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Small distributed generation versus centralised supply: a social cost–benefit analysis in the residential and service sectors

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Abstract

This paper aims at measuring the social benefits of small CHP distributed generation (DG) in the residential and service sectors. We do this by comparing the social costs of decentralised and centralised supplies, simulating "ideal" situations in which any source of allocative inefficiencies is eliminated. This comparison focuses on assessing internal and external costs. The internal costs are calculated by simulating the optimal prices of the electricity and gas inputs. The external costs are estimated by using and elaborating the results of the dissemination process of the ExternE project, one of the most recent and accurate methodologies in this field. The analysis takes into account the main sources of uncertainty about the parameter values, including uncertainty about external cost estimations. Despite these sources of uncertainty, the paper concludes that centralised supply is still preferable to small DG. In fact, the overall range of DG social competitiveness is restricted, even considering further remarkable improvements in DG electrical efficiency and investment costs. The results are particularly unfavourable for the residential sector, whereas, in the service sector, the performance of DG technologies is slightly better.

Keywords: Distributed generation; Social cost–benefits analysis; Technological change

1. Introduction

Restructuring and privatisation of electricity and gas industries is occurring world wide and clearly confirms the general tendency to abandon the traditional organisation based on the operation of large firms.

Nevertheless, the impact of the market reforms in terms of social welfare is not clear yet. Although several analyses have been proposed in this field, the results do not converge. In the meanwhile, some recent dramatic events (i.e. the California energy crisis, the collapse of Enron and the black-out in the USA and in several European countries) and some profound changes introduced in those countries firstly promoting liberalisation processes have increased the number of those who question the real benefits of such an organisational change.

However, while this issue is still being debated, technological change and innovation offer us the prospect of revolutionary new scenarios. In particular, the performance of the small power technologies (i.e. reciprocating engine and gas turbine) has improved remarkably over the last decade. This has aroused the interest of operators, regulators and legislators in distributed generation (DG), namely, the integrated or stand-alone use of small, modular power generation close to the point of consumption as an alternative to large power generation and electricity transport over long distances.

DG can provide several benefits which can be divided into two categories.[1] The first includes the so-called

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[1] As regards DG benefits and the relationship between technological change and market organisation, see Pfeifenberger et al. (1997) and Arthur D. Little (1998).

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structural benefits whose existence does not depend on how markets are organised: avoided electricity transmission costs; reduced energy costs through combined heat and power generation;[2] increased power supply reliability, etc. The second category includes the so-called market-related benefits whose extent depends on how markets are organised (e.g. decreased exposure to electricity price volatility).

However, the realisation that DG could provide these benefits does not mean that decentralisation is undoubtedly preferable to large power generation, for the following reasons.

First, fuel cost saving due to combined heat and power generation and avoided transmission costs might be offset by higher investment costs.

Second, despite the higher overall energy efficiency, and consequently reduced greenhouse gases emissions (GHG), DG technologies might involve higher non-GHG emissions (SO_x, NO_x, particulate, etc.).

Third, there are considerable differences between centralised and decentralised technologies in terms of the impact of non-GHG emissions (SO_x, NO_x, particulate, etc.). These differences might be due to micro-localisation effects. Unlike large power plants (high stack and extra-urban location), distributed technologies have low stacks and might be located in densely populated urban areas. Because of low stacks (emissions at extremely low altitudes), pollutant atmospheric dilution could be lower so that the increases in pollutant concentration close to the plant could be higher than those of a large power plant. Due to location, these high increases in pollutant concentration occur in highly populated areas and seriously damage human health. These combined effects might cause an environmental impact (per unit of pollutant emitted) higher than that of a large power plant.

Taking into account these effects, we aim at evaluating what is the real social benefit of energy supply decentralisation. Nevertheless, we do not analyse all the possible typologies of DG. We focus on small DG that is supply decentralisation by means of plants with power size ranging from 5 kW to 5 MW (following the classification[3] of Ackermann et al., 2001).

Furthermore, we are interested in applications representative of a wide deployment of small DG plants. This implies that we should analyse the residential and service sectors. Therefore, we simulate the application of small CHP DG to a residential building and a hospital (as representative of the service sector).[4] Moreover, this choice allows us to verify whether we are moving towards a radically different energy market paradigm.

The results showed in this paper are based upon a detailed technical analysis of energy flows of the fuel cycles (centralised and decentralised systems). Environmental externalities are assessed by using the results of the dissemination process of the ExternE methodology,[5] one of the most ambitious and internationally recognised attempts at coming up with "true" external cost estimates for the different power technologies (Krewitt, 2002). We are aware such a methodology could be largely imperfect. Nevertheless, we think that it could provide useful and reliable indications when used to compare technological alternatives and when the uncertainty about value estimations can be internalised into the estimating model.

Finally, the analysis focuses on a simulation of a particular territorial context, the case of Italy. However, as we will explain in Section 2, this simulation is particularly significant, so that the results obtained can be generalised.

The paper attempts to analyse all the issues affecting the comparison between centralised supply and DG: economics of electricity supply (including network effects); economics of combined heat and power generation; economics of supply reliability; valuation of environmental externalities, etc.

In particular, the article is organised as follows. Section 2 illustrates the general approach and main assumptions of the analysis. Section 3 focuses on economics of CHP generation, comparing centralised and decentralised supply in terms of energy efficiency, the first rough performance indicator. Section 4 evaluates internal costs and benefits, which are calculated by simulating optimal prices of the electricity and natural gas inputs (by using a specific formulation of the peak load pricing problem). Section 5 focuses on external costs and benefits, which are calculated by using and elaborating the results of the dissemination process of the ExternE project. The results are presented in terms of cumulative probability distribution in order to evaluate the impact of statistical and political uncertainty, mainly regarding the estimation of the marginal cost of atmospheric pollutant emissions.

[2]Customer proximity greatly increases the potential for cogeneration. The high costs of transporting heat even over short distances make large-scale cogeneration unattractive.

[3]Ackermann et al. consider DG an electric power source connected directly to the distribution network or on the customer site of the meter. They suggest the following categories: micro DG (1 Watt < kW); small DG (5 kW < 5 MW); medium DG (5 MW < 50 MW); large DG (50 MW < 300 MW).

[4]Service sector includes several applications (hospital, airports, public buildings, universities, etc.). In order to strengthen our analysis we refer to an application (the hospital) which is particularly suitable for small combined heat and power generation, given the level of heat and cold consumption.

[5]The ExternE project is a major research program launched by the European Commission at the beginning of the 1990s to provide a scientific basis for the quantification of energy-related externalities and to give guidance supporting the design of internalisation measures (Krewitt, 2002).