1. Hello everyone my name is Bekir Caner yağcı, welcome to my Master thesis Mid-term presentation. In this project, I am investigating the hidden flexibilities provided by industrial P2X considering grid support strategies.
2.

I will start the presentation by giving a brief explanation about my research problem and the problem owners. Secondly, I will talk about what I understand from flexibility and how I measure it in my project. Then I will state my research questions with brief explanations. After that, in methodology and modelling part I will explain how I am doing this project, my tools, my co-simulation flowchart, models and so on. Finally, I will show you my co-simulation cases, initial results and I will close this presentation with my future plans. So let's start with the research problem.

3.

More and more RES are integrating to electricity network but highly volatile nature of these generation units introduce a great challenge for grid operator to balance the electricity supply and demand. In order to increase the percentage of RES in the network, the flexibility of the system must be increased. ----------------- Electrification of the industry is one the most promising ways to increase this flexibility, because, industrial processes currently account for 30-35% of the world's total energy demand and related carbon emissions. Replacing production based on fossil fuels in chemical, petrochemical, food, steel and other industries leads to more sustainable and flexible multi-energy networks. -------------------- Industrial systems are able to provide large amounts of energy and energy storage with various efficiencies, ramp up/down rates and storage durations. However, in the previous projects, during the modelling of such multi energy systems significant amount of simplifications are made and this led to losing some of the essential dynamics on the results that might be crucial to understand the flexibility provided by that PowertoX system. ----------------- Inaccurate analysis of flexibility of a device or system may bring increased transmission losses, higher operational costs or misinterpretation of the system capacity. ---------------------- Finally, of course, the planning and operation of such multi-energy system needs to be coordinated to make optimal use of the available resources. Even though (Palensky & Dietrich, 2011, p. 382) suggests that, a good combination of Market DR (price signals) and Physical DR (grid management) is necessary to run a network optimal, many of the existing simulation models for the energy management of MES do not have any information about the energy cost of other components in the network. They only consider adjustable power level, this approach results in unnecessary trading of electricity with the utility grid and means an increase in operational cost for P2X owners.

4.

In this project, Flexibility defined as ability of a component or a collection of components to response challenges caused by power fluctuations in energy systems. From an operational perspective, P2X flexibility becomes relevant in situations where there is excess RE supply relative to demand in the power system and, therefore, electricity prices are low. During excess RE time, increasing power state of P2X to the nominal values or to a specific power state for a defined holding duration provides power balance for the grid and reduces operational cost for P2X owners by shifting their load with the help of storage technologies. to time of low electricity prices.

This figure here is to help me to explain characteristic parameters of flexibility. There are activation, deactivation and modulation periods that are dependent on the ramp up/down rate of the system and holding period where efficiency of the device should be modelled in detail, otherwise the available capacity can be miscalculated. So basically if we are talking about flexibility of a device we should consider at least one ramp up, one ramp down and one holding time. Finally, the hidden flexibility, in this project, is defined as the difference between the amount of energy consumed by the simplified and the detailed model of P2X during flexibility service.

5.

With the problems I have mentioned, My first research question is … Coupling of different energy sectors is inevitable to have successful transition to 100% Renewables. When it comes to electrification of industrial area there are so many options exist with various combination of electricity, heat, gas and storage technologies. However, which technology can bring the best performance for the grid and the most profit for the P2X owner needs to be investigated

My second question is … Power-to-X technologies, especially Heat pumps and electrolysers, have the potential to be an integral part of an efficient, renewable and interconnected multi energy system. However, due to the approximations made in model formulations, flexibilities provided by those devices to the grid can be concealed in the simulation results. Therefore, modelling of P2X should be investigated with respect to be optimally adapted to the requirements of flexibility analysis.

My last research question is … Due to the interdependencies and connectivity between previously distinct energy vectors, a more holistic energy management and modelling approach must be provided, but complex simulations need to be set up for this. So the question was how to combine and control models such that they operate at the optimum operation point during flexibility and the simulation method is simple enough to compile in minutes, and I found the answer to this question in co-simulation with energysim.

6.

This figure here shows the general implementation of my co-simulation. it is to show some of the available inputs & outputs and also my tools. As you can see, simulation initializes by running optimal power flow first in pandapower, I used pandapower to solve optimal power flow problem with cost functions, it allowed me to have one environment that has information about all the all agents in MES. it also allowed me to consider market prices in order to find the most optimum deployment of flexibility, we will come to that. Then the results of this optimal power flow are sent to OpenModelica agents. Openmodelica allowed me to have dynamic simulations of multi domain systems with reduced computational burden thanks to its object-oriented, equation based programming language After OM simulations, outputs are sent to pandapower for optimal power flow back again. Finally, energysim allowed me to combine all models and implement such complex simulation to evaluate the flexibility available from P2X.

7.

So this is my detailed flow chart you can identify the higher control level and lower control level with red and blue dashed lines, I will go step by step now, at t=0, Optimal Power Flow (OPF) model in pandapower calculates the best operating point for P2G & P2H in order to meet generation of RES with the objective of minimizing operating cost. After that, the results of the optimal power flow are sent to MES agents for the initialization of the simulations. Here active power orders are sent to controlled side. For demand side management, P2X models are controlled here but this could be the RESs as well. However, in this case, RE sources supply the maximum available power in the area from wind and solar and the excess RE is injected to the grid. OM models has 3s time step until the next exchange time which will be 5-15 min. Finally, each FMUs send out the binding information to the higher control level and defines the available operation range for itself, then higher control level calculates the exact operation point within this defined range by solving the optimal power flow problem back again.

8.

