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# Towards sustainable energy planning and management

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**ABSTRACT**

Rising energy costs, anthropogenic climate change, and fossil fuel depletion calls for a concerted effort within energy planning to ensure a sustainable energy future. This article presents an overview of global energy trends focusing on energy costs, energy use and carbon dioxide emissions. Secondly, a review of contemporary work is presented focusing on national energy pathways with cases from Ireland, Denmark and Jordan, spatial issues within sustainable energy planning and policy means to advance a sustainable energy future.

***Keywords:***

Global energy trends;
Sustainable Energy Planning;
National Energy pathways;
Spatial Analyses; Energy Policy;

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## 1. Introduction

Energy security, fossil fuel depletion, socio-economic impacts and environmental pressures are all motivating factors that have brought energy policy, energy planning and energy management onto the public agenda over the last decades.

Nearly 50% of proven oil reserves are located in the Middle East [1] which has had a turbulent history in the 20th and 21st century from the Suez Crisis, the Yum Kippur War, over the Iran-Iraq war, the Iraqi invasion of Kuwait and the subsequent American-led invasion of Iraq to the Arab Spring. Combined with rising global oil demands, this has contributed to oil prices increasing more than 10-fold from 1970 to 2012 [1] which has had significant socio-economic impacts on oil-importing as well as oil exporting nations. For oil importing nations, the situation was particularly severe in the 1970s, coming from a situation of readily available low cost fuels to a situation of rapidly increasing costs. Other fuel sources such as coal followed oil's lead, however with less volatility – see Figure 1. In fact, not only the price hikes of oil but also the periods of comparably low prices and thus the sheer volatility of the oil price has proven a challenge. Any long-term investments in oil exploitation have thus been – and are still – faced with financial uncertainty as are investments in alternative solutions including renewables and energy savings.

While the urgency of a sudden impact is no longer preeminent, socio-economic impacts remain important as fuel costs form large balance of trade imbalances for net importers of energy. Lastly, environmental concerns are not being adequately met. While earlier environmental issues of smog, dust, and acid rain could be solved by end-of-pipe solutions in the form of e.g. filters, scrubbers, and catalysts, climate change enhancing carbon dioxide emissions keep increasing as it is an inherent effect of the combustion of fossil fuels.

Progressive iterations of assessment reports from the Intergovernmental Panel on Climate Change have strengthened the scientific evidence behind anthropogenically enhanced greenhouse effects, as stated in 2013 *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased"* [2]. From 1880 to 2012, the average land and ocean surface

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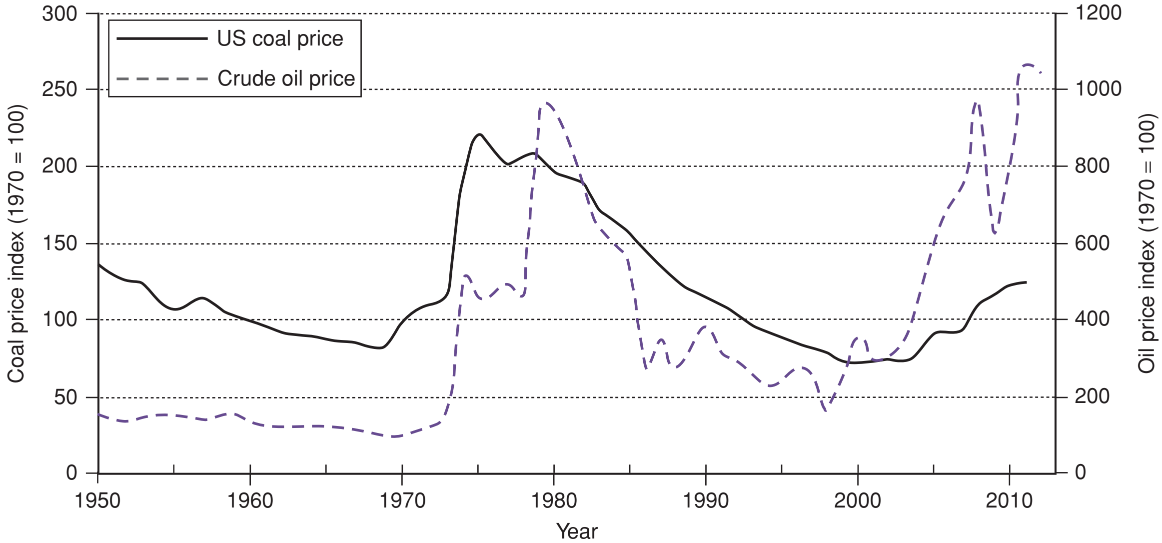


