Electricity and Natural Gas Price Structures in the Netherlands as a Barrier against Coupling of Power and Heat Sectors

Gamze Ünlü

Abstract

Wind and solar energy are becoming the dominant renewable electricity sources leading the energy transition and decarbonization of the power sector in the Netherlands. The integration of these technologies into existing power sector is a challenging task since the supply of weather-dependent VRE (Variable Renewable Energy) does not usually follow the load pattern. One approach for more sustainable, reliable and cost-effective energy system is sector coupling. Increasing the coupling between heat and power sectors has the potential to decrease the system costs, reduce the peak electrical load, serve as an additional supply of flexibility to the power system and decarbonize the fossil-fuel intensive heat sector. For this potential to be unlocked the end-users such as industry and households should economically benefit from the coupling. Energy taxes and levies for electricity and natural gas is one of the potential barriers against the wide-spread use of power-to-heat technologies. This study compares the power system optimal results with the prices that consumers are exposed by using the power systems model COMPETES in a 2030 scenario for the Netherlands. The effect of the taxes and levies are investigated for the technologies of heat pumps and hybrid boilers for households and industry, respectively. A tax shift from electricity to natural gas which is proposed in Climate Agreement is a promising option to unlock the potential of coupling for power and heat sectors.

Keywords: Sector coupling, power sector, heat sector, taxes and levies, power-to-heat, policy barriers

1. INTRODUCTION

Variety of renewable energy technologies have been developed and in different parts of the world, wind and solar power started to be the dominant renewable electricity sources leading the decarbonization of the power sector. The integration of these technologies into existing power sector is a challenging task since the supply of weather-dependent VRE (Variable Renewable Energy) does not usually follow the load pattern. This implies that besides developing the necessary sustainable technologies, an important phase of the energy transition is the integration of the growing ratio of renewable technologies and the connections between the end-use sectors (industry, transport, residential). The focus of the transition was mainly on the power sector for a long time and more progress is needed in the other sectors such as heat sector, one of the most fossil-fuel intensive sectors [1]. One approach for more sustainable, reliable and cost-effective energy system is sector coupling. Sector coupling refers to the idea of interconnecting the energy consuming sectors agricultural, residential, transport and industry, with the power producing sector [4]. The coupling between power and heat sector is one of the globally discussed decarbonization options. The heat sector needs much more effort and improvement as it still relies on gas and coal as primary energy sources [1]. The potential benefits from the power system side can only be unlocked if there are financial incentives for end-consumers such as households and industry to adopt power-to-heat technologies. In this study, two of the commercially available technologies, heat pumps, and hybrid boilers are chosen for the two end-users to investigate the benefits. Heat pumps absorb heat from a cold space and release it to a warmer place requiring only a small amount of external energy such as electricity [2]. They are devices with high efficiency (coefficient of performance, COP) as less energy is required than the released heat. In electrically powered heat pumps, the heat produced can be three or four times larger than the electricity needed. A hybrid boiler consists of a natural gas and an electric boiler. It can either run on electricity or natural gas depending on which source is cheaper to obtain heat. More electricity can be consumed when electricity prices decrease and when renewable production is high. Gas can be used when electricity prices increase and when renewable generation is less. This gives the opportunity to utilize the low electricity prices and helps to balance the load on the electric grid.

The commodity prices, investment costs, and network costs are mentioned as the main three barriers against the wide-spread adoption of the power-to-heat technologies such as heat pumps and hybrid boilers [3], [4], [5]. End-consumers are exposed to several extra cost components in addition to the market prices of electricity and natural gas. The benefits that are optimal for the power system can be sub-optimal for the end-users due to the price distortions in the system. These kind of distortions are barriers against sector coupling from the end-user side. Lack of a positive business case for end-users would cause avoidance of electricity based solutions despite the technology developments. It is essential that end-users have incentives to switch to these technologies to reveal the benefits of the coupling for the power system. This analysis aims to investigate the deviation of the end-users from the optimal results of the power system due to the inclusion of extra costs on top of the electricity and natural gas prices and to gain insights about the taxes and levies as a potential barrier for the usage of electricity in power-to-heat technologies.

