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# Towards grid parity in insular energy systems: The case of photovoltaics (PV) in Cyprus

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H I G H L I G H T S

- This study presents aspects of achieving grid parity in insular energy systems, based on a case study applied in Cyprus.
- The impact of the manufacturing cost and the feed in tariff on accomplishing grid parity event is analysed.
- A sensitivity analysis is conducted to define the parameters that strongly affect the goal of grid parity.
- It is concluded that grid parity may be easier achieved in insular energy systems due to the higher cost of primary energy.

A R T I C L E I N F O

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A B S T R A C T

Grid parity is defined as the threshold at which a grid-connected renewable energy sources (RES) system supplies electricity to the end user at the same price as grid-supplied electricity. Predictions from the 2006 time-frame expected retail grid parity for solar in the 2016 to 2020 era, but due to rapid downward pricing changes, more recent calculations have forced dramatic reductions in time scale, and the suggestion that solar has already reached grid parity in a wide variety of locations. This study presents aspects of achieving grid parity in insular energy systems, based on a case study applied in Cyprus. The analysis presents the variation of the manufacturing cost, the selling price of the produced energy, and the performance of the solar panels to examine the conditions of accomplishing grid parity event. It is also concluded that grid parity may be easier achieved in insular energy systems due to the higher cost of primary energy.



## 1. Introduction

Grid parity is considered the peak point of RES technologies. Regarding solar PV, it has been defined as the threshold at which a grid-connected PV system supplies electricity to the end user at the same price as grid-supplied electricity (Elliston et al., 2010). It has been reported that grid parity has already been reached in several countries. On the contrary, many support that grid parity is much more complex and difficult than presented, primarily due to the sensitivity of RES reaching grid parity towards the political support and financial incentives (Lund, 2011; Olson and Jones, 2012).

The benefits of an insular energy system reaching grid parity are multi-fold. An insular energy system is defined by the country's incapability, due to smallness and/or remoteness, to interconnect with other electricity generators and consumers through a wider transmission grid outside its national borders. This type of energy systems are usually detected in small islands such as Cyprus, where the production and the transmission of power is costly to be achieved. Amongst the benefits offered by grid parity to an insular energy system is the more affordable electricity, the increased security of energy supply, and sustainable growth.

This paper aims to address the question whether Cyprus has already reached grid parity. Firstly, the conditions of achieving grid parity, the technical characteristics of an insular energy system, and the description of the energy system of the case study are introduced in Section 2. The raised question regarding Cyprus and the grid parity event achievement is answered in Section 3 by examining a range of values of the manufacturing cost, the performance ratio of the PV system, and the selling price of the energy produced by means of a parametric analysis. This analysis intends to assess the parameters that define a grid parity event by investigating the case of a PV farm with 1 MW installed power. The findings of this work (given in Section 4) also reveal the significance of an insular power system, such as Cyprus' to achieve grid parity.

## 2. Theoretical background

### 2.1. Conditions for reaching grid parity event

The concerns over climate change as well as the increasing fossil-fuel prices have encouraged the moving away from the

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**Nomenclature**

*Abbreviation*

| | |
|---|---|
| CASM | Coalition for American Solar Manufacturing |
| DOC | Department of Commerce |
| EAC | Electricity Authority of Cyprus |
| EArray | Effective energy at the output of the array |
| EEZ | exclusive economic zone |
| EffArrR | Efficiency Eout array/rough area |
| EffSystR | Efficiency Eout system/rough area |
| ETS | Emission trading system |
| EC | European Commission |
| EU | European Union |
| E_Grid | energy injected into grid |
| FiT | feed-in tariff |
| GHG | greenhouse gases |
| GlobEff | effective global, corr for IAM and shadings |
| GlobHor | horizontal global irradiation |
| GlobInc | global incident in collection plane |
| IRR | internal rate of return |
| ITC | International Trade Commission |
| LCOE | levelised cost of electricity |
| NPV | net present value |
| O&M | operation and maintenance |
| PR | performance ratio |
| PV | Photovoltaics |
| RES | renewable energy sources |
| R&D | research and development |
| T Amb | ambient temperature |

