Spatial arbitrage value of transmission upgrade investments. An economic and environmental assessment

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Under the ambitious targets for a green power system set by the European Council by 2050[1], the need of new investments in flexible and efficient technologies to support high shares of renewable generation is on the top of the agenda of all national European governments. This study contributes to the current discussion on the economic viability of new investments in electricity storage and transmission line upgrade [1] and the associated environmental impact in terms of changes in CO2 emissions and renewable power integration [2] [3]. The analysis is based upon a simple model simulating the operation of a transmission line upgrade project. The case study is applied to the Italian power market (IPEX) where prices in different zones differ significantly due to high variation in the share of generation mix across zones and poor interconnections in some areas of the system. The line upgrade investment increases the power capacity between two interconnected zones, thus alleviating intra-zonal congestion. Its operation maximizes spatial arbitrage value by shifting power from the cost-efficient zone (with low marginal generation costs) to the neighbouring zone (with higher marginal costs), up to the interconnection capacity. The investment analysis focuses on the case of Sicily that coincides with the geographical zone of SICI, and the pole of limited production, Rossano (ROSN), that is located in CSUD and is connected to the island through a submarine cable (Fig. 1). This case study is of particular interest because the zone SICI features the highest and more volatile price levels in the country. Moreover SICI is interconnected to the mainland through one single line (Rossano-Rizziconi-Sorgente) which is in the process of being upgraded through a new double-circuit transmission line of 380 kv[2], that will increase the transferred capacity between the two areas. Additionally, the potential of wind and solar generation [4] makes this region the potential leading producer of renewables in Italy[3].

(FIG 1)

In the first part of the study we assess the profitability of the line upgrade project. We assume 2013 as the reference year for the NPV analysis, so that profits and costs flow is the same as in 2013 during the entire investment period.

In the second part of the study we assess the environmental impact of the project's operation in terms of CO2 emissions and changes in the share of renewable generation in the simplified system. For the calculation we take into account the power transferred (MWh), the marginal technologies[4] setting the price in correspondence of each hour of operation in each zone and the carbon content associated to the marginal technology during each hour, expressed in terms of kgCO2/MWh. The environmental impact is determined by

[1]European Council (23 and 24 October 2014) Conclusions on 2030 Climate and Energy Policy Framework. http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/ec/145356.pdf

[2] http://www.terna.it/LinkClick.aspx?fileticket=90765

[3] Currently wind and solar production is around 30% of the total production in the country (http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_cmsaf_opt/G_opt_IT.png).

[4] The marginal technology index provided by GME SpA

considering the carbon content/share of renewable of the power transferred from the lower price zone to the neighbouring zone. This transfer substitutes the power that would have been generated in the more expensive zone by the marginal technology without line upgrade. This power substitution directly affects the level of greenhouse gases and share of renewable in the system. The net result is calculated by the difference in the carbon content/renewable power between the transferred power and the power that would have been generated by the available marginal technology (a numerical example is given in table 1).

(Table 1)

The profitability assessment of the investment projects shows low but positive NPV values for the transmission line upgrade investments. In table 2 we give an economic estimation of both variables by considering the costs of carbon set at 15 €kgCO2/MWh and the renewable power valued at 80€/MWh of green power (GME SpA).

(Table 2)

The environmental impact assessment shows positive impact on both emissions and share of renewable power. CO2 emissions decrease while renewable power increases. Figure 2 shows the composition of the power transfer during 24 hours of line operation, where the lower part of the figure represents the power that is transferred to the neighbouring zone in place of the power that would have been provided by generation plants in the importing zone.

(Fig. 2)

This analysis distinguishes between private and system values of investments in line upgrade. Both values result to be positive for the considered project. In particular we can find a possible explanation of the positive environmental impact of line operation in the economic theory of trade. If we think of the line upgrade as an improvement in the power trade options between neighbouring zones, the line acts as a facilitator for cheap power to be transferred to the neighbouring zone experiencing high power prices during critical hours of the day. Power flows from one zone to the other as long as marginal costs of the first zone are lower than the marginal costs of the second zone. Power trade allows for economies of scale and better environmental quality, as long as conventional (expensive/dirty) expensive sources are replaced by renewable (cheap/clean) sources of power [5] (Table 3).