2. ELECTRICITY AND NATURAL GAS PRICE STRUCTURES

The end-user energy prices for electricity and natural gas consists of supply costs, network costs, and government taxes and levies. The supply costs have both variable and fixed components and paid to the energy supplier (e.g. Eneco, Nuon, Greenchoice). The variable part is paid based on the amount of energy that is used per kWh for electricity or m3 for natural gas. In a free energy market, rates for energy supply change during the year in the wholesale or retail market. In addition to the variable part, there is a fixed part of the supply cost for the services that are provided and independent of energy consumption. This is a subscription fee for the services and energy suppliers are free to determine the level. Network costs include costs for transport and connection to the gird and charged by grid operators both for distribution and transmission grids. For households, network costs are fixed based on the capacity of their connection. For large consumers such as industrial ones (connection > 3x80 A, Intermediate Voltage) transport dependent tariff is applied. This variable rate for transportation consists of the contracted transmission capacity (kW contracted) and measured maximum capacity (kW max). Contracted capacity is the expected maximum power required by a consumer during the year (€/kW/year). Measured maximum capacity KW-max is the maximum power used by a terminal in a month or week (€/kW/month (or per week)). If kW max exceeds kW contract, the latter will be increased so that both are aligned. The last component of electricity and gas prices, government energy taxes and levies, include VAT (BTW), energy taxes (Energiebelasting) and a premium sustainable energy (SDE, ODE) which aims to collect grants for sustainable energy projects. These are paid based on the consumption of electricity (per kWh) and natural gas (per m3). VAT (Value Added Tax) rate is 21\% in the Netherlands.

Small and large consumers connected to the electricity grid are differentiated based on the technical structure of the Dutch grid (low, medium, high voltage). However, for this analysis, they are classified according to their energy consumption to identify which tax interval they belong to. Households belong to the first tax interval for both gas and electricity assuming they consume between 2 500 kWh and 5 000 kWh electricity and 20 GJ (568 m3) to 200 GJ (5686 m3) natural gas annually [6], [7]. For industry, the consumption is within the last two tax brackets assuming the annual electricity consumption is more than 50 000 kWh for electricity and 1 000 000 m3 for gas consumption. Industrial users within the last tax bracket are considered as large industrial users with an electricity and natural gas consumption higher than 10 million kWh and 10 million m3 while others are considered as the small industry. According to this classification, Table 1 presents the variable costs for natural gas and electricity for the three type of consumers. It is observed that with increasing consumption the amount of energy taxes keeps decreasing.

Figure 1 shows the overall shares of the price components for households when the network costs for gas and electricity are also included. It is observed that 70% of the electricity bill and 66% of the natural gas bill consists of taxes, levies, and fixed components. Fixed network and supply costs form 25% and 13% of the energy bill for electricity and natural gas, respectively. These ratios are based on the consumption of an average household. For the industry, the structure of network costs is more complex compared to households. Transport-dependent tariffs are based on the contracted capacity as explained above. There are different type of exemptions and rules also based on the operational hours of the technologies. Inclusion of network costs is more reasonable when savings from the overall energy bill is calculated. An analysis of network costs should take some aspects into consideration. For households, it is possible that no connection upgrade is required to install the heat pumps for example if the other electric appliances are energy-efficient. This means network costs are the same and paid always as households need a connection to power grid independent of their heating system. On the other hand, households can save from being disconnected from the natural gas grid. This is 13% of their natural gas bill. Most of the time it is the case that industry exceeds the contracted kW capacity to use power-to-heat technologies and the deployment of power-to-heat loads lead to substantial additional expenditure from the network tariffs. In this case, network costs also become a barrier to power-to-heat technologies. These aspects can be taken into account to include network costs. In this study, only the variable cost components are included in the calculations as only the heating costs are calculated.

