Energy Economics 86 (2020) 104708

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

The welfare and price effects of sector coupling with power-to-gas

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STARTING POINT

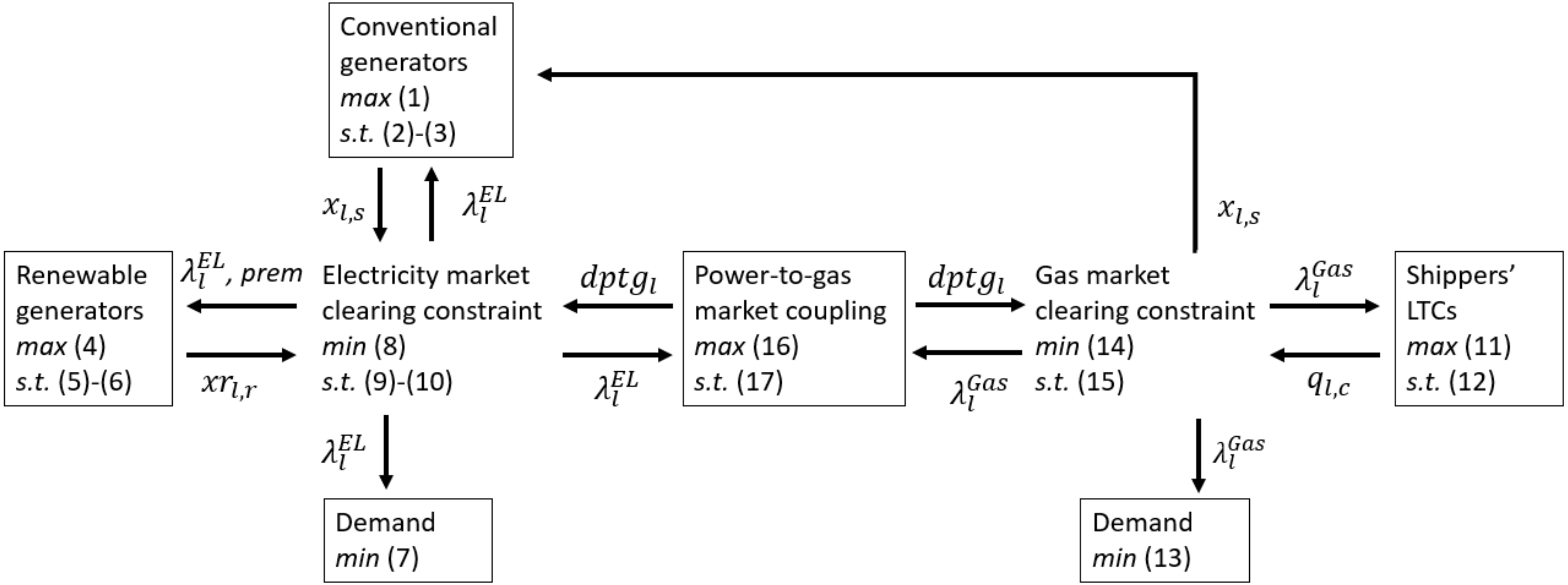
PAPER CONTRIBUTION

- Context (Jones et al., 2018)
  - RES-E peaks expected by 2030
  - Power-to-gas one of the solutions to reduce spillages
- Modelling work that inspired us
  - Misaligned incentives (Saguan and Meeus, 2014)
  - Power-to-gas electricity market price-setting and erosion of profits (Vandewalle et al., 2015; Green et al., 2011)
  - Gas market (del Valle, 2017)

KEY REFERENCES

- Jones, C.W., Piebalgs, A., Glachant, J.-M., 2018. Energy Priorities for the Von der Leyen Commission. European University Institute
- Saguan, M., Meeus, L., 2014. Impact of the regulatory framework for transmission investments on the cost of renewable energy in the EU. Energy Econ. 43, 185–194.
- Vandewalle, J., Bruninx, K., D’haeseleer,W., 2015. Effects of large-scale power to gas conversion on the power, gas and carbon sectors and their interactions. Energy Convers. Manag. 94, 28–39.
- Green, R., Hu, H., Vasilakos, N., 2011. Turning the wind into hydrogen: the long-run impact on electricity prices and generating capacity. Energy Policy 39, 3992–3998.
- del Valle, A., Dueñas, P.,Wogrin, S., Reneses, J., 2017. A fundamental analysis on the implementation and development of virtual natural gas hubs. Energy Econ. 67, 520–532.