*Symbol*

| | |
|---|---|
| *D*(%) | depreciation of materials |
| *EY*(kWh, p/kW,*i*) | energy yield |
| *I*(-) | year |
| *I*(€) | total annual income |
| *In*(€) | insurance annual fee |
| *IR*(%) | inflation rate |
| IRR*(%)* | internal rate of return |
| *L*(€) | cumulative annual instalments |
| *Main*(€) | maintenance annual expenses |
| *NfE*(€) | non-foreseen expenses |
| *NPV*(%) | net present value |
| *OC*(€) | inflated operating and maintenance expenses |
| *P*(€) | profit |
| *Saf*(€) | safety annual expenses |

conventional electricity generation, and the rapid emergence and development of new technologies. Depending on the natural environment and the climatic conditions, the appropriate renewable energy technologies have now come forward to satisfy the rising energy demand; in Cyprus solar energy and the photovoltaics (PV) are considered to have the greatest potential. Although the prohibitively high costs were the main challenge of the new renewable technologies, the Member States have adopted feed-in tariff (FiT) schemes that are designed to promote the penetration of the RES into the energy mix through appealing financial revenue. The successful FiT schemes induced the blooming of the solar PV market the past few years and consequently the solar PV panel prices to drop at a remarkable rate to realise a self-sustained market without the need of incentives and subsidies. The raised question is whether Cyprus has already reached the threshold at which a grid-connected PV system supplies electricity to the end user at the same price as grid-supplied electricity; the so-called grid parity (Elliston et al., 2010).

Grid parity, considered a milestone in the history of solar PV by many enthusiasts, is a function of an array of variables and has been given a number of definitions and allowing for various sensitivity analyses in literature. Bhandari and Stadler (2009) define grid parity year as the time point in future when the electricity from grid connected PV will be able to compete with the grid electricity generated from conventional fuels. Using experience curve analysis it is demonstrated that grid parity in Cologne, Germany is to be reached in 2023 when allowing for the avoidance costs, and in 2013–2014 for the end user electricity prices. Another study supports that grid parity has already occurred in the Netherlands in April 2012, as the levelised cost of electricity (LCOE) of grid electricity appears to be 0.057 €/kWh more expensive than the LCOE of a 2.5 kWp PV system Van Sar et al. (2012). Furthermore it has been stated that grid parity will occur when the solar PV systems costs drop below the $2/W (Yang, 2010); hence we can safely say that we are now beyond this point. Breyer and Gerlach (2012) using the grid-parity dynamics based on experience curves and the LCOE have develop a grid parity model that was applied to more than 150 countries. They concluded that grid parity will be achieved globally within the next decade, starting for large residential market segments in Europe between 2010 and 2012 and for large industrial market segments in Europe, Asia and America between 2011 and 2013. The study further elaborates grid parity events will first occur on islands and regions of high solar irradiation and high electricity prices, where the LCOE of solar electricity generation will fall from 0.16 €/kWh to 0.06 €/kWh throughout the period 2010 to 2020.

On the other hand, many support that grid parity is much more complex and difficult than presented, pointing out to the sensitivity of RES reaching grid parity towards the political support and financial incentives (Lund, 2011; Olson and Jones, 2012). Lund (2011) portrays renewable energy technologies to achieve 62% share in the global electricity production by 2050 if the long-term commercialisation policies are to be adopted and a full-cost breakdown of solar PV in 2032 after a learning investment of €1432 billion, a value of great vulnerability to the input parameters. Another paper points out some weaknesses to the popular envision of grid parity. First it explains that a fair comparison of the cost of renewable energy would be against the avoided cost of the renewable resources rather the cost of grid electricity. This work also argues the renewable can never achieve cost parity since they cannot provide reliable base-load electricity. The third point argues that grid parity cannot be realised due to the claim that is not a fixed point. The increasing market penetration might be the cause of the declining costs of the renewables, but it also induces the lowering of the grid parity cost target (Olson and Jones, 2012). The recent developments regarding allegations that Chinese companies dump below the cost solar panels in the EU are another representative example of the sensitivity of RES towards political strategy. The European Commission (EC) has now agreed an undertaking with the Chinese government declaring the minimum module price at 0.56 €/$W_p$ and the annual import limit at 7 GW. Any EU company violates the agreement will be obligated to pay a tax at least of 47.6% (PV Magazine, 2013a).

The significance of reaching grid parity in Cyprus can be fully realised once its impact is assessed.

1. Reaching grid parity contributes in maximising the national energy self-sufficiency, as recommended by the Green Paper on the security of energy supply (EC Green Paper 00/769).

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