Table 1. Electricity and natural gas prices variable components [8]

	Electricity			**Natural Gas**		
Euro/kWh	Households	Industry (Tax Category 3)	Industry (Tax Category 4)	Households	Industry (Tax Category 3)	Industry (Tax Category 4)
Variable Supply Cost	0.091355	0.0507	0.0507	0.0374	0.0214	0.02149
Energy Tax	0.09863	0.0142	0.00058	0.0300	0.0024	0.00131
VAT	0.02468	0.0045	0.00018	0.074	0.00063	0.00034
ODE	0.0189	0.0074	0.0003	0.00536	0.00060	0.00031
Total	0.2335	0.0769	0.0517	0.081	0.025	0.0235

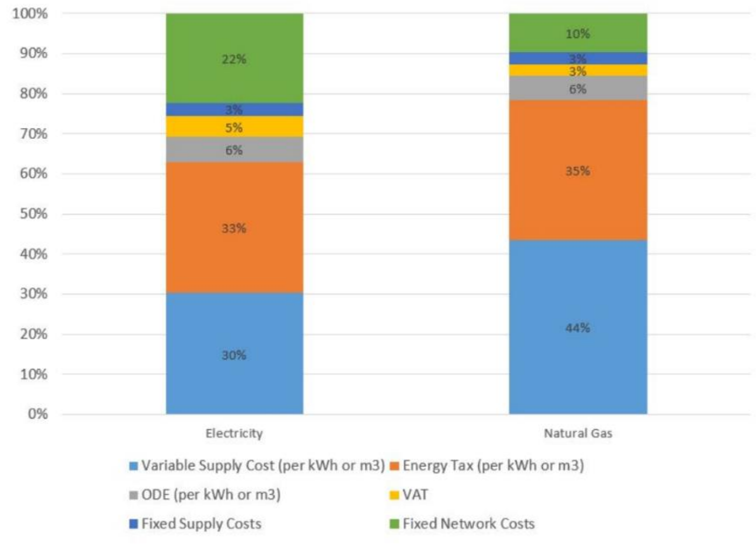

Figure 1. Components of electricity and natural gas prices for households [1]

[1] Fixed supply costs for electricity and gas are obtained from one of the energy suppliers Nuon. Electricity and gas network costs are the average of the 7 network operators in [9].

3. METHODOLOGY AND DATA

For this study, modeling is used as the main methodology. The optimal electricity prices for the Netherlands in 2030 is determined by the power systems model COMPETES (Competitive Market Power in Electricity Transmission and Energy Simulator). COMPETES is a network constrained power system optimization model which minimizes the total power system costs of the European power market under technical constraints of generation units and transmission constraints between countries. The model also includes electric heat pump load for households and the hybrid boiler technology for the industry. For the year 2030, it is assumed that the potential power-to-heat demand from the industry is 33 TWh while for households it is 5.86 TWh [10], [11]. The household heat pump profiles that are used in this study was used in 2014 for the FlexNet Project of ECN (Energy Research Center Netherlands) for an average climate year 2012 [12]. These profiles are constructed by a model for a single household based on the solar radiation, outside temperature, building type (e.g. in-between, corner, apartment, isolated house), insulation level and the type of heat pump technology (hybrid, air, ground heat pumps). As all types of heat pumps require high-level insulation the profiles are created assuming that the households are well insulated. The model input is only the hourly heat demand for the hybrid boiler. This demand is assumed to be flat and continuous all year. The other important model variables and their values for the 2030 Scenario are seen in Table 2.