Figure 1: Crude oil and coal prices from 1950 until 2012. Source: [1].

temperature has increased by 0.85°C, from 1901 to 2011 sea level rose by 19 cm [2] due to thermal expansion of sea water combined with a net contribution from melting glaciers. Carbon dioxide emissions from 1750 and forward have alone given a positive radiative forcing of 1.68 $W/m^2$ [2] – and combined with other greenhouse gasses, the result is an approximately 1% larger uptake in energy from the sun than what is being reemitted from Earth. In spite of this situation and the scientific evidence, from 1990 to 2012, energy related carbon dioxide emissions increased by 44.4% [3]. While Kyoto Protocol [4] signatories had a decrease of 12.4% [3] over the same period of years, climate change is thus still lacking general decisive action.

Looking ahead, a growing world population combined with a more prosperous global economy (see Figure 2) are contributing factors to a steadily increasing energy demand and associated carbon

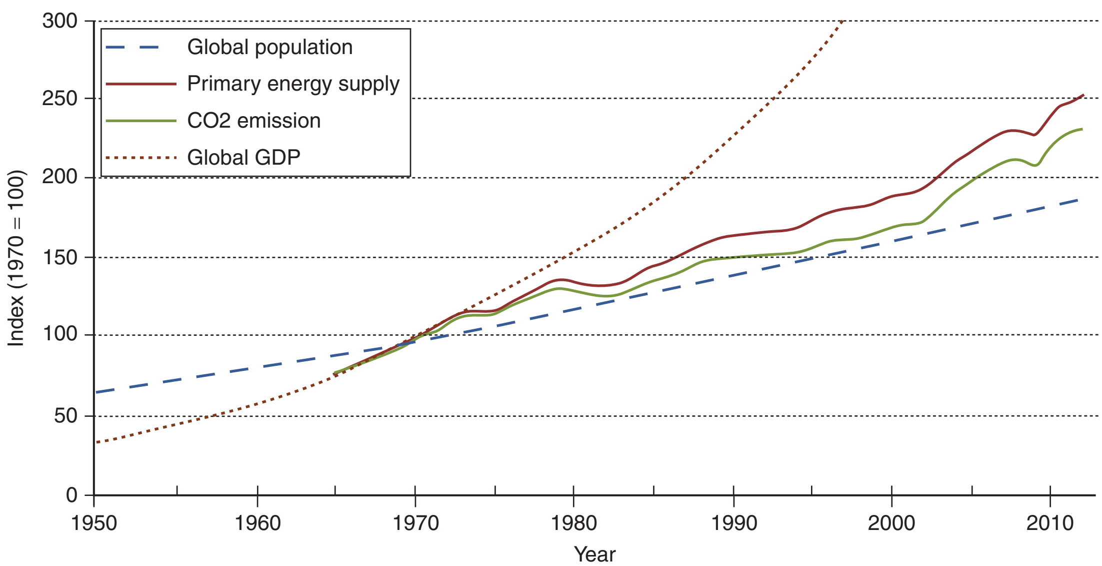


Figure 2: Global indicators for energy, emissions, population and economy. Note; Gross Domestic Product (GDP) is in Purchasing Power Parity (PPP). Population and GDP are based on five-year interval datasets and interpolated in between. Sources: Population [15], energy and emissions [1], Global GDP [16].

dioxide emissions, and there is nothing in the trends to indicate any short term change in this situation – however there is a need for this unsustainable praxis to change. This calls for a multi-faceted approach addressing supply, conversion and demand of energy as well as appropriate planning, policy and framework conditions. Future energy systems need to be environmentally benign, systems need to be integrated across sectors [5–7], designed for optimal flexibility in exploiting fluctuating energy sources [8] and the organisation and framework conditions of the energy sector needs to be adapted to the changing situation [9–12].

