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# The economic viability of commercial wind plants in Greece A complete sensitivity analysis

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**Abstract**

The influence of the governing techno-economic parameters on the economic behaviour of commercial wind parks is investigated. For this purpose, a complete cost–benefit analysis model, properly adapted for the Greek market, is developed in order to calculate the pay-back period and the economic efficiency of similar investments in the energy production sector. Moreover, the impact of various parameters — such as capital cost, return on investment index, local inflation rate index, electricity price escalation rate, installation capacity factor, M&O cost, turn-on key cost of the power plant, size of wind turbines used — on the economic viability and attractiveness is extensively investigated, using a well-elaborated simple "expert system" type numerical code. Finally, the prediction results are summarised in a representative sensitivity analysis map, including the most reasonable economic scenarios. Taking into account the analytical results of the proposed study along with the existence of high wind potential regions in Greece, a remarkable growth of the wind energy sector is expected in the near future, leading to considerable investment profits and offering a strong position (share) of the liberalised local power market. 

*Keywords:* Wind plant; Economic viability; Sensitivity analysis

## 1. Introduction

According to the EU Electricity Directive, which came into force on 19 February 1997, 60% of the community's electricity market is opened up to competition during 1999. In Greece, electricity market liberalization will start in February 2001, leading to fundamental changes of the local power industry, (Kleinpeter, 1995). Although liberalization will lead to price competition, which generally is not in favour of renewable generation, this is not the case for Greece. More precisely, the Aegean Archipelago has excellent wind potential, as in many regions the annual mean wind speed at 10 m height is up to 11 m/s (PPC, 1985). On the contrary, the mean electricity production cost of autonomous power stations (APS), used to fulfil the electricity demands for most of the Aegean Sea islands, is extremely high, approaching the value of 50 Drs/kWh (0.15€/kWh). In general, the electricity production cost of a medium-size APS is approximately three times higher than the corresponding marginal cost of Greek PPC, approaching the 0.25€/kWh. Finally, Greeces dependency on imported fuel ($\approx 70\%$ of its domestic energy consumption is imported), leads to a considerable exchange loss, especially with countries outside the EU, (Kaldellis and Kodossakis, 1999). For all the above-mentioned reasons, the Greek State is strongly subsidizing private investments in the area of wind energy applications, either via the 2601/98 development law or via the "Energy Operation Program" of the Ministry of Development. As a result, requests for more than 350 MW of new wind parks exist in the Min. of Development, in order to take advantage of the subsidization by 40% of the total cost of the project (Kaldellis and Kodossakis, 1999).

The present work is concentrated on the examination of the economic viability and efficiency of wind turbine (WT) installations in Greece. Accordingly, the impact of the governing techno-economic parameters on the behaviour of wind power plants is investigated. For this purpose, a complete sensitivity analysis, properly adapted for the local market, is carried out, in order to encourage the decision makers to invest in the wind power market, even under the existing unsteady worldwide techno-economic situations. The results of the proposed analysis, for the most reasonable economic scenarios, are summarised in the last part of the study,

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using a representative sensitivity analysis map for commercial wind turbines.

## 2. Theoretical model

### 2.1. Investment cost

The future value (after $n$ years of operation) of the investment cost of a WT installation is a combination of the initial installation cost and the corresponding maintenance and operation cost, both quantities used are given in current values. The initial investment cost includes the market price of the machine (usually ex-works) and the corresponding installation (or balance of plant) cost. Using a market survey by the authors (Kaldellis, 1999), specially adapted for the Greek market, the specific ex-work price $Pr$ of a WT can be approached by a simple exponential expression, as a function of the rated power $N_0$ of the machine, i.e.

$$Pr = 929.2 + 2435.6\, e^{-N_0/33.4}, \quad Pr(\text{€}/kW) \tag{1}$$

(see also Fig. 1). Consequently, the turn-on key price $IC_0$ of a WT plant is given as

$$IC_0 = PrN_0(1 + f), \tag{2}$$

where $f$ expresses the installation cost (e.g. foundation cost, electrical interconnection cost, access tracks) as a fraction ($f \approx 30 \div 60\%$) of the ex-works price of the WT (see Fig. 2). Keep in mind that the exact value of $f$ also depends on the number and size of machines and on the location of the wind farm. As an example, the windiest sites on the hilltops of small islands, being often remote from the central grid, along with the coastal