Table 2. COMPETES Model 2030 Scenario Variables [11]

Scenario Variable	Values
Renewable Penetration:	Wind on-shore: 9.305 GW Wind off-shore: 11.264 GW Solar PV: 25.025 GW
Technology Mix for Households:	Air heat pump: 25.9 % Ground heat pump: 11.1% Hybrid heat pump: 63%
Natural Gas Price:	7.015 euro / GJ
CO2 Price:	41.81 euro/ton CO2

The optimal electricity prices from the model are used to calculate the price of one unit of heat by using electricity and natural gas. This depends on the efficiency of the technology for the households and industry as it is seen in the below formula.

$$Price\ of\ Heat = \frac{Electricity\ price}{\eta_{electric}} + \frac{Natural\ gas\ price}{\eta_{gas}}$$

Even though hybrid heat pump is not included in the model, the input hourly heat pump electric load data for households is used to make decisions in between electricity and natural gas outside of the model, similar to the decision of the hybrid boiler in the model. To test different conditions, the thermal heat load is calculated based on the input heat pump electric load profile by using the changing coefficient of performance based on the temperature. An electric heat pump has a changing coefficient of performance based on Table 3. A natural gas boiler has an efficiency of 85% while an electric boiler has an efficiency of 95%. The optimal prices from the model do not include the taxes and levies for natural gas and electricity. The model choices based on these prices are compared with the choices after the taxes and levies are included for the natural gas and electricity prices. The amount of change reveals the degree of the suboptimality for the end-users. The operational hours that is more cost-efficient to use electricity before and after the addition of the taxes and the heating cost savings are compared for different technologies. The cost savings are only based on heating costs and calculated by using the electricity and natural gas prices including the supply costs, and energy taxes and levies (energy taxes, ODE, VAT). The natural gas prices for the industry include the estimated CO2 price for 2030 as it is included in the ETS (Emission Trading System). Household natural gas prices do not include the ETS CO2 (41 euro/tonne) prices as household are not involved in the ETS. The comparison for operational hours provides an idea of how much of the year using electricity is more cost-efficient for certain technology and consumers. The heating costs and savings complement this comparison by providing a financial perspective for the business case of different technologies.

Table 3. Temperature and coefficient of performance relation [13]

Temperature (°C)	COP
-10	1.3
-5	1.9
0	2.5
5	2.8
10	3.1
15	3.6

4. RESULTS FOR HOUSEHOLDS AND INDUSTRY

Figure 2 summarizes the hours of the year when it is more cost-efficient to use electricity or natural gas for industry and households. The first four cases are related to the industry. Case 1 is the electricity prices from the model output and the natural gas prices with CO2 price. The model prices do not include any efficiency factor for a specific technology. In this case, electricity is cheaper than using natural gas 34% of the year. For all other cases, the comparison is made based on the price of one unit of heat considering the technology efficiencies. Case 2 shows the usage of electricity and natural gas for a hybrid boiler without any taxes included. In this case, 18% of the time electricity is the cheaper option. In the latter cases, the taxes are added for the industry. In Case 3 (for tax category 3 industrial consumers), the time electricity is cheaper is 2% of the time, 1405 hours less than the case without taxes. In Case 4 (for tax category 4 industrial consumers), 30% of the time electricity is cheaper. This is 1032 hours more than the case without taxes. It is observed that the addition of the taxes decreases the number of hours that electricity is used for industry category 3 consumers while there is an increase in industry category 4 consumers. The reason behind this increase is that for category 4 consumers natural gas taxes are slightly higher than electricity taxes as it can also be seen in Table 1. The addition of the taxes makes consumer prices for natural gas slightly more expensive than electricity. A comparison between model results and the decision with real consumer prices reveals the suboptimality for the end-consumers. The decision after the taxes are added is different than the model decision 16% of the year (1405 hours) for the tax category 3. All of these hours, electricity was chosen to be used by the model. After the addition of the taxes, the decision switches since using natural gas is more cost-effective. For tax category 4, the decision was different 11% of the year (1032 hours) than the model decision. This time after the addition of the taxes, model choices change in favor of the electricity.

Table 4 shows the heating costs for both categories of industrial users. Without the inclusion of the taxes, the overall heating costs are less for both types of consumers. After the addition of the taxes, based on the new decision, the heating costs increase 19% for tax category 3 consumers and 8% for tax category 4 consumers. It is also seen that using natural gas boiler is cheaper for category 3 consumers compared to the hybrid boiler with the current price structures. For category 4 consumers, a hybrid boiler is a cheaper option with a small difference compared to a natural gas boiler. However, this analysis does not include network costs for the industry as stated before. It is highly probable that the costs will increase even more in this case and make the natural gas boiler a cheaper option.