ELECTRICITY AND GAS MARKET MODEL



RESULTS

Table 5
Welfare analysis - base case.

Scenarios				
Power-to-gas costs €/kw				RES target
1000	500	200	0	
		No spilling		55%
		No spilling		60%
		No spilling		65%
0 MW	0 MW	0 MW	500 MW	70%
−Δ	−Δ	−Δ	8 M€	
–	–	–	0 M€	
0 MW	0 MW	250 MW	1450 MW	75%
−Δ	−Δ	3 M€	28 M€	
–	–	−1 M€	0 M€	
0 MW	50 MW	1300 MW	2500 MW	80%
−Δ	1 M€	19 M€	65 M€	
–	0 M€	−6 M€	0 M€	
0 MW	1250 MW	2450 MW	3650 MW	85%
−Δ	4 M€	58 M€	126 M€	
–	−25 M€	−12 M€	0 M€	
0 MW	2650 MW	3900 MW	5100 MW	90%
−Δ	37 M€	132 M€	228 M€	
–	−16 M€	−21 M€	0 M€	
900 MW	4450 MW	5750 MW	6950 MW	95%
6 M€	117 M€	265 M€	396 M€	
−9 M€	−30 M€	−33 M€	0 M€	
4450 MW	7200 MW	9600 MW	10,800 MW	100%
140 M€	429 M€	684 M€	890 M€	
−61 M€	−57 M€	−60 M€	0 M€	

SENSITIVITIES

- RES investment costs
- CO2 price
- H2 blending/injection limits
- Power system characteristics
- Shape of load duration curve
- RES generation availability

