Supporting green gases with renewable energy policies

Martin Roach, Vlerick Business School / KU Leuven, + 32 2 225 41 61
Leonardo Meeus, Vlerick Business School / Florence School of Regulation, +32 2 225 41 29

Overview

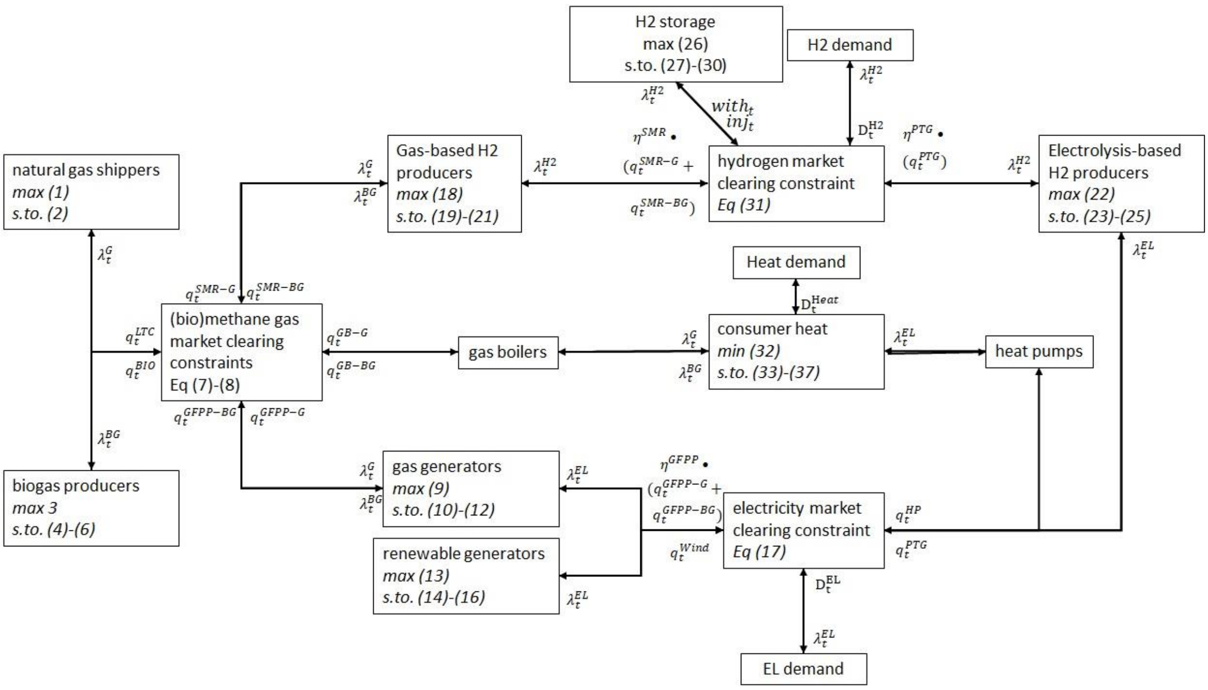
Although green gases such as green hydrogen and biomethane can contribute to the decarbonization of the gas sector to reach climate neutrality by 2050, today they are immature or not cost-competitive enough. Some stakeholders have advocated for a renewable gas target in the upcoming revision of the renewable energy directive. Renewable energy targets are an existing EU policy tool, which specify that a share of final energy consumption must be met by renewable energy sources (RES). Historically, some MSs including France, Germany and Italy, have introduced a sector-specific RES Electricity (RES-E) target accompanied by support schemes (CEER, 2018). If the recent experience in the electricity sector is regarded as largely successful in deploying renewable electricity generation technologies, then such a policy tool may have provided some inspiration for a gas target. For this reason, previous academic discussions on the economic rationale for supporting RES and the concerns about overlapping or interacting policy instruments are relevant.

Jaffe et al. (2005) describe two interacting market failures are at play which provide an economic rationale for directly supporting environmentally beneficial technologies. First, greenhouse gas emissions are a negative externality and represent an environmental market failure. Second, technology innovation and diffusion create knowledge spillovers and represent a positive externality. Therefore, a first-best solution which addresses emissions reductions only creates incentives for renewable energy as a side effect. Lehmann and Gawel (2013) review and discuss the criticisms and rationales for combining RES-E support schemes with the EU ETS. The authors argue, for example, that the proper choice of energy and abatement technologies does not only depend on the negative externalities related to CO2 emissions, and is subject to other market failures such as knowledge spillovers, among others. Therefore, the authors conclude that the rejection of RES-E support schemes rests on a narrow set of assumptions that climate change mitigation is the only public policy objective and the negative externalities from CO2 emissions is the only market distortion where government intervention is required. del Rio (2017) also point out different market failures and political economy aspects as sufficient economic justification to have a policy mix. The author highlights that potential negative interactions between renewable energy deployment and the EU ETS can be alleviated through coordination or design of policy instruments. Possible interactions effects between policy instruments has also been studied numerically. Weigt et al. (2013) discuss the impact of overlapping instruments, an RES-E target and the EU ETS, on CO2 abatement and find that their combination led to interaction effects such that greater emissions reductions were achieved than either individual instrument on its own.