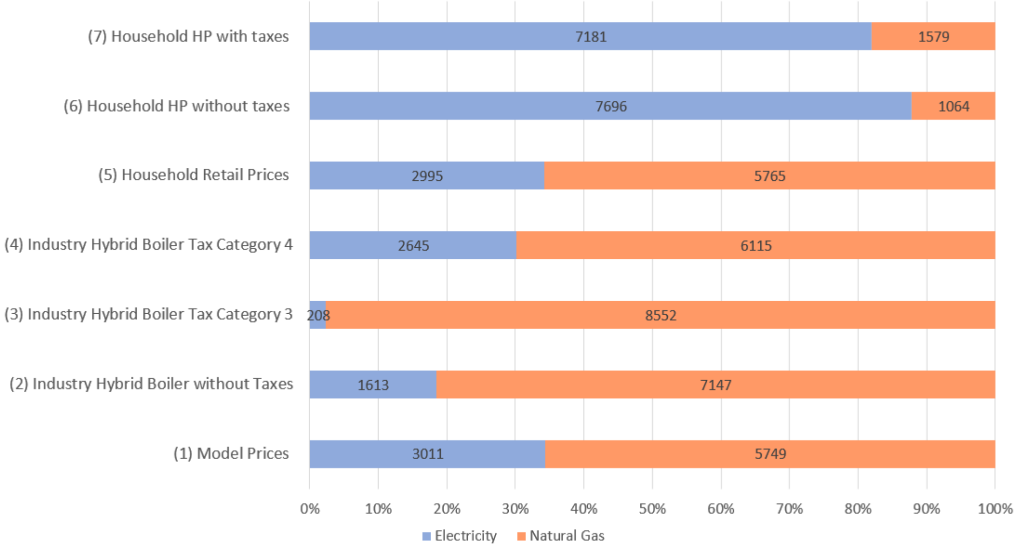

Figure 2. Cost-efficient operational hours for electricity and natural gas in the year 2030

Table 4. Heating costs of different technologies for different industrial end-users

Heating costs (Billion euros)	**Without Taxes Hybrid Boiler**	**With Taxes Hybrid Boiler**	**With Taxes Natural Gas Boiler**
Industry Tax Category 3	1.35	1.60	1.55
Industry Tax Category 4	1.35	1.47	1.49

Cases 5, 6 and 7 in Figure 2 are related to households. Household retail prices do not include efficiencies of any technology. In this case, 34% of the year electricity is cheaper. When the efficiency of the heat pump technology is also included, it is observed that 87.5% of the year it is more cost-efficient to use electricity. The addition of the taxes decreases this percentage to 82%. It is observed that due to the high efficiency of the heat pumps the distortion is less compared to the industry. The heating costs of households are calculated for three cases: the first calculation assumes that there is the possibility to switch in between sources depending on the cheapest one. This can be considered as a hybrid heat pump. Heating costs are calculated with taxes (1). Another calculation is made based on the model input data when only electricity is used to satisfy the heat demand including taxes (2). Finally, heating costs are calculated if only natural gas boiler is used (3). The comparison shows the hybrid boiler is the cheapest option for households with 1.2 billion euros and it is followed by all-electric heat pumps with 1.3-billion-euro operational cost. Satisfying all of the heat demand from natural gas is the most expensive option with 1.6 billion euro operational costs. This implies that with the current prices hybrid technology is more cost-efficient and might be a good transition technology.

The tax shift that is addressed in Climate Agreement Report, which is a package of policy measures that aims to bring 49% of emission reductions for the Netherlands by 2030 compared to 1990 increases the operational hours of electricity and decreases the heating costs for the end-users. The tax shift is proposed as follows:

1- An increase in the price of natural gas by 5.5 ct/m3 (0.0056 euro/kWh) (19% increase) and lowering that of electricity by 2.7 ct/kWh (27% reduction) (0.027 euro/kWh) as a first step.

