1. The consequences of the pandemic on the Energy System. How did covid-19 affect the energy industry and the energy transition?

COVID-19 pandemic outbreak affected our societies greatly, offering a chance to rebuild our energy grid and rethink the way of living. The energy sector faced an unprecedented shock, energy demand dropped by 5% in 2020, energy related CO2 emissions by 7% and investment by 18%. What was the impact of COVID-19 pandemic on the different type of technologies? Is it possible to predict their prices? How can other major events affect the energy systems?

The main objective of this Master thesis is to quantify the consequences of covid-19 on the energy systems and especially on the different technologies. The student will investigate and create a mathematical model to forecast the development of the main parameters of an energy system such as: the prices, the energy demand, the energy consumption, the production and the greenhouse gas emissions. The goal is to compare these predictions both with the presence and absence of COVID-19 in order to understand what the impact of the pandemic was.
2. Social Acceptance and Machine Learning. What is the Willingness of Pay and the main barriers within Belgian population in the introduction of alternative fuels?

The introduction of new technologies and new policies is affecting both the industry and the consumers. Demand, Consumption, Prices, and other parameters of the energy system can be affected towards the energy transition. An essential part of our energy grid is the consumers and their behavior. Therefore, it is essential to study the social acceptance and the willingness to pay in each community.

The main objective of this Master Thesis is to study and predict the Willingness of Acceptance and the Willingness to Pay of the Belgian population in the introduction of alternative fuels and their possible applications. A survey will be created to measure the potential acceptance or/and resistance, and the goal is to identify the "Greener Regions" of Belgium according to the responses of the survey. The student should automate the procedure by using a Machine Learning algorithm or another sophisticated method and predict the behavior of the consumers according to the findings of the survey.
3. **Machine learning for large combustion data analysis**

Flame displacement speed is an important quantity of interest for turbulent premixed flames. Developing robust models for it requires a thorough understanding of the underlying physics of turbulence-flame interaction and would benefit in simulating turbulent flames of practical interest, say flames in gas turbine afterburners. A physics-based, linear model for flame speed based on asymptotic analysis for laminar flames is already available in the literature. While there are validations that the linear model indeed works for turbulent flames, the studies have also noted shortcomings for regions where one flame interacts with others. In this master project, our objective is to first check whether a machine learning (ML) model that is inspired from the available physics-based model (say linear regression) is indeed able to predict the flame speed in turbulent flames. After confirming existing results, we would move to augment the existing physics-based model using ML tools to model flame speed in regions where the physics-based model is falling short.

In this research project, you have an opportunity:

1. to work on large datasets obtained from direct numerical simulation of turbulent premixed flames.
2. work with existing physics-based models and understand how such models are developed. What are assumptions involved to simplify calculations and limit the use of such models?
3. Use ML based techniques to confirm existing knowledge and then use them to overcome issues in existing models, to finally propose a hybrid (physics-data) model to enable simulation of more complex flames.
4. Flame interface extraction from Mie scatter images of a turbulent reacting flow

Measurements of velocity in flames rely chiefly on optical methods such as PIV and LDA. In both cases, sufficiently small particles or aerosols are used to seed the mixture, which can follow the relevant turbulent frequencies. However, the expansion of gases in flames means that in the region of the flame (brush), the particle density is proportional to the gas density. The objective of this project is to extract the flame interface by exploiting the particle density difference between the reacting and non-reacting regions of the flow field, such that the interface is determined as the position of the maximum gradient in the Mie scattering intensity field.

In order to determine the appropriate flame interface, a histogram-based thresholding method will be adopted for each Mie scattered image. A preliminary threshold calculated from the (Mie signal) global intensity histogram, coupled with a ridge finding algorithm will be implemented to detect the maximum gradient.

From Mie scatter image to binarised image

A rough idea of the ridge finding algorithm
5. Modal analysis of turbulent reacting flows

Laser diagnostics enables the capture of dynamic features in turbulent flows with high spatial accuracy but also generates a large amount of data. The challenge is therefore to extract relevant dynamics from the dataset, in other words, to distil out the coherent motions from the otherwise random signal. The problem can be seen as a data reduction problem retaining important features in a form sufficiently compact to allow interpretation. In the present work, we use the Proper Orthogonal Decomposition (POD) to extract information from the collected data.

Proper Orthogonal Decomposition (POD) is a well-established statistical method in fluid mechanics and is used to reduce large data sets down to their most prominent spatial features, referred to as modes. In short, it extracts a basis for a modal decomposition of a given ensemble of data. Much like Fourier decomposition, these modes are orthogonal bases which can combine to recreate the original data.

In this project, the heat release rate (HRR) dynamics of a turbulent reacting flow will be examined by conducting proper orthogonal decomposition (POD) analyses for the chemiluminescence field measured in a test burner.

**Example for velocity data:** (NOTE in this project chemiluminescence data will be used instead)

![Instantaneous flame image](LEFT) and fluctuating velocity field (RIGHT)

![Reconstructed iso-contours](LEFT) and modes (RIGHT)
6. Conditional statistical analysis of thermal dissipation field of reacting flows

The motivation of this study is to analyse high-resolution optical diagnostic data on thermal dissipation fields in turbulent reacting flows in a modular micro gas turbine burner and, subsequently, measure conditional statistics of geometric flame structure thus providing detailed analysis for model development and validation. The analysis of planar Rayleigh data allows identification of the characteristic lengths which varies significantly from reactant to product zone. A comparison of the morphology and length scales of dissipation fields in the reacting flows, provides both quantitative and qualitative analysis of the effects of flame and flow parameters on the fine-scale dissipative structure arising from turbulent mixing.

The analysis will be focused to see the dependence of the character and morphology of thermal dissipation structures strongly on the reactivity of the flow, the global stoichiometry, and the turbulent intensity.

Temperature field (LEFT) and mixing (or dissipation) layers (RIGHT)

A schematic of quantitative analysis