ELSEVIER

Energy Policy 34 (2006) 3757–3764

ENERGY POLICY

www.elsevier.com/locate/enpol

A new energy planning methodology for the penetration of renewable energy technologies in electricity sector—application for the island of Crete

E. Tsioliaridou[a,*], G.C. Bakos[a], M. Stadler[b,1]

[a]Department of Electrical and Computer Engineering, Energy Economics Laboratory, Democritus University of Thrace, 12 Vas. Sofias Str, 67100 Xanthi, Greece

[b]Institute of Power Systems and Energy Economics, Energy Economics Group, Vienna University of Technology, 25–29 Gusshausstrasse,1040 Vienna, Austria

Available online 3 October 2005

Abstract

This paper introduces a new energy planning methodology for more efficient promotion of renewable energy source (RES) technologies in the electricity sector. The proposed methodology has been developed under the European Programme ALTENER and the main outcome is a comprehensive computer simulation tool called INVERT. In this paper, a practical application of INVERT as well as a brief description will be presented through a detailed case study for the island of Crete. A number of different RES technologies, namely wind, small hydro, photovoltaic, biomass and solar thermal plants, have been simulated in sensitivity analyses based on new or additional RES promotion schemes. Simulation runs, considering existing and future electricity potential, have been carried out up to 2020. Transfer costs and CO_2 emissions of hypothesis scenarios have been compared with a reference scenario and the results will be presented and analysed.

Keywords: Energy policy; Electricity sector; Renewable energy sources

1. Introduction

Energy planning for renewable energy source (RES) penetration on a national or European level has been the core objective of a number of national and European projects (Zervos et al., 1998; Green-Net, 2002–2004; Green-X, 2002–2004). Comprehensive databases have been developed under Green-Net and Green-X projects, describing potentials and costs for different RES technologies in European countries. Both projects were aiming at enhancing the proportion of electricity from RES by applying a least-cost approach.

The perspectives of RES in Crete have been analysed from the Regional Energy Agency of Crete in cooperation with the National Technical University of Athens (NTUA). The study was focused on the exploitation of RES for electricity production for the period 1998–2010.

The major problem of Crete's energy system is the inability of the existing electrical system to meet the increasing demand, especially during the summer months. The existing autonomous electrical system faces a chronic problem caused by the high increase in electricity demand and the reluctance of the population to accept the installation of new thermal power stations. Innovative solutions are needed, which should provide both a sustainable development and a high standard of living. The use of RES can become the basis of a new alternative energy policy for the island and the use of appropriate available technologies can have multiple impacts on the environment.

The objective of this paper is to investigate the development of RES plants based on both current existing and new RES promotion schemes supported by the

*Corresponding author. Tel.: +30 6937335759; fax: +30 2541079734.
E-mail address: etsiolia@ee.duth.gr (E. Tsioliaridou).

[1]On the way to Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA.

0301-4215/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2005.08.021

government in order to achieve a higher share of RES and a lower level of CO_2 emissions. Taking into account the RES potential for the island of Crete, the motivation of this work is to introduce new promotion strategies, which will result in maximum CO_2 reductions with minimum public expenses.

2. INVERT simulation tool

INVERT simulation tool (Stadler et al., 2005) is a comprehensive computer model supporting the design of energy planning for RES, with respect to electricity sector (RES-E).

In principle, INVERT allows simulating the existing building stock (heating, cooling, domestic hot water (DHW) systems, solar thermal), rational use of energy (RUE), as well as renewable energy sources according electricity supply (RES-E), heat production (RES-CHP) and bio-fuel production for any desired region. Due to the flexible design, INVERT allows comparative and quantitative sensitivity analyses of the interactions between RUE, RES-E, RES-CHP and bio-fuels as well as greenhouse gas (GHG) reduction for each selected region.

The basic idea of INVERT is to compare the spent money in the electricity or building sector with the corresponding reduction of CO_2 emissions in the same sector.

It evaluates the effects of different promotion schemes (investment subsidies, feed-in tariffs (FITs), tax exemptions, subsidy on fuel input, CO_2 taxes, soft loans and additional aside premium) on the energy carrier mix, CO_2 reductions and costs for society due to promoting certain strategies.

The INVERT simulation tool outputs for the relevant RES-E part in this paper are:

- CO_2 emissions (total reductions due to promotion schemes) (kton/yr),
- transfer costs for promoting RES-E technologies (Mio €/yr) and
- electricity production from RES-E power plants (GW h/yr).

Simulation runs for the case study of Crete include[2] the following RES technologies (Kranzl et al., 2004):

- wind-on-shore plants,
- small hydro stations,
- photovoltaic (PV) systems,
- biomass energy and
- solar thermal power plants.

[2]In principle, INVERT allows one to define any desired technology, but for the detailed investigation for the island of Crete, five technologies are most important.

The INVERT simulation tool provides a maximum flexibility regarding the specific data input of an individual region such as RES potentials, investment costs, efficiency or payback time. The main advantage of this tool is that the results of simulations are transparent; the user has the opportunity to see and explain the outcome of a simulation. The user may also modify model-specific definitions like simulation time frame, interest rates and technology data in a very flexible way. Furthermore, after the successful completion of a simulation—for a certain year—the user is able to change the promotion scheme settings for the next simulation year, based on the current situation in the investigated region.

In the following, the basic principles of INVERT will be presented and explained.

3. Methodology description

In this section, a brief description of the relevant RES-E part is given.

In the RES-E (as well as RES-CHP and bio-fuel part of INVERT) for each facility ("band"), the potentials and costs (short- /long-term marginal costs) for the electricity/heat as well as bio-fuel production are gathered and sorted in a least-cost order. Each band is described by a certain set of parameters. For example, PV systems: all PV locations with the same full loud hour can be gathered and treated as one unique band. Of course, there are different costs for each plant in a band. In other words, in reality, we would obtain a continuous cost curve. However, for the modelling in INVERT, we use stepped discrete functions as an approximation (= static cost–resource curves) (Fig. 1).

The simulation tool considers also the effects of learning curves and market barriers which lead to the concept of dynamic cost–resources curves. These are applied in the simulation tool INVERT. The market barriers reduce the potential and the learning curves reduce the costs of the static cost–resource curve as indicated by the "dynamic cost–resource curve for a certain year".

It is assumed that all RES-E bands get installed or used when the costs (in the dynamic cost–resource curve) for the electricity are lower than the electricity reference price (for

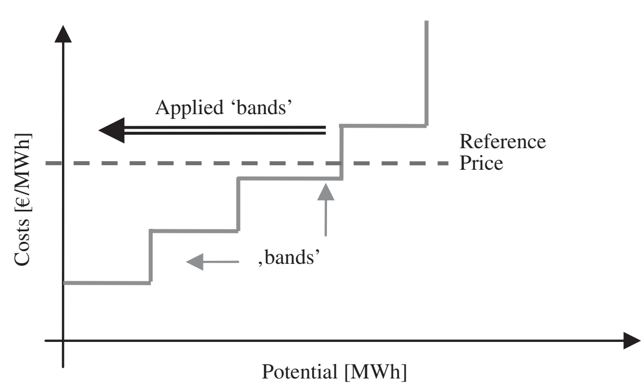

Fig. 1. Static cost resource curve.