2- An increase in the price of natural gas 20 ct/m3 (0.02 euro/kWh) (67% increase) and lowering that of electricity 7.34 ct/kWh (0.0734 euro/kWh) (74% decrease).

The first suggestion is thought as a modest contribution and more is needed for a substantial achievement. Calculations in Climate Agreement Report show that the second shift is expected to decrease the payback period of label B insulation from 25 years to 20 years and percentage of homes with a hybrid heat pump increases from 20% to 60% in 7 years [11].

For the households after the proposed tax shift, it is more cost-efficient to use electricity almost the entire year. The remaining amount of time in which natural gas is more cost-efficient is less compared to the current situation. For small industry (Category 3 industry consumers) the first shift is still not very effective and still 59% of the time natural gas is more cost-efficient in that case. For industrial consumers, for the second tax shift, it is not possible to lower the electricity prices more since some prices go negative. Therefore, only the natural gas price is increased. With a higher increase in the natural gas prices in the tax shift 2,93% of the hours it is more cost-efficient to use electricity. For industry category 4 consumers, the current taxes were already changing the usage in favor of electricity. However, the heating costs for the hybrid boiler and natural gas were closer to each other. It is probable that the inclusion of network costs can change the situation in favor of the natural gas boiler. So a tax shift would also guarantee the positive business case more for these consumers. With the first shift the hours that are more cost-efficient to use electricity increases to 97%. If the natural gas tax increase is applied as suggested in shift 2, electricity is cheaper to use over the entire year.

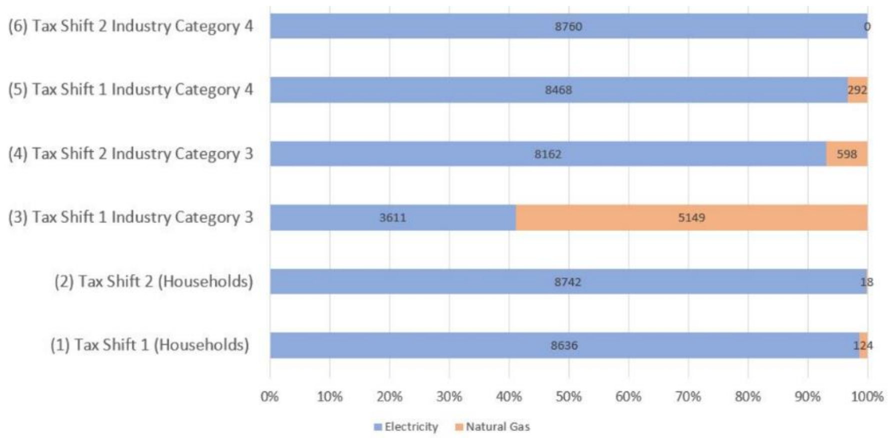

Figure 3. Cost-efficient operational hours for electricity and natural gas in the year 2030 after the tax shift

Table 5 shows that the tax shift 1 decreases the heating costs 32.5% for the hybrid heat pumps and 34.7% for all-electric heat pumps. Tax shift 2 decreases the heating costs by 54% for the hybrid heat pumps and 55% for the all-electric heat pumps. For category 3 industrial consumers, the first tax shift decreases the heating costs 1.25% and the second shift decreases by 50%. For category 4 industrial consumers, the first tax shift decreases the heating costs 42.1% while the second shift decreases by 45%. The natural gas boiler costs increase for all the end-users. For households, after the tax shift, all-electric technologies are slightly less costly compared to hybrid heat pumps. For industry category 3 consumers, hybrid boiler becomes a cheaper option. For large industrial consumers, with the first tax shift, the cost gap between hybrid boiler and natural gas boiler increases from 0.2 billion euros to 0.85 billion euros providing more heating cost savings which might be enough to cover the increased network costs.