Here you see the formulation of the optimization problem. Global objective is to minimize the operational cost. Cost function is polynomial. It could be piecewise linear, but polynomial cost function with linear cost per MW is the most convenient option to input static intraday price signals during co-simulation. Local objective is to supply demand at all times. Minimum active power is controlled such that demand is always satisfied. PID controller follows demand change to calculate the minimum active power so that the active power order selected by higher control is always greater than or equal to demand. When there is no available space in the storage, electrolyser is forced to work under 10% load for a predefined time. Also, when the storage is lower than 50% PID reference is increased to 0.1 pu to keep the storage at least at 50 % for emergency.

Maximum active power decision depends on the available storage capacity. Pmax is the nominal power, when there is an available space in energy storage; however, it strictly follows minimum active power, for a predefined time, when the storage is full. For RES models, maximum active power is calculated considering the available windspeed and solar irradiation in the area at that time.

9.

This figure here shows my MES. Basically there is one industrial microgrid with AC feeder.(Bode & Schmitz,2018) compares different combinations of MES and concludes that, a combination of P2G with electric heat pumps or combined cycle gas turbines has the best cost performance in a MES with renewables. Additionally, hydrogen is one of the most convenient options because it can be stored at high energy densities and it is very easy to store or transport hydrogen with existing gas networks.Moreover, Electrolyser technology is able to provide required ramp up/down rate for grid services. Another convenient option is using excess RE in district heating networks. Because, boiler combined with heat pump usually recommended for its high conversion efficiency. Considering these and Port of Rotterdam, a hypothetical Maasvlakte Energy Park, is designed. According to the articles about port of Rotterdam, The outer contour of Maasvlakte will be installed with wind turbines and the installed capacity will be approximately 100-130 MW with 36, 3.6MW windturbines. A floating solar park will be installed in Slufter, the installed capacity of the PV farm will be approximately 100MWp. Combination of these RES with the best available P2X options in the industrial area is assumed to be a hyphotetical Energy Park in Maasvlakte. To talk about the modelling…

10.

Here you see my Wind turbine generator model. 3.6 MW GE DFIG wind turbine from Modelica iPSL Library. Behaviour of the model is equivalent to current controlled voltage source converter. Turbine model converts mechanical power coming from wind into AC power order considering power produced by generator. Electrical Control commands the active and reactive power to be generated based on the power system conditions and turbine model. Generator provides interface between the controller and the network. The net result is controlled current source that injects the active and reactive power specified by electrical control into the network. Finally, the output of the generator is connected to Point of Common Coupling (PCC) by PV, PQ buses and transformer as shown in the figure. Moving on to power to gas model.

11.

First order dynamics of industrial ProtonExchangeMembrane Electrolyser is modelled taking pressure, temperature, and current effects into consideration. It calculates the electrical power consumed and the hydrogen flow rate for charging compressed gas storage. Storage model calculates the energy stored. Energy level of the tank can be calculated from the available volume if the tank pressure and temperature is assumed constant. After storage, controller decides minimum and maximum active power constraints considering the physical condition of the system. Finally, static generator provides electrical interface to the network.

12.

I will carry out three experiments. In the first one, I will control RES to follow demand and measure the amount excess RE and its duration. Using this, I will define a specific amount of time for the flexibility service, namely holding duration. In the second experiment, to investigate the hidden flexibilities, I will compare the amount of flexibility provided at nominal power order for different Electrolyser models but with the same holding time decided in case 1 and I will do the same comparison for heat pump mode as well. In my third experiment, I will investigate the optimal deployment of flexibility using cost functions and demand-side management. Therefore in this case demand follows generation and the active power boundaries coming from agents, limit the higher control level to calculate the exact operation point for loads. Finally flexibilities provided by each agent is measured for the discussions in this case as well.

13.

This figure here shows the dynamics of the wind turbine generator model. Active power starts at 1.3 p.u. and stabilizes at 1 p.u after 10s. Reactive power, oscillates between ±0.5 p.u and reaches limit values when step increase occurs at the terminal bus voltage. Shaft acceleration can be observed in the active power at initialization. Open loop control responds to large disturbances such as abrupt/unexpected active power increases. At initialization, and during the voltage step increase at 40s, a condition occurs where active and reactive power cannot both be satisfied without violation of current limit. In this case, converter control gives priority to the reactive current, as can be observed with linear active power decrease in the figure. Power factor controller, that maintains the nominal power factor and forces reactive power to follow active power changes, must be adjusted since it is unable to stabilize reactive power at “0” here. Finally, closed loop voltage regulation control responds to step voltage increase at 40s by increasing the magnitude of the reactive power oscillations.

14.

This figure shows the response of P2G system to step increase in active power order between 10-60s and step increase at terminal bus voltage at 90s. First order response of electrolyser to new set value of electrical power consumed and active and reactive power response to voltage step increase can be observed.

15.

This figure here shows the electrolyser cell voltage response to varying cell current densities. An electrochemical steady-state model is created with first order dynamics to predict the stack voltage and the stack temperature evolution from instantaneous operating conditions such as the applied current, pressure or the ambient temperature. Here the values are different since the operating conditions for temperature and pressure is different in both cases. Also, some of the considerations taken in the reference model are ignored in my model, such as cooling system losses of the electrolyser power plant. However, as you can see, activation overpotential is dominant until approximately 1.75 A/cm2 and ohmic overpotential which has linear response is dominant at high current densitiy. Therefore, I am able to model the characteristics of an electrolyser cell with this model.

16.

At last, to talk about my future plans , in the following weeks, I need to finalize my PVfarm and PowertoHeat models which will be similar to Windfarm and P2G. I also need to create .csv and txt input data for ws, solar irradiation and demand profiles. Then I will combine all models in energysim and implement my experiments for the flexibility analysis. Later I can improve the details of my models or the resolution of the input data for better results.