BREAKDOWN OF RES GENERATOR REVENUES

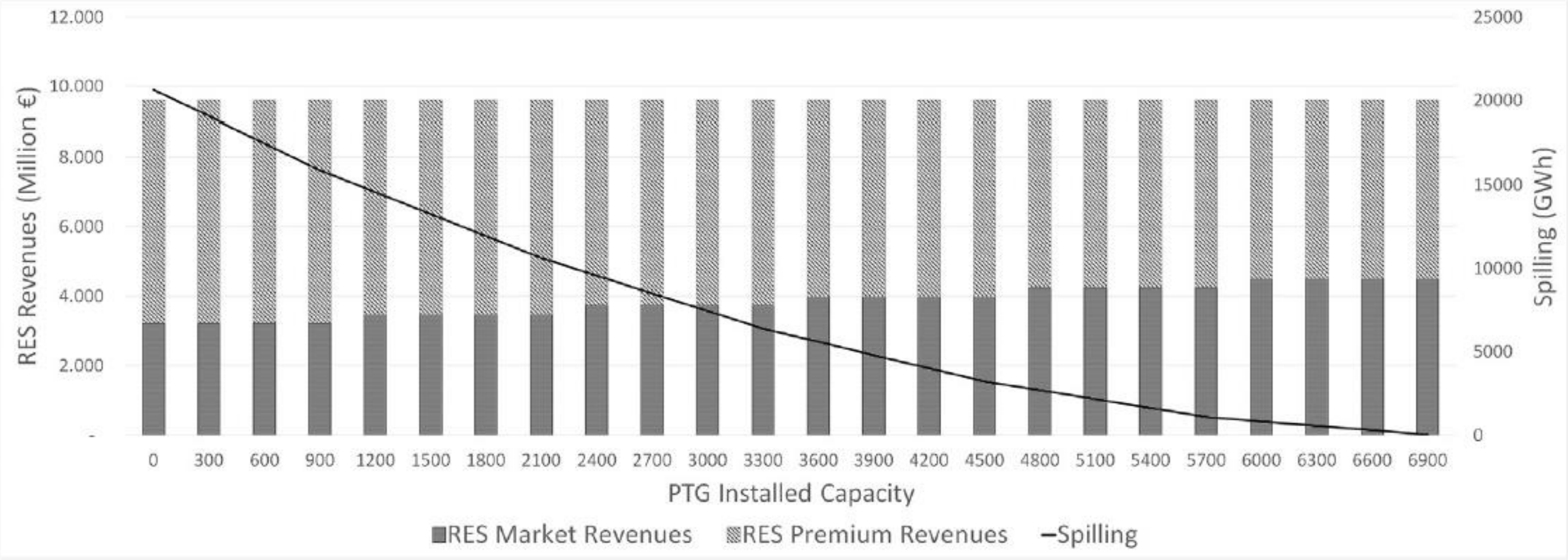


Fig. 9. Breakdown of RES generators' revenue from electricity market and out-of-market capacity based premium.

CONCLUSIONS AND FUTURE WORK

1) PTG can play a price-setting role in the electricity market, but this erodes profit in arbitrage opportunity.

2) Misaligned incentives limited between the electricity and gas sector, but in some instances, PTG is welfare enhancing, but is loss-making for the PTG actor.

Model 2.0

- Increase detail of electricity and gas system.
- Study the interaction between renewable electricity and gas targets and support schemes.

SUPPORTING GREEN GASES WITH RENEWABLE ENERGY POLICIES

MARTIN ROACH
LEONARDO MEEUS

03/03/2021

RELEVANCE OF THE PAPER

- Show the impact of some of the possible tools the European Commission is considering to support green gases.
  - RES-Electricity and RES-Gas target

- Anticipating interactions between gas, electricity, and CO2 pricing

POSITIONING IN THE ACADEMIC LITERATURE

STATIC AND DYNAMIC EFFICIENCY

- del Río, P., Resch, G., Ortner, A., Liebmann, L., Busch, S. and Panzer, C., 2017. A techno-economic analysis of EU renewable electricity policy pathways in 2030. *Energy Policy*, *104*, pp.484-493. https://doi.org/10.1016/j.enpol.2017.01.028
- Newbery, D., 2018. Evaluating the case for supporting renewable electricity. *Energy Policy*, *120*, pp.684-696. https://doi.org/10.1016/j.enpol.2018.05.029
- Özdemir, Ö., Hobbs, B.F., van Hout, M. and Koutstaal, P.R., 2020. Capacity vs energy subsidies for promoting renewable investment: Benefits and costs for the EU power market. *Energy Policy*, *137*, p.111166. https://doi.org/10.1016/j.enpol.2019.111166
- Meus, J., Van den Bergh, K., Delarue, E. and Proost, S., 2019. On international renewable cooperation mechanisms: The impact of national RES-E support schemes. *Energy Economics*, *81*, pp.859-873. https://doi.org/10.1016/j.eneco.2019.05.016