Table 5. Heating costs of different technologies for households and industry after the tax shift

Heating cost (Billion euros)	Current Tax Structure	Tax Shift 1	Tax Shift 2
Households Hybrid	1.27	0.857	0.587
Households Heat Pump	1.31	0.855	0.585
Household Natural Gas	1.68	2.05	2.62
Industry Category 3 Hybrid	1.60	1.58	0.79
Industry Category 3 Natural Gas Boiler	1.55	1.7	2.27
Industry Category 4 Hybrid	1.47	0.85	0.8
Industry Category 4 Natural Gas Boiler	1.49	1.7	2.2

5. DISCUSSION AND CONCLUSION

This study investigates the effect of energy taxes and levies on the consumers as a barrier against the wide-spread use of power-to-heat technologies. It is found out that the taxes and levies encourage the use of natural gas for households and small industry while for the large industry the taxes increase the cos-efficient hours for electricity. For households, even though the operational costs of a natural gas boiler are higher and heat pumps provide savings in any case with or without taxes, investment costs are still an important barrier. The two barriers investment costs and commodity prices are connected to each other as the operational savings by switching to power-to-heat technologies are important to cover the investment costs. The investment costs are higher for an all-electric heat pump (10 000 and 19 000 euros) and lower for hybrid heat pumps (4000-8000 euros). With the current structure of taxes and levies 18% of the time it is still more cost efficient to use natural gas. There is a potential to increase the operational savings for households and shorten the payback periods for power-to-heat technologies. In addition, these hours are sensitive to decreasing outside temperatures. The data set that is used for this study is for an average weather year 2012. It is highly possible that for an extreme weather year, an increase in the hours that it is more cost-efficient to use natural gas is observed. For the industry even without the inclusion of the network costs the position of the hybrid boiler is not advantageous compared to a natural gas boiler. It is expected that with the increased network costs, the situation will be worse hybrid boilers.

It is found out that a tax shift from electricity to natural gas is an option to increase the operational savings for households to shorten the payback times and incentivize power-to-heat technologies. As the penetration rate of power-to-heat technologies increases, the investment costs might also decrease until 2030. It is also important to note that the efficiency of the technology that is used affects the heating costs and savings. It is observed that in the case of hybrid boiler, using electricity is cost-efficient only a limited amount of time. When the same calculation for heat pumps and households is made, due to the high efficiency of heat pumps, it is observed that even though there are higher amount of taxes for electricity, electricity is preferred most of the time and heat pumps contribute to the decreasing of the heating costs. This is one of the reasons for the difference between the end-users. If a hybrid boiler technology is used for households, the tax structure might pose a greater barrier for the usage of electricity. Power to heat technology that is used for industry and households are different in terms of energy efficiency. For industry, research and development of power-to-heat technologies is more challenging due to the temperature differentiation of the heat demand. The heat pumps that are being developed for medium (100 °C-400°C) and high-temperature heat demand (>400 °C) have a lower coefficient of performance compared to the ones for the built environment.

It is important to carefully design the policy instruments such as tax shift in order to avoid inefficiencies and distortions in the market. The two-step tax shift that was discussed in the Climate Agreement Report helps to reduce the barriers against power-to-heat technologies for the end-users. However, there are concerns that it will increase the energy costs for the low-income houses that are connected to the natural gas grid and cannot afford heat pump technologies. Possible solutions for this include reducing income tax, increasing rent allowance or other benefits to compensate for the increase in the energy bill for these houses.