There are two key questions addressed in this paper which we will study with the aid of a stylized multi-sector equilibrium model. First, can we replicate the renewables success of the electricity sector in the gas sector? If green gases are in a similar position today as renewable electricity, a policy maker may see a renewable gas target as a viable way forward. The European Commission is considering a range of supportive policies targeting the gas sector, but we only demonstrate the impact of one of them, a RES-G target with direct market-based support. Second, is a RES-G target complementary or substitutive to the RES-E target or ETS, and what does this imply for the design or implementation of a RES-G target? The prior experience with RES-E targets has taught us that energy policy instruments may interact, but this has not been investigated for a dual RES-E and RES-G target.

Methods

We propose and solve a model based on a non-cooperative game representing a stylized and integrated electricity, gas, and hydrogen market. To compute the Nash equilibrium, we use a mixed complementarity problem (MCP) reformulation (Gabriel et al., 2013). Below is the schematic overview with reference to the mathematical formulation of each agent's optimization problem.



Perfectly competitive agents invest in and operate renewable and conventional technologies responding to market prices in a single shot model. Shippers procure natural gas via long term contracts. Biomethane is produced using organic matter and injected into the gas network. Gas-fired and renewable generators serve wholesale electricity demand, steam methane reforming and electrolysis-based power-to-hydrogen producers serve industrial hydrogen demand, and gas boilers and heat pumps are installed by consumers to serve residential heat demand. Neither dynamic generation constraints nor network constraints are considered. Market clearing constraints endogenously determine the market prices. A policymaker agent sets an exogenous RES policy which consists of one or two RES volumetric energy target constraints, which are modelled as certificate markets. The dual variable of a RES target constraint is equal to the feed-in-premium for eligible technologies.

We take a stylized numerical example consisting of four representative days to capture seasonal or daily characteristics of demand or renewable generators. Representative sample data for electricity demand and renewable generation availability are obtained from the Belgian TSO Elia. The heat demand of buildings and the coefficient of performance of an air-source heat pump in Belgium is extracted from the time series dataset created by Ruhnau et al. (2019). We only assume one representative technology for each agent and obtain the technology cost data from the Danish Energy Agency. Additionally, agents are risk-neutral and have complete information. Although RES Targets are modelled as certificate markets, we do not allocate these policy costs to agents.

We consider 2 RES policies and one emissions reductions policy. The first RES policy is a RES-Electricity target which promotes wind and biomethane-sourced gas generation and is close to the status quo. An emissions reductions policy is considered. The second RES policy is a RES-Electricity, as previously defined, in combination with a RES-Gas target that promotes biomethane and green hydrogen.

Result for question 1

Can we replicate the renewables success of the electricity sector in the gas sector?

In the case of a RES-Electricity, we incrementally increase the RES-E target ambition to determine whether any green gas is deployed. We do not observe any deployment of biomethane. However, power-to-gas is deployed in response to the spillage of wind and negative electricity prices which only occurs at a high RES-E target ambition at or above approximately 60%. Power-to-hydrogen is indirectly supported by a high RES-E target.

In the case of an emissions reductions policy, more mature renewable technologies and other electricity-based solutions are the least cost options. Heat pumps are rendered more cost-competitive compared to natural gas boilers. Wind is the other least cost renewable energy resource to displace natural gas generation. When the emissions reductions are very stringent, wind will be deployed to an extent that it causes spillage, and therefore can indirectly supports power-to-hydrogen.

In the case of a dual RES-E and RES-G targets, whether power-to-gas is deployed still depends on the RES-E ambition because biomethane is the least cost green gas technology to meet the RES-G target. At a low RES-E target ambition, only biomethane is deployed. At a higher RES-E target ambition in which there is spillage, power-to-gas can contribute to partly meeting the RES-G target.

In summary, existing policies such as an RES-E target or emissions reductions policy largely support more mature or electricity-based solutions, and only indirectly support green gases.

It also begs the question if the goal of a RES-G target, as specified in technology-neutral terms, is to support the least cost technology or support a range of green gas technologies.

Result for question 2

Is a RES-G target complementary or substitutive to the RES-E target or ETS, and what does this imply for the design or implementation of a RES-G target?

In analyzing a handful of scenarios changing RES-E and RES-G target ambitions, the combined ambition of a RES-E and RES-G target is less than the sum of each individual target acting alone due to substitutive interaction effects.

As the RES-E target ambition increases, holding the RES-G target constant, gas generators are displaced by wind, thereby requiring less and less green gas in total. Similarly, cost-competitive heat pumps displace gas boilers. In these ways, increasing the RES-E target or deploying heat pumps can partly substitute the RES-G target ambition.

As the RES-G target ambition increases, holding the RES-E target constant, gas generators using biomethane can be counted towards the RES-E target, thereby crowding out some wind generation. In this way, biomethane can partly substitute the RES-E target ambition. In other words, a RES-G target can act as a supply side RES-E target.

Conclusions

If immature and emerging green gas technologies are not directly supported by RES policies with electricity or emissions reduction targets yet face similar market failures as renewable electricity technologies, then an RES-Gas target with direct market-based support can be a second-best solution to ensure green gas deployment. To future-proof a RES policy consisting of a RES-E and RES-G target, a policymaker should consider the effectiveness of the RES-G target to support a range of green gas technologies and anticipate the substitutive effects of dual targets in the design.

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