an autonomous grid with rich renewable resource base – Lesvos island, Greece

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<u>Examples of issues to be addressed by an integrated design approach to RES planning:</u>

- ENERGY DEMAND – PROGRAMMES
  Energy demand raises by 5% annually, Lack of coordinated energy conservation programmes
- TECHNOLOGICAL OPTIONS
  Fuel choice, power generation choice, interconnection
- PUBLIC PRESSURE (NIMBY)
  Regional development plan, preference for tourism development
- ENVIRONMENTAL CONSIDERATIONS
  Aesthetics, local pollution, CO_2 emissions, impact during construction / operation / decommission
- SOCIAL ATTRIBUTES
  Employment creation, compatibility with current activities, potential for reducing black-outs, change of rural life-style, distance from capital city
- RENEWABLE POTENTIAL
  Geothermal, wind, solar
- SPATIAL PLANNING
  Areas in the 'Natura' network, distance from sea, landscape conservation policy

4. Discussion – Conclusions

Under a general perspective, design for sustainability represents an effort to consider both the environmental and socio-economic systems. The integrated design of alternative energy options implies the simultaneous consideration of the technological, resource base, environmental, economic and social attributes of energy systems. It is impossible to design a faultless natural environment or an ideal society, but it seems possible to modify the controllable characteristics of contemporary designed artefacts (e.g., factories, products, services, programmes) in ways that create environmental and social benefits without hampering development and without wasting valuable resources.

Particularly for the case of RES the accurate analysis of social impact indicators, such as health system situation, educational level, social relationships, economic situation, and ethic habits, coupled with a detailed analysis of the other important dimensions of energy schemes, namely economic profitability, environmental impact, technological appropriateness, and availability of resource used facilitates the quest for a correct energy supply system solution for each social situation.

A procedure which can introduce renewables in a more fair basis would be one that incorporates multiple criteria. Within such a framework, and assuming active and committed public participation in the decision-making process, the intangible characteristics of RES and the different points of view that emerge from them, might be reflected in the criteria and weights chosen. In any case the broad range of economic, environmental and social factors needs to be considered across the system life-cycle.

The proposed integrated design for alternative energy options encourages explicit consideration of resilience in both engineering systems and the larger social systems in which they are embedded. In this way energy systems can be endowed with intrinsic characteristics that improve their social robustness and adaptability. This entails work towards sustainability by adopting a fresh perspective of systems' thinking.

Based on these insights, this paper developed an initial, generalized integrated framework of sustainable energy systems design, including explicit consideration of system boundary conditions and external impacts. It is long established that for the successful commissioning of a technological project, an extended platform is needed to cover the planning, designing, constructing and operation phases; a platform that will address the complex technical, economic, environmental and social issues involved. Here we presented this new integrated agenda with the emphasis on renewable energy planning and the technological, economic, environmental and social design dimensions incorporated in a new platform together with the necessary decomposition analysis. The whole new framework is based on the analytical multi-criteria methodology as a means for indirect social acceptance measurements coupled with public participation techniques and will hopefully pave the way towards a new under transition, energy future.

Potentially, a well-structured analytical framework for deciding on renewables could reveal where real prospective for their development exists. Nonetheless, it is the historical and social conditions, which occasionally determine social values that will verify the "worth" of such approaches.

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