Specifically, in many countries and regions these changes will have to entail a stronger focus on the efficient utilisation of local, renewable energy resources, while balancing nations' increasing need for security of supply with local challenges, such as economic development and employment. The development of such decentralised systems of energy supply, conversion and demand therefore requires careful planning in light of the increased impacts on local communities and an increasing number of stakeholders in the form of e.g. producers, consumers, owners, developers and planners of energy systems [13]. From a techno-economic perspective, these complex challenges call for detailed and integrated analyses of local energy systems, outlining e.g. various possible long-term choices for communities, cities and municipalities [14]. At the same time, detailed choice possibilities also need to be outlined at the national and trans-national levels in order to encourage optimal choices at the local level. From a socio-political perspective, a stronger involvement and active participation of communities in the planning and implementation of renewable energy systems is required, as well as a stronger support and better coordination from central levels of government for these local and regional energy planning activities [11].

The International Journal of Sustainable Energy Planning and Management is a dedicated forum for research in sustainable energy systems. It brings together researchers working within energy systems analyses of local, regional and global levels, researchers working on feasibility studies and researchers working on public regulation to form an interdisciplinary platform for pertinent research on energy planning topics.

This first issue of the journal presents a variety of analyses covering primarily national energy systems with the different options there are for minimising energy usage through systems' optimisation.

## 2. National energy pathways towards sustainability

In [17] Connolly & Mathiesen investigate one potential pathway towards a 100% renewable energy system with regards to technical and economic performance. They develop a seven step sequence to establish sustainable energy pathways for a country, taking Ireland as an example. These sevens steps include establishing a reference, implementing district heating, implementing individual and district heating heat pumps, reducing grid stability restrictions, introducing flexible electricity demands as well as electric vehicles, implementing the production of synthetic fuels for transport, and using synthetic gas to replace any remaining fossil fuel usage. In their findings, Connolly and Mathiesen establish that the Irish energy system may be converted using these steps without compromising on economic performance of the energy system. They stress that in the future, flexibility in the energy system should not come from the production side but rather from the demand side due to the significant fluctuating power contribution to the energy system.

Østergaard et at [18] take a more narrow approach than Connolly and Mathiesen in terms of the delimitation of the energy system, however since the case study deals with a hot, semi-arid region rather than a temperate and rainy country, other infrastructures are pertinent for inclusion. In the case of Jordan, a main energy demand at present – and expected to increase even more in the future – is the desalination of water. The analysis goes to demonstrate that while synergies should be exploited in the best possible manner, conditions vary in different countries – and thus also the synergies to be exploited. Investigating the future fresh water demand of Jordan, the analysis compares the energy system impact of utilising either reverse-osmosis (RO) desalination or multiple-stage flash (MSF) desalination. RO is electricity consuming while MSF primarily uses heat which may be covered using the same technologies as in cogeneration of heat and power (CHP) plants – and thus also the same modelling approach. At the current development stages, the energy system's performance isn't affected considerably by the choice of desalination technology though.

## 3. Data availability and the spatial dimension in sustainable energy planning

Data availability is a recurring theme when simulating energy systems, making energy systems analyses, or developing energy scenarios. Möller and Nielsen [19] address the issue of geographical mapping of heat demands and heat supply options in order to establish data sets for energy systems analyses. Based on a database of 2.5 million buildings in Denmark and Geographical Information Systems, heat atlases are created that may be used to assess heating options as well as potential heating savings at different savings' costs. In addition, the work incorporates the spatial dimension often overlooked in single-node energy planning models.

## 4. Energy policy and implementation

Meyer et al [20] also address the energy consumption of buildings – however from a policy point of view. Thus where [19] addresses methods for assessing the technical potential for energy savings, [20] addresses the barriers for implementing energy savings as well as the possibilities for overcoming these barriers. Potential solutions to increase energy efficiency in buildings include labelling, economic incentives to replace buildings deemed unfeasible to insulate – or even Personal Carbon Allowances if stringent savings are to be realised.

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