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Energyscapes: Linking the energy system and ecosystem services in real landscapes

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ABSTRACT

The drive for sustainable energy production is leading to increased deployment of land based renewables. Although there is public support, in principle, for renewable energy at a national level, major resistance to renewable energy technologies often occurs at a local level. Within this context, it can be useful to consider the "energyscape" which we initially define as the complex spatial and temporal combination of the supply, demand and infrastructure for energy within a landscape. By starting with a consideration of the energyscape, we can then consider the positive and negative interactions with other ecosystem services within a particular landscape. This requires a multi-disciplinary systems-approach that uses existing knowledge of landscapes, energy options, and the different perspectives of stakeholders. The approach is examined in relation to pilot case-study comprising a 155 km^2 catchment in Bedfordshire, England.

1. Introduction

Human use of energy is the major driver of anthropogenic climate change and challenges our ability to live sustainably [1] and [2]. However energy and climate change are not the only issues that determine sustainability, as we must also maintain and ideally enhance the ecological and social systems on which we depend. The benefits (and dis-benefits)

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that we gain from ecological systems are termed ecosystem services [3], [4], [5] and [6] and wise stewardship of the Earth requires us to understand how changes in energy demand, production and supply affect such services. For some ecosystem services, such as the provision of food, the interactions can be examined using established spatial models. By contrast it has proved to be less easy to quantify the impact on the cultural services within a given area, and it is often these issues that form the focus of objections to renewable energy development.

The need for a low carbon energy system is seen as an essential part of the solution to anthropogenic climate change and is recognized by Governments (e.g. [7]). However, there is growing recognition that the deployment of low carbon energy technologies may have substantial impacts on a range of ecosystem services in the locality where they are deployed [8]. Most land based renewables (LBR), including bioenergy, have a lower energy content than fossil fuels and consequently have much larger spatial footprints. This need for increased land area and more efficient use has led to a growing interest in more distributed approaches to energy production and distribution as a way to reduce carbon emissions [9]. In addition human population growth and increasing per capita consumption places further demands on land to provide food, fiber, and potable water; space for accommodation, occupation and recreation; and conservation of natural and social heritage. Modification of any of these services may compromise the delivery of others and the risk of such trade-offs must be recognized if conflicts between policies and goals are to be avoided.

New tools are needed to allow us to understand how changes to our energy system (both large and small) interact with ecosystem services, both in terms of technical assessments and in terms of planning decisions [10]. The standard approach for assessment involves planning applications and environmental impact assessments that narrowly focus on selected elements and exclude other important features. The situation is exacerbated by the potential deployment of different combinations and scales of renewable energy technologies in different localities. In these circumstances, the largely unknown synergies and conflicts generated by the technologies may well produce outcomes different from the sum of their individual effects.

As the provision of energy becomes decentralized the issues become more location and site-specific; it will become increasingly important to consider energy demand, production and supply in a more local area or landscape context. Decision makers are faced with the challenge of developing systems which will allow local sources of energy to be incorporated with currently centralized supplies. There is currently uncertainty regarding the stability and temporal dynamics of the interactions between different renewable technologies and local energy demand, this is complicated by the historical legacy and the infrastructure needed to deliver the energy generated. Some of this uncertainty is associated with the relatively poor availability of data with which to investigate local spatial interactions consistently across regional or national scales. Perhaps surprisingly, even nationally available basic resource data are often insufficiently detailed to reliably identify technically optimal locations for smaller scale renewable energy installations, let alone support analysis of more subtle issues (e.g. [11]). The widespread acceptance of the incompatibility of datasets and modeling across scales also creates a schism between local and national planning.

The difficulty of understanding the impact of changes to the energy system is further compounded by our limited understanding of how it affects the provision of ecosystem services at a range of scales, from local to national and global. Each environmental function is potentially affected by changes to land management and the exploitation of associated ecosystem services; their response may be immediate or show delay and variation over time making the system impossible to model accurately. While there is plenty of research devoted to developing approaches for the technical and economic optimization of distributed generation systems (e.g. [12] and [13]), taking the perspective of the whole system is rare [14]. Ecosystem services and their social effects, have been largely neglected [15] and where they have been examined they are usually considered at the national or larger scales, rarely considering local impacts, interactions and multiple effects [16]. Where environmental considerations are taken into account, these are largely constrained to direct impacts such as atmospheric carbon emissions (e.g. [17] and [18]). Our understanding of how to deploy energy production technologies to minimize negative local impacts and maximize energy benefits is usually incomplete and inconsistent. In fact, there is generally a disconnect in our understanding of actions and impacts elsewhere.

From the problems described above, it is clear that we do not currently have sufficient understanding of the processes and complexity in the real world to effectively forecast the impacts of changes to the energy system. Here we propose an alternative method of viewing the system, which provides the broader, whole system perspective that is needed for energy planning. It recognizes the importance of different spatial scales and uses scenario studies to explore with stakeholders the desirability and feasibility of particular local or regional interventions into the energy system. The approach requires a change in paradigm for most energy researchers who take a strictly scientific reductionist view. We recognize that this cannot be achieved rapidly, but in this paper we present a framework that will enable and encourage new spatial models, theories and datasets to be developed, accessed and used interchangeably (what is known as 'plug and play'). It also allows existing national land use databases such as the Countryside Survey [19] to be used to assist interpretation across scales and targeting of resources to maximize the returns from existing data.

Most traditional modeling of the energy system employs an additive approach, concentrating on energy sources. These are each examined and then their outputs summed; the calculations are usually aspatial, taking no account of the geographic distribution of material, let alone any interactions. Even where demand is included (e.g. [20]) geography and interactions are ignored. Efforts have been made to link such energy production models to a spatial infrastructure (e.g [21]), but not the whole system. These models serve a valuable purpose in providing a crude estimate of overall potential, but they are impossible to interpret for local environmental impacts [22] and are imperfect for assessment in the context