There are also subsidies provided for sustainable energy investments. Dutch Sustainable Energy Investment Grant (ISDE) is a program launched by the Dutch government to encourage the adoption of sustainable heating technologies such as heat pumps, solar boiler, biomass boiler or pellet stoves. For 2018 the Ministry of Economic Affairs and Climate Policy has allocated 100 million euros for this subsidy scheme. The subsidy is for businesses and households and partially compensates the initial investments depending on the device and its energy performance. The amount of subsidy varies between 1000 to 2500 euro depending on the technical parameters of the heat pump [14]. In addition, the government considers including hybrid boilers under the renewable subsidy scheme SDE ++ which is the widened version of the SDE renewable energy subsidy scheme. The new version will focus on CO2-reducing technologies and provide incentives through an operating grant (financing the running costs). There are concerns that a production subsidy might lead to disruption of the electricity market and possibly additional emissions since the option fosters the production even when there is no renewable energy.

Without additional policy instruments, it is unlikely that the potential benefits of sector coupling will be unlocked as there are important barriers both for households and industry. Different types of policy measures are on the agenda of the Dutch government to encourage the end-users. There is substantial flexibility potential from the industry side which does not have a positive business case in 2030 with the current policies. For the industry, the tax shift might also need to be supported by a reform in the network costs. For households, one of the key policy measures is to increase the energy savings by a tax shift from electricity to natural gas. There are already subsidy schemes provided for sustainable heating technologies. With the increase in energy savings due to the tax shift, the remaining amount that households need to pay will decrease. In the process of designing policy instruments, the involvement of various actors is also important to make the transition more cost-efficient. The negotiators include environmental organizations, municipalities, housing corporations, energy companies, construction companies, and banks.

REFERENCES

[1] Schaber, K. (2013). Integration of Variable Renewable Energies in the European power system: a model-based analysis of transmission grid extensions and energy sector coupling. *Dissertationschrift - Fakultät Für Elektrotechnik Und Informationstechnik Der Technischen Universität München*, 1–199. https://doi.org/10.1086/474122

[2] Bloess, A., Schill, W. P., & Zerrahn, A. (2018). Power-to-heat for renewable energy integration: A review of technologies, modeling approaches, and flexibility potentials. *Applied Energy*, *212*(August 2017), 1611–1626. https://doi.org/10.1016/j.apenergy.2017.12.073

[3] Praetorius, B., & Lenck, T. (2017). *Neue Preismodelle für Energie*. Retrieved from https://www.agora-energiewende.de/en/topics/-agothem-/Produkt/produkt/388/Neue+Preismodelle+für+Energie/

[4] Olczak, B. M., & Piebalgs, A. (2018). Sector Coupling: the New EU Climate and Energy Paradigm. *FSR Energy*, (2018/17). https://doi.org/10.2870/35692

[5] Stephanos, C., Höhne, M.-C., & Hauer, A. (2018). Coupling the different energy sectors − options for the next phase of the energy transition. *German National Academy of Sciences Leopoldina*, (August). Retrieved from www.akademienunion.de

[6] *Eurostat. (2018). Natural gas price statistics. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics*

[7] *Eurostat. (2018). Electricity price statistics. Retrieved from* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics

[8] Belastingdienst. (2019, January 08). Energiebelasting. Retrieved from https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/zakelijk/overige_belastingen/belastingen_op_milieugrondslag/energiebelasting/

[9] *Vastelastenbond. (2018). Network costs 2018 | All costs of the network administrators. Retrieved from https://www.vastelastenbond.nl/energie/netwerkkosten-2018/*

[10] ECN. (2017). *Nationale Energieverkenning 2017*. Amsterdam/Petten. https://doi.org/ECN-O--16-035

[11] Dodion, P., & Melotte, J. (2018). *Effecten ontwerp Klimaatakkoord*.

[12] Sijm, J., Gockel, P., Joode, J. de, Westering, W. van, & Musterd, M. (2017). *The demand for flexibility of the power system in the*. Petten.

[13] Haller, Michel & Haberl, R & Carbonell, Daniel & Philippen, Daniel & Frank, Elimar. (2014). SOL-HEAP. Solar and Heat Pump Combisystems.

[14] RVO. (2019). Investeringssubsidie duurzame energie ISDE. Retrieved from https://www.rvo.nl/subsidies-regelingen/investeringssubsidie-duurzame-energie-isde