(Table 3)

An upgrade of the transmission line as in our model adds capacity of transmission between the two zones by, in fact, facilitating additional power trade between the two zones under cost-efficient criteria (buying the cheaper power between 2 zones). This additional flexibility provided by the line results to be environmentally improving.

The ambitious targets on CO2 emissions set by the European Commission by 2050 towards a decarbonised and efficient energy sector call for adequate system analysis. This study shows positive NPV values for the investment transmission line upgrade between two Italian zones. The analysis of the private value of the investment is accompanied by the assessment of its social value. The line upgrade investment project is profitable and improves environmental quality. In general policy incentives in support of one technology would intervene if its social value would at least cover the negative results of the private profits assessment. For the line upgrade investment the positive environmental effects would represent a good reason for policy support. These measures would attract investments and foster further environmental quality.

Appendix

Fig.1 Zones and interconnection for the case study

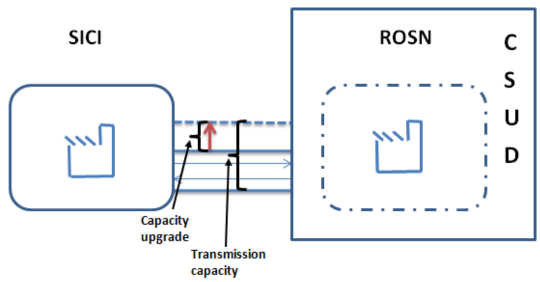

Table1. Net CO2 emission from transmission line operation

	Zone 1 Price-mg tech- (kgCO2/MWh)	Zone 2 Price-mg tech- (kgCO2/MWh)	Line operation	Net CO2 emissions (kgCO2/MWh)
H1	Lower price - Res (0)	Higher price - Gas turbine (90)	Power transfer from Zone 1 to zone 2	-90
H2	Higher price - Oil (70)	Lower price - Hydro (0)	Power transfer from Zone 2 to Zone 1	-70
Net CO2 emissions	-70	-90		-160

Table 2 NPV and results from the environmental impact assessment

NPV, € (€/MWh)	net CO2 when SICI is congested (kgCO2/MWh)	Environmental benefit in SICI (€kgCO2/MWh)	net CO2 when ROSN is congested (kgCO2/MWh)	Environmental benefit in ROSN (€kgCO2/MWh)	Net result €kg/MWh (kgCO2/MWh)
737,170,552.05 (2.91)	-319,585.88	1,342,260.68	-12,471.90	52,381.98	1,394,642.65 (-332,057.77)

Fig. 2 Results of line operation SICI-ROSN, detail on marginal technologies, 24h

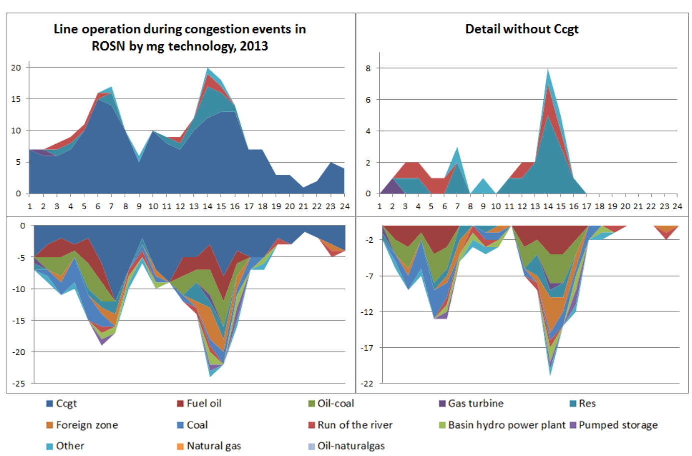

Table 3 Power source and CO2 levels

	Low price/marginal costs zoneA	High price/marginal costs zoneB	Power transfer	Level of CO2/renewable
Source / Emission rate	Renewable / Low	Conventional / High	From A to B	Decreases / Increases

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