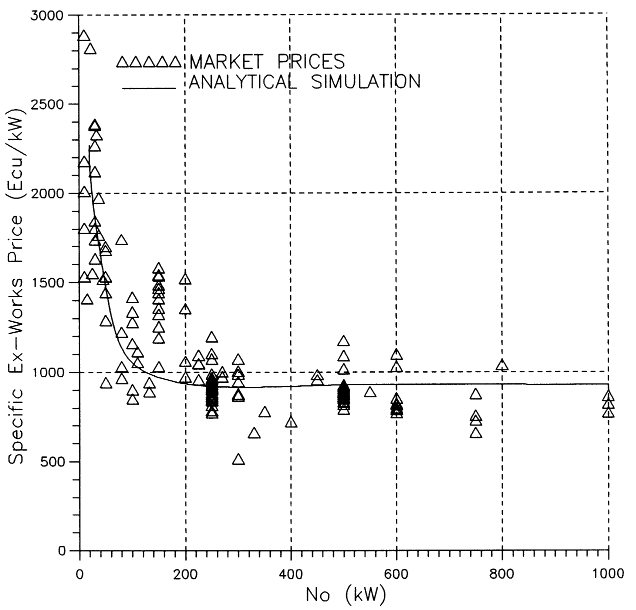


Fig. 1. Ex-works prices of commercial WTs, 1998

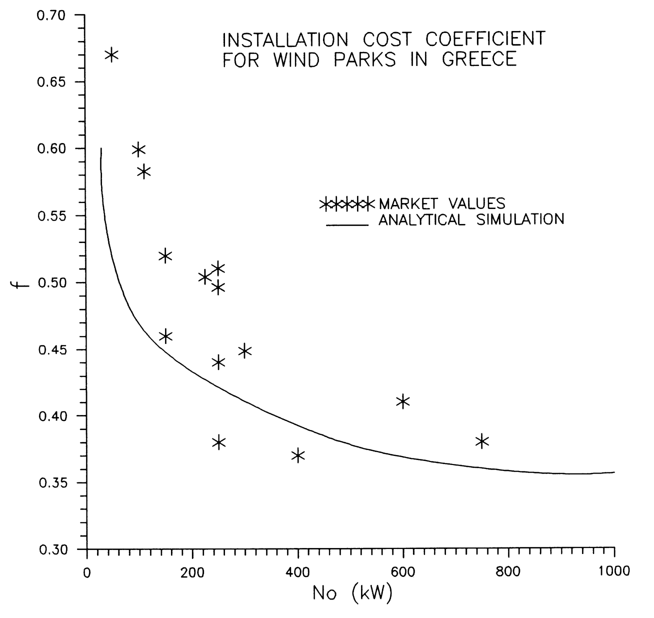


Fig. 2. Installation cost coefficient for wind parks in Greece, 1998

locations, where deep piling into silt is needed, tend to incur cost above average values (EEC, 1999). According to our experience, the most appropriate wind farm in Greece includes about 10 WTs in the range of $300 \div 500$ kW each. Summarising, the future value of the initial investment cost can be expressed as

$$IC_n = aIC_0 \prod_{l=1}^{l=n} (1 + i_l) + \beta IC_0 \prod_{l=1}^{l=n} (1 + i'_l), \tag{3}$$

where

$$\alpha + \beta = 1 - \gamma \tag{4}$$

and $\gamma$ is the subsidy percentage by the Greek State. According to the existing 2601/98 development law, a 40% subsidy is provided to private investors in the area of wind energy applications, for all over the country. The first term on the RHS of Eq. (3) describes the invested capital $\alpha IC_0$ future value ($i$ return on investment index), while the second term expresses the corresponding cost ($i'$ capital cost) of the loan capital, $\beta IC_0$.

The maintenance and operation (M&O) cost can be split into the fixed maintenance cost $FC_n$ and the variable one $VC_n$. Expressing the annual fixed M&O cost as a fraction $m$ (see Fig. 3) of the initial capital invested and assuming an annual increase of the cost equal to $g$, the future value of $FC_n$ is given as

$$FC_n = mIC_0 \left[ \prod_{l=2}^{l=n} (1 + i_l)(1 + g_1) + \prod_{l=3}^{l=n} (1 + i_l) \times \prod_{j=1}^{j=2} (1 + g_j) + \cdots + \prod_{j=1}^{j=n-1} (1 + g_j)(1 + i_n) + \prod_{j=1}^{j=n} (1 + g_j) \right]. \tag{5}$$