Energy 76 (2014) 899–910

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

The effect of climate change on electricity needs – A case study from Mediterranean Europe

Theodoros Zachariadis [a,*], Panos Hadjinicolaou [b]

[a] Cyprus University of Technology, P.O. Box 50329, 3603 Limassol, Cyprus
[b] The Cyprus Institute, P.O. Box 27456, 1645 Nicosia, Cyprus

ARTICLE INFO

Article history:
Received 10 January 2014
Received in revised form
10 August 2014
Accepted 1 September 2014
Available online 23 September 2014

Keywords:
Degree-days
Econometric model
Regional climate model
Welfare losses

ABSTRACT

This paper assesses additional electricity requirements and the associated costs in the Mediterranean island of Cyprus by the mid-21st century because of projected anthropogenic climate change, following an interdisciplinary approach that combines climate science with economics. An econometric model of electricity demand is used, in conjunction with climate projections from a state-of-the-art Global Circulation Model with a regional focus on the Eastern Mediterranean. Annual electricity demand is projected to rise by about 6% compared to a 'no climate change' case. Although these additional power requirements are not very remarkable on an annual basis, total costs up to 2050, which may exceed 730 million Euros at today's prices, imply that the country may need to forgo one or two years of economic growth in order to cope with extra electricity needs due to climate change. This outlook indicates that a reasonable future energy path in regions with Mediterranean climate would involve substantial deployment of solar-powered electricity generation, which can meet peak load requirements while reducing the country's energy dependence. Moreover, this forecast highlights the need for adaptation to climate change through investments in the improvement of the energy performance of the building stock.

1. Introduction

According to the current scientific consensus, warming of the global climate system seems to be unambiguous, and is most likely due to anthropogenic emissions of GHGs (greenhouse gases)[1]. Energy supply and demand are expected to be among the sectors to be seriously affected by climate change; virtually all energy sources, from hydropower to solar power, and all energy infrastructure, from thermal power plants to electricity transmission lines, may experience various disruptions because of climate change induced events [2]. In the case of Europe, some positive effects are projected for hydropower production in northern Europe due to higher rainfall levels and glacier melt. Conversely, hydropower production in southern Europe is projected to decrease by 25% or more by 2050 and up to 50% by the 2070s, as the hydropower sector highly depends on water. Furthermore, extreme heat waves can pose a serious threat to uninterrupted electricity supply, mainly because cooling air may be too warm and cooling water used in power generation may be both scarce and too warm. Extreme weather events, flooding and storm surges could damage infrastructure in vulnerable areas causing power outages. On the demand side, energy requirements for heating in winter will decrease in higher latitudes while demand for summer cooling will rise in South Europe [3]. In general, the main impact of climate change on energy demand is expected in buildings, hence the growing number of studies in recent years (see e.g. Ref. [4] for an extensive review).

A limited number of studies exploring climate change impacts on energy use have been performed for Mediterranean countries [5–7] and have found climate change to considerably affect summer electricity demand. The Eastern Mediterranean is not the only world region with semi-arid climate conditions and high dependence on summer electricity use: areas such as California and Australia display similar characteristics and similar vulnerability to climate change, hence there has been a number of earlier analyses that have focused on these regions (see e.g. Refs. [8,9] for California and [10,11] for Australia).

In this paper we present an assessment of climate change effects on electricity needs in Cyprus, a small island state in the Eastern Mediterranean with a population of about 800,000, which became

* Corresponding author. Tel.: +357 25002304; fax: +357 25002667.
E-mail addresses: t.zachariadis@cut.ac.cy, theozachariadis@gmail.com (T. Zachariadis).

http://dx.doi.org/10.1016/j.energy.2014.09.001
0360-5442/

a member of the EU (European Union) in 2004.[1] The country possesses no indigenous fossil energy resources and is therefore highly dependent on imported petroleum products. Its power system is isolated and depends mainly on fuel oil for the operation of power plants, with plans to use natural gas for some of its power generating capacity later in this decade. In terms of climate change impacts, Cyprus is located in a hot spot: it already has a semi-arid climate and is located in a region that is expected to experience the most adverse climate change effects in Europe [12], with significant temperature increases and some drop in already low rainfall levels [13]. Electricity is especially important for the country both due to its isolated national power system, which has to satisfy all demand at any time in order to avoid economically damaging power outages, and because residential and commercial buildings account for 80% of total final electricity consumption. As all space cooling appliances and 38% of space heating devices use electricity [14], power usage in buildings has two peaks, one in summer and one in winter months [15]. Therefore, changes in winter and summer temperatures due to climate change will affect the energy needs of buildings, and particularly their electricity requirements.