INTERACTION BETWEEN RENEWABLE POLICIES AND CARBON PRICING

- Weigt, H., Ellerman, D., Delarue, E., 2013. CO2 abatement from renewables in the German electricity sector: Does a CO2 price help? Energy Economics, Supplement Issue: Fifth Atlantic Workshop in Energy and Environmental Economics 40, S149–S158. https://doi.org/10.1016/j.eneco.2013.09.013
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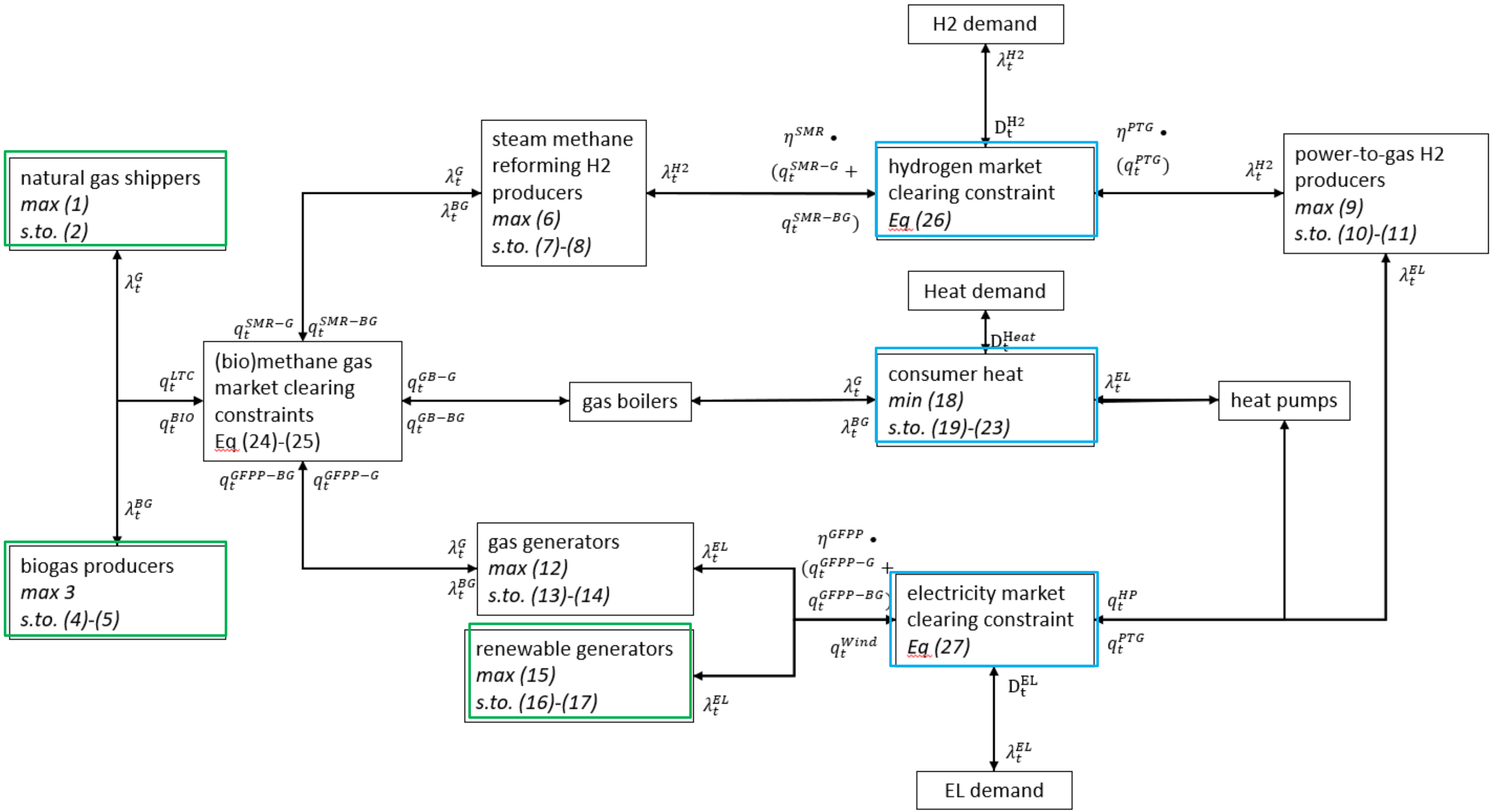
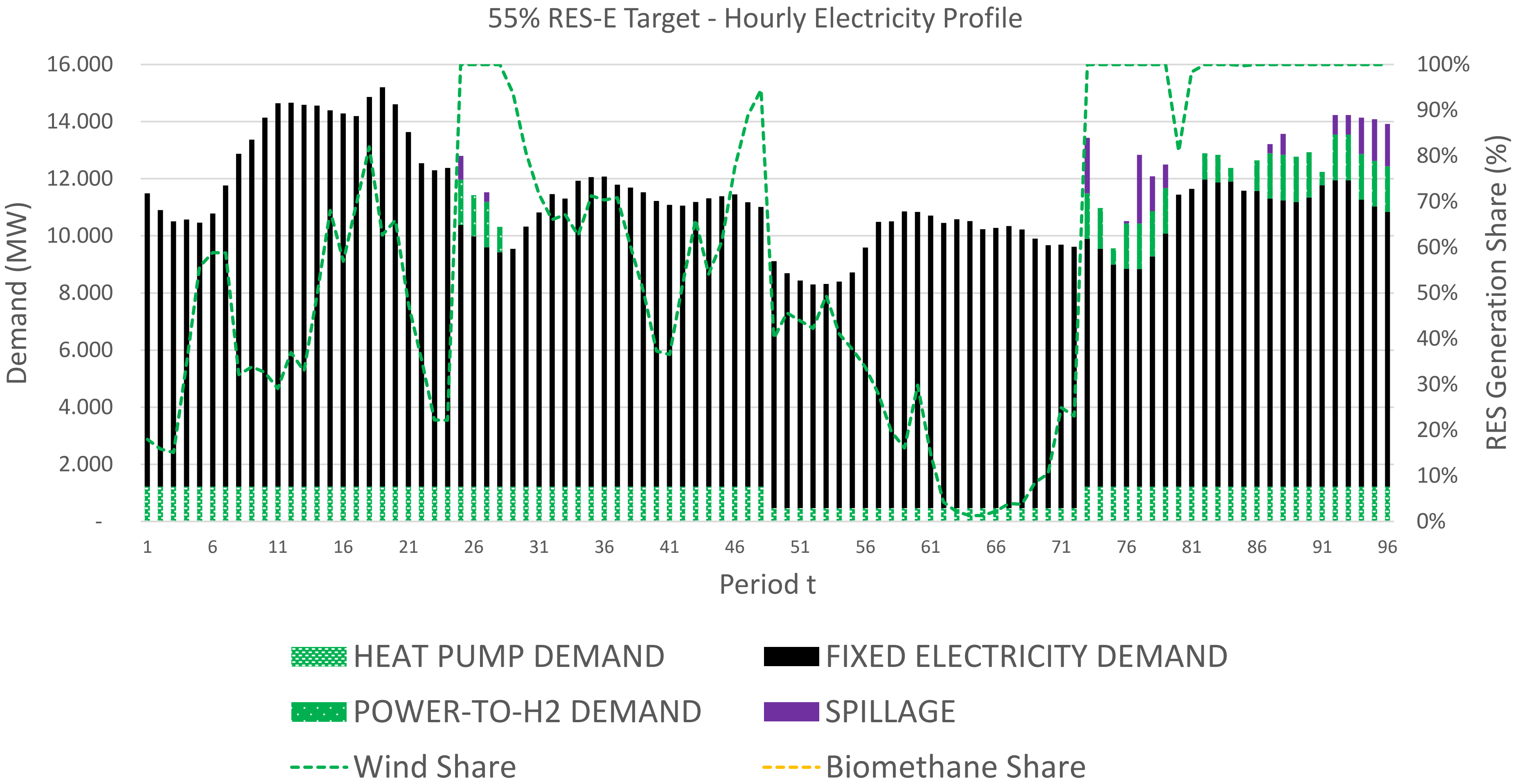
MATHEMATICAL FORMULATION
SUPPLY AND DEMAND SEGMENTS

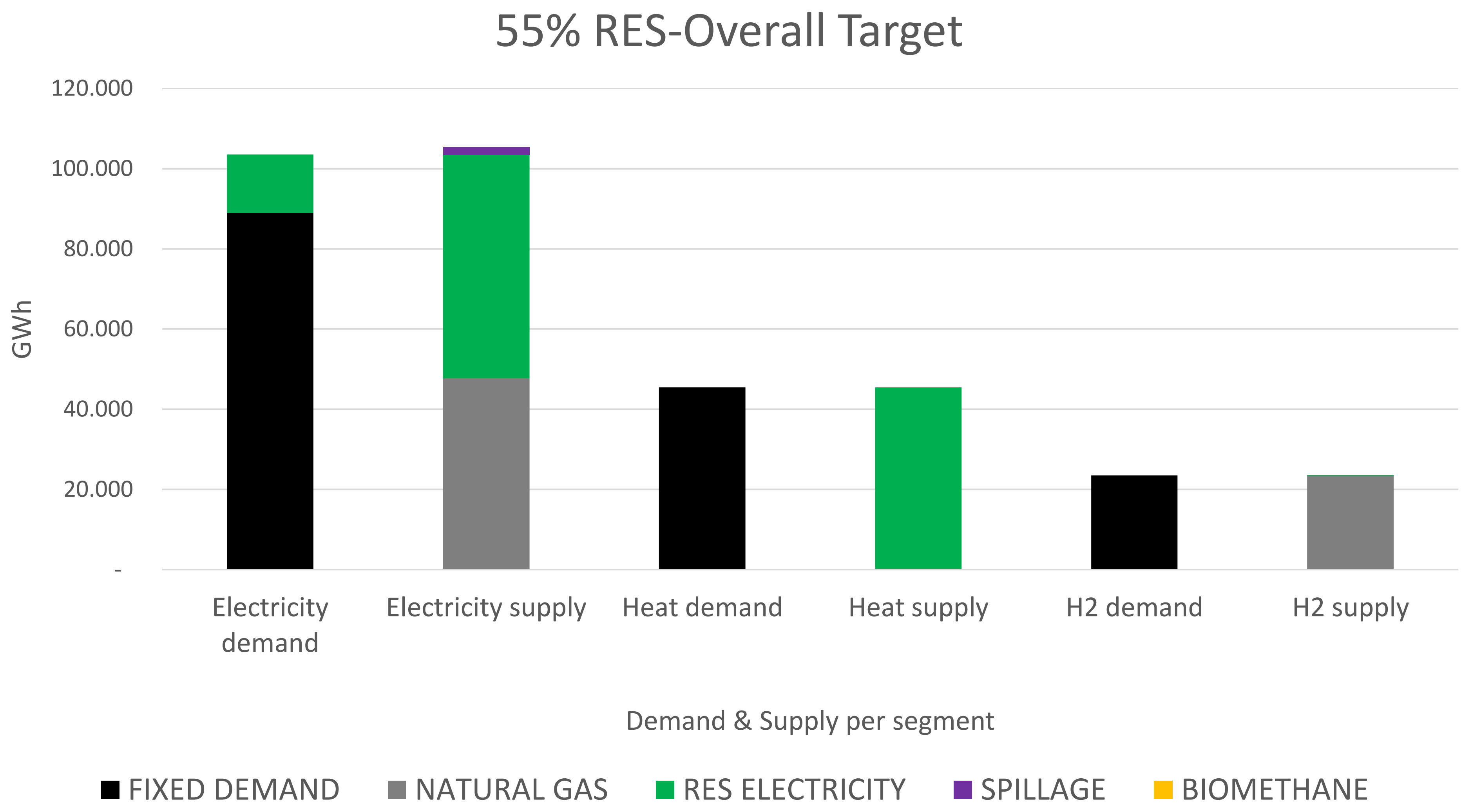


STYLIZED APPROACH / NUMERICAL EXAMPLE

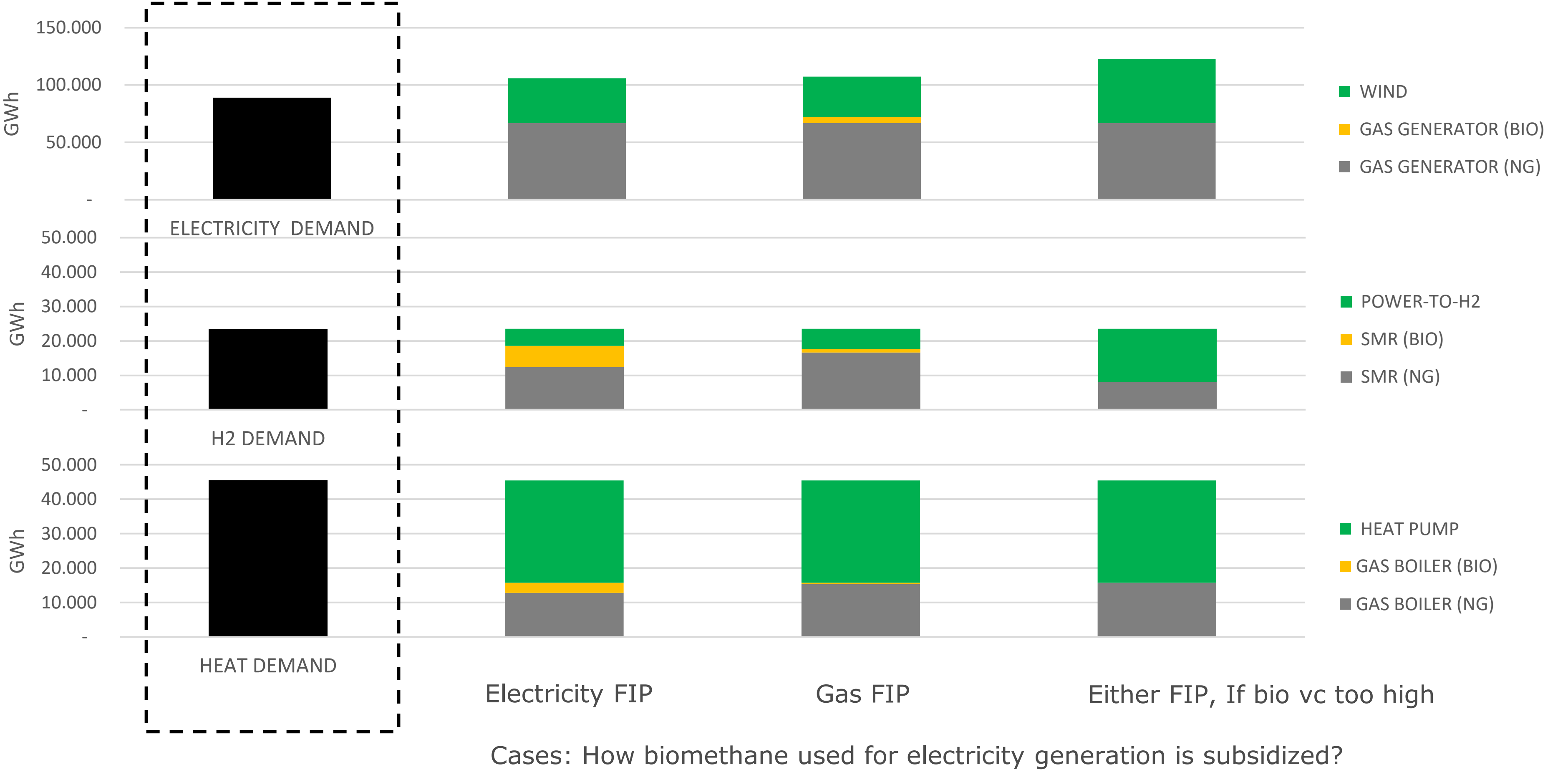
- Actors are perfectly competitive and have complete information
- 4 representative days (demand and res generator availability)
- Danish Energy Agency technology data as input data for investment costs (equivalent annualized costs) and efficiency:
  - Biogas plant, basic configuration + biogas upgrading; Large offshore wind; Alkaline Electrolyser; Heat pump, air-to-water, existing one family house
  - Gas turbine, combined cycle; Natural gas boiler, existing one family house; Steam Methane Reformer
- Assume shippers have access to natural gas at fixed variable costs of 20 €/MWh and biogas producers have a limited cost-competitive feedstock supply – increasing variable costs.
- The RES targets are modelled as certificate markets.
- Formulated and solved as a mixed complementarity problem

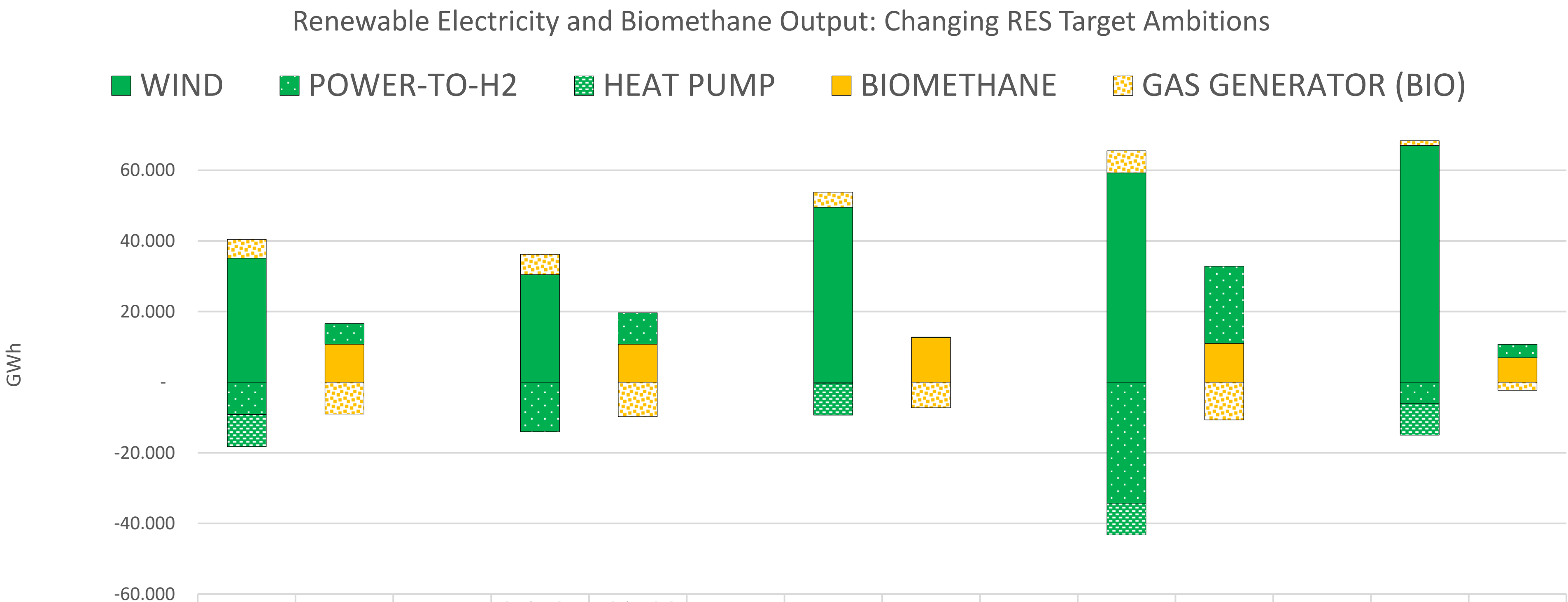


period (t)	70	71	72	73	74	75	76
PRICE - EL (€/MWh)	33,90	33,90	33,90	-45,39	15,90	15,90	-45,39


55% RES-Overall Target
120.000
100.000
80.000
60.000
40.000
20.000
-
GWh
Electricity demand
Electricity supply
Heat demand
Heat supply
H2 demand
H2 supply
Demand & Supply per segment
FIXED DEMAND
NATURAL GAS
RES ELECTRICITY
SPILLAGE
BIOMETHANE

IMPACT OF RES-G SUBSIDY DEFINITION ON BIOMETHANE UNDER 25% RES-E AND 10% RES-G TARGETS





	25% RES-E	10% RES-G		25% RES-E (no Heat Pump)	10% RES-G (no Heat Pump)		50% RES-E	10% RES-G		25% RES-E	20% RES-g		60% RES-E	10% RES-G
POWER-TO-H2	-	5.846			8.903			175			21.785			3.780
GAS GENERATOR (BIO)	-	-9.038			-9.747			-7.193			-10.617			-2.272
GAS GENERATOR (BIO)	5.333	0		5.751			4.244			6.264			1.341	
BIOMETHANE	-	10.791			10.791			12.648			11.009			6.952
HEAT PUMP	-9.042	0		-			-9.042			-9.038			-9.042	
POWER-TO-H2	-9.191	0		-13.999			-275			-34.254			-5.943	
WIND	35.150	0		30.497			49.571			59.277			67.042	

CONCLUSIONS

- Technology neutral targets are more difficult to formulate given the range of technologies available – at different stages of maturity – and in the end relate back to the policy objectives in mind: static and dynamic efficiency.

- Emerging technologies which present sector coupling dynamics may increase market and policy interactions.

Q&A

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