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**title: Mini-Lecture 6.1 –- Residential Sectors in MUSE**

keywords:

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authors:

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This mini-lecture introduces the concept of the residential sector

# Learning objectives

- Understand the role of the residential sector, its technologies and the main energy and societal challenges

# Overview of the residential sector and its demands?

Energy is used for many different reasons in the residential sector, as shown by Figure 6.1.1. This image shows the share of residential energy by service demand. We can see that energy is used for many different purposes, from heating and cooking to cleaning and ironing. This split of energy demand will vary across different countries. Figure 6.1.1 shows residential energy demand in Italy, which will differ to countries in Asia, for instance. This is largely dependent on different climates, levels of development and lifestyles.

![](assets/Figure\_6.1.1.png){width=100%}

\*\*Figure 6.1.1:\*\* Residential sector in Italy and the different demands [@en12112055]. (Note: DHW refers to Domestic Hot Water).

The total magnitude of energy demand varies by country as a total value, but also as energy demand per capita. This is strongly dependent on the level of electricity access and availability of other fuels in the country. Residential activities can use different forms of energy. For example, cooking can be met by burning biomass, oil products, natural gas or electricity. The fuels used vary by country.

## Residential sector technologies

Some of the key residential technologies include lamps, cooking stoves, heating and air conditioning systems, as well as other electrical appliances. Some of these technologies can only use one fuel, such as electrical appliances and air conditioning which rely on electricity.

However, in other cases multiple different fuels can be used for the same purpose. For example, heating. Heating can be met by burning biomass, natural gas, oil or electricity, for instance. These technologies have differing performance parameters. For example, electric stoves are usually much more efficient than biomass stoves. Different technological options also have different impacts on the environment and on human health. For example, the emissions from biomass can have detrimental impacts on human health, whereas electric stoves do not have emissions in the home.

It is possible to model these different options in MUSE, which allows us to gain insights into their environmental and cost implications. Modelling can allow us to model the entire system as a whole, understand the trade-offs between certain technologies and make decisions on which policies to implement.

## Residential sector in MUSE

Within MUSE we can model different technology options. For instance, if we are to model an electric stove and a biomass stove we would have different inputs (CommIn.csv file). However, we would have the same output (CommOut.csv file) of cooking demand. We can also model an increase in efficiency of a technology by lowering the value in the CommIn.csv file. It is possible to change the efficiency over time using interpolation or a flat-forward extension as explained in mini-lecture 5.4. We can also consider the costs of investing in more energy efficient appliances by increasing the cost of these high efficiency appliances relative to the low efficiency appliances. By doing this, we can understand where and when investments in energy efficiency might be economic.

# Summary

In this lecture we have explored the residential sector. We considered the different demands that can reside within the residential sector and the different technologies that can be used to meet these demands. We also learnt of the difference in demands between countries and how we can model different technologies within MUSE.

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**title: Mini-Lecture 6.2 -- The transport sector in MUSE**

keywords:

- Transport sector

- Energy modelling

authors:

- Alexander J. M. Kell

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This mini-lecture introduces the transport sector. We will explore the different demands and technologies within the transport sector and how we can model them within MUSE.

# Learning objectives

- The main characteristics of the transport sector

- How these can be modelled within MUSE

# Overview of the transport sector and its demands

The transport sector is vital in the modern age. In the last few decades, the use of transport has increased significantly. This is as more people gain access to vehicles and develop lifestyles which rely on transport.

Figure 6.2.1 shows different modes of transport. As can be seen, road transport is the most used transport mode. We can also see that over 90% of fuel used in the EU transport sector is petroleum based. This is similar across the world. However, this creates challenges due to the unsustainability of fossil fuels.

![](assets/Figure\_6.2.1.jpg){width=100%}

\*\*Figure 6.2.1:\*\* Transport modes and fuel share in the EU [@en13020432].

Due to the unsustainability of fossil fuels, other solutions have been taken up with support from governments around the world. For example, cars, motorbikes and buses can be fuelled by electricity. Electric vehicles have seen large reductions in cost and improvements in performance. Electric vehicles could play an important role in overcoming the sector's challenges.

It is possible to model the different technologies in MUSE, and observe competition between technologies based upon their technoeconomic parameters.

## Emissions

The transport sector was estimated to be responsible for around 16% of global emissions in 2016 [@owidco2andothergreenhousegasemissions]. Thus, scenarios consistent with meeting global climate targets require transport sector emissions to decline rapidly. Therefore a rapid move towards sustainable technologies, such as electric vehicles is required. It is true, however, that some of the modes of transport are difficult to decarbonise. For example, it is difficult to decarbonise shipping and aviation technologies. This is because the energy density of lithium ion batteries and other technologies are lower than oil-based products. It is worth mentioning, however, that decarbonising transport is only useful if the energy sector increases its low-carbon electricity sources to supply the transport sector.

## Transport sector in MUSE

Similar to the residential sector, we can define different technologies for the transport sector using technoeconomic parameters. For example, we can split road transport into three categories:

- Cars

- Motorcycles

- Buses

We can then split these three categories into their propulsion system. For instance:

- Electric vehicles

- Conventional vehicles

We can source road transport data from national energy balances such as from the IEA, and divide this between cars, motorcycles and buses based on the split of transport by mode in the country.

We can then run a MUSE model with the different parameters and see the effect of these different parameters on agent investment decisions. These parameters could be fuel prices, technology costs or performance parameters. We can also run the model with a carbon limit, which places a tax on carbon emissions, allowing us to work out how to pick a desirable policy depending on what we are trying to achieve.

# Summary

In this mini-lecture we have considered the transport sector and how we can model this within MUSE. We discussed the emissions of the transport sector, and how different technologies can be used to reduce these emissions.

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**title: Mini-Lecture 6.3 -- The industrial and commercial sectors**

keywords:

- Industrial sector

- Commercial sectors

- MUSE modelling

authors:

- Alexander J. M. Kell

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This mini-lecture reflects on

# Learning objectives

- The main characteristics of the industrial and commercial sectors

- How these can be modelled within MUSE

# Overview of the industrial and commercial sectors

Next, we will explore the industrial and commercial sectors and their respective energy demands. Figure 6.3.1. shows the energy consumption for different sectors, including industrial, by OECD (generally high-income countries) and non-OECD countries (generally low- and middle-income countries). It is evident that the industrial sector is responsible for a large share of energy consumption across the world. The industrial sector is forecast to rise in non-OECD countries significantly. We must also consider this growing expected demand in the modelling process and during policy design.

![](assets/Figure\_6.3.1.png){width=100%}

\*\*Figure 6.3.1:\*\* Energy consumption by sector, OECD and non-OECD [@world1020007].

Energy is used in industry for a number of different purposes. For instance, heating and cooling, running machinery and chemical processes. These processes use a large variety of fuels and depend on the purpose, location and the technoeconomics.

The commercial sector has a lower energy demand when compared to the industrial sector. This is because commercial processes, typically, are less energy intense and on smaller scales. This demand is often lighting, heating and to run office equipment and appliances.

## Industrial and commercial technologies

Commercial activities use many different technologies which require energy inputs. For example, office electronics, lighting and heating systems. Many of these technologies use electricity. However, for some demands natural gas is used, for example for heating commercial buildings.

The industrial sector uses a wide range of technologies. This includes heavy machinery, boilers, heating and air conditioning. Again, a wide variety of fuels can be used for this. However, there exist a number of processes, such as steel manufacturing which requires very high temperatures. This is usually only done by burning fossil fuels, as it can be difficult to reach these high temperatures with electricity.

## Modelling industrial and commercial sectors in MUSE

Similarly to the residential and transport sectors, we can use an energy balance [@iea\_world\_energy\_balance] to estimate industry demands -- for instance, for industry heating demands. There are different technologies available for industrial heating. These can be grouped in a way that makes sense for your case study. However, as an example we can group these into high heat and low heat, which are modelled as separate demands. This is because generating very high temperatures requires different technologies and processes to generating low heat.

Again, we can group the technologies by their input fuel, such as biomass, coal, oil products or electricity with the `CommIn.csv` file. Through modelling with MUSE we can understand the emissions and economics of different technologies.

In addition, the commercial sector will have a different demand load profile to the residential sector. This is because, typically, the demand will follow office times for the specific region, whereas the residential sector will follow the inverse of the office schedule.

# Summary

In this mini-lecture we explored the industrial and commercial sectors. We learnt the difference between these two sectors in terms of demand and