Energy forecasts for national policy analyses are usually performed with the aid of end-use accounting models or econometric models [16]. Especially for assessing climate change effects on the energy sector of a country, almost all econometric models that have been employed so far are based on time series analysis of energy use [17]. We follow this path and use a state-of-the-art empirical model of electricity demand in Cyprus that was developed through a comprehensive econometric analysis of electricity demand [18]. The econometric estimates were later updated by using additional recent data, which led to newly estimated elasticities. On the basis of this econometric model, Zachariadis [7] performed electricity projections up to 2030 under the assumption that average temperature in the Eastern Mediterranean is expected to rise by about 1 °C by that year. He estimated electricity consumption in Cyprus to be 2.9% higher in 2030 than without climate change, calculated the welfare loss of additional electricity needs to reach 45 million Euros in 2030 (at constant prices of year 2007) and assessed the present value of costs for the entire period 2008–2030 to exceed 200 million Euros'2007.

This paper makes use of that econometric model employing up-to-date exogenous forecasts of macroeconomic and oil price variables as of mid-2014. Apart from this, our paper expands and improves that earlier study in three important aspects. Firstly we re-estimate the parameters of the previous econometric model by extending our sample to the latest six years up to 2013; thus our estimates reflect the developments in electricity use during a period of a serious economic downturn in Cyprus. Secondly we extend the forecasts up to the mid-21st century, which is more meaningful because climate change is expected to be more pronounced by that time rather than in the first decades of the century. In doing so, we are faced with issues regarding the appropriate use of econometrically estimated model parameters for a long term energy forecast that extends to a period when many structural changes in economic activities, technology and energy use should be expected.

Thirdly, we base our forecast on temperature projections from detailed RCM (regional climate model) simulations that have been carried out with the aid of GCM (Global Circulation Models), and are the most up-to-date state-of-the-art climate forecasts for the Eastern Mediterranean. In this way we develop synergies between climate science and economics in order to arrive at reliable assessments of climate change impacts in the energy sector. This latter feature is also an important contribution to the international literature exploring the effects of climate change on energy use: as Aufhammer et al. [19] describe in detail, the use of GCMs for examining economic effects of climate change may lead to substantial errors due to aggregation bias; properly developed RCMs, as the one used in this paper, greatly improves the reliability of these impact assessments – and there is only a handful of studies in the international literature using a RCM to assess the economic effects of climate change in the energy sector.

For various reasons the use of RCMs as applied in this paper is extremely important for studying climate change effects at regional level. The current horizontal resolution of GCMs used in century-long climate simulations is around 150 km, which does not resolve regional climate forcings associated to orography, coastlines, and land surface properties. Results from several GCM simulations for the South-East Europe and Mediterranean from the latest assessments of the United Nations IPCC (Intergovernmental Panel on Climate Change) suggest strong warming up to 6 °C by 2100 [20]. In order to adequately quantify potential impacts of climate change (e.g. Refs. [6,21]), climate projections are needed at a much finer resolution than that of GCMs – of a few tens of kilometres or less; this can be achieved through “downscaling” methodologies. The dynamical downscaling approach followed in this paper consists of a high-resolution atmospheric model (i.e. an RCM) forced at its lateral boundaries by output from a global-scale GCM, usually as an off-line one-way nesting, generating meteorologically coherent small-scale features [22].

There have been some efforts applying such mesoscale or regional climate models with grid-box sizes between 27 and 50 km to project the effects of anthropogenic global warming in the EM (Eastern Mediterranean) region by the end of this century. Önol and Semazzi [23] used the RegCM3 RCM driven by the fvGCM (finite-volume GCM) and concluded that temperature would increase by 4 °C and precipitation decrease by 20–30%. Evans [24] has forced the MM5 (**Pennsylvania State University/National Center for Atmospheric Research** mesoscale model) with CCSM3 (Community Climate System Model version 3) global model fields for the first and last five years of the 21st century and found a temperature increase of 2–4 °C in winter and 2–6 °C in summer. Precipitation decreased strongly (30%–50%) in winter along the EM coast. Recently Lelieveld et al. [12] presented a comprehensive regional climate assessment and discussed potential impacts of future climate change in the EM region based on projections from the PRECIS (Providing Regional Climates for Impact Studies) RCM. They found a gradual warming of about 3.5–7 °C throughout the 21st century compared to 1961–1990. This paper follows the latter approach.

After presenting briefly the econometric model in Section 2, we report in Section 3 the results of the climate simulations underlying our subsequent electricity forecasts. We then present forecasts of electricity consumption by main economic sector up to the year 2050, for different oil price scenarios with and without climate change; this enables us to assess the potential climate induced change in electricity demand as well as the economic losses associated with the additional power needs in the country. Section 4 reports on the assumptions and results of the ‘no climate change’ case while Section 5 describes the corresponding results of the climate change scenarios. We discuss the policy implications as well as the advantages and shortcomings of our top-down economic approach in the concluding section.

2. The electricity demand model

Obtaining time series of annual sectoral electricity consumption data we were able to conduct econometric estimations with single-equation ARDL (autoregressive distributed lag) models. A similar

[1] The information provided here refers only to the area controlled by the government of the Republic of Cyprus.