SENSITIVITY OF SOLAR FOSSIL HYBRID ELECTRICITY TECHNOLOGY PENETRATION TO PRICE AND EFFICIENCY PROJECTIONS

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Overview

With many aging coal and nuclear plants nearing retirement age, new electricity production capacity will need to be built over the next several decades. There are many methods of generating electricity, each with different benefits and drawbacks. While solar and wind generation are now cost competitive with fossil fuels in many parts of the country, both have issues with intermittency which must be addressed through redundancies, such as natural gas turbines that supplement generation during low output, or energy storage. Conversely, renewable technologies usually do not require continuous fuel purchase, which can reduce the lifetime cost.

If the pairing of renewables and fossil generation is done intentionally, there can be cost-savings by decreasing the footprint of the facility and sharing transmission capacity. The Hybrid Solar Gas Combined-Cycle (HSGCC) technology considered here combines solar thermal and natural gas combined cycle such that the solar heat increases the temperature of combustion and decreases the amount of fuel required. Previous research efforts (Barigozzi et al. 2012, Spelling and Laumert 2014) have analyzed the technological potential of a facility that combines natural gas combined cycle (NGCC) and solar thermal to reduce the demand for fuel compared to NGCC while relieving operators of concerns about intermittency. This analysis investigates whether such a technology could be competitive in the US electricity market and how it might impact emissions from the electricity system.

Methods

The MARKAL model is used to analyze the market potential of HSGCC for a range of possible values for investment cost and avoided fuel use. MARKAL is a linear optimization model that minimizes the total cost of a reference energy system while satisfying all user-defined demands and constraints. The EPA US nine-region database (US EPA, 2013), calibrated to the 2016 Annual Energy Outlook, defines the reference energy system for this analysis (US EIA, 2016). Using this database, MARKAL identifies the economically optimal evolution of the energy system from 2005 through 2055, in five-year timesteps and at the U.S. Census Division spatial resolution. The database includes constraints representing existing regulations, including Renewable Portfolio Standards (RPS) that require some fraction of a state’s electricity to be generated by renewable sources. A representation of the HSGCC technology was added to the database in the West South Central, Mountain, and Pacific regions, respectively. These regions include states such as Texas, Oklahoma, Arizona, California, New Mexico and others in the south and west with strong solar resources and available land required for this technology. This technology is not modeled in other regions because the conditions are less favourable for solar thermal.

To represent this technology in MARKAL most parameters are based on an advanced NGCC facility, however it is assumed that O&M and investment cost will be higher, and demand for fuel will be lower. Emissions are modeled based on fuel combustion, so this technology will have lower air pollutant and greenhouse gas (GHG) emissions as it requires less fuel to generate the same amount of electricity.

A range of parameters is tested to examine under which conditions the technology has the greatest market potential. Four different investment costs, from $1550-1880/kW, and four different levels of fuel savings, 15-30%, based on values given in Barigozzi et al. (2012) and Spelling and Laumert (2014) are considered. A system is more likely to achieve larger fuel savings with larger investment cost as this could include a larger solar receiver area, but in this analysis the variables are treated independently. As this hybrid technology is partly renewable and partly traditional, it is unclear how state governments might determine compliance with regulations like renewable portfolio standards (RPS). Therefore, each of the sixteen fuel and price combinations is modeled twice, one case in which the technology is defined as renewable and one in which it is not.

Results

The HSGCC technology penetrates the market for most options within the parameter space tested here, in some cases producing 12% of electricity in 2050. HSGCC market penetration and the resulting net emissions implications are shown to be a function of the cost of the technology, how much fuel it is able to displace, and whether the technology qualifies as renewable for any state level renewable portfolio standards (RPS). Much more of the HSGCC is used when the technology can satisfy the RPS, but the emissions results are mixed since the technology is displacing other renewable technologies at a higher rate. All fuel and cost combinations considered utilize HSGCC when it is classified as renewable, but otherwise its penetration is limited to runs involving at least 25% fuel savings with no more than an $800/kW cost increase over NGCC.

In all scenarios, emissions of each pollutant species (CO_2, NO_x, SO_2, PM_{10}, $PM_{2.5}$, VOC, CH_4) are within two percent of the base case on a national basis, since HSGCC has limited availability. In general, emission changes are smaller in cases when the HSGCC is not considered to be renewable. One interesting result is that CH_4 emissions decrease by up to two percent when HSGCC is not considered renewable, but increase 1% in cases where HSGCC satisfies RPS requirements, except for the case with the largest fuel offset and lowest additional investment, in which case the CH_4 emissions also decrease. Whether a new hybrid facility is built to help satisfy RPS will impact which technologies are displaced. When this technology is used to meet RPS goals, it is more likely to displace other renewable technologies, which affects the potential emissions impact. When compared to a case without HSGCC available, cases where the technology is used and considered renewable have less waste to energy and less stand alone concentrated solar thermal power while cases where HSGCC is used but not considered renewable have less traditional NGCC.

Conclusions

There are conditions under which this hybrid concentrated solar and natural gas or HSGCC facility could be economically viable in the future electricity grid. Parameters were tested that are reasonable under ideal conditions based on prior research. Both lower costs and less use of natural gas can increase the utilization of the hybrid technology. Although all versions of the HSGCC technology have a higher investment cost than NGCC, the hybrid technology requires less fuel over its lifetime, which reduces recurring costs.

This analysis only considered one possible fuel price projection. This will likely have an impact on the results as the fuel savings are an important factor in whether and how much of this technology is used and should be analyzed in future work. Selecting a site with adequate solar resource would be important in building an actual facility, as it will be a large factor in ensuring the reduction in required natural gas is achieved. The demand for area on which to build this facility is larger than that required for many powerplants, so additional analysis of space requirements and viable locations could be useful. Categorization of this technology in state RPS structures will change the technology's contribution to electricity generation and the emissions generated by the overall electricity system, but there may be a trade-off for some emissions or the total amount of renewable generation. Analyzing how HSGCC might fit into RPS will be an important future step. Possible standards which allow this technology to partially qualify as renewable should be considered for the impact on emissions and overall renewable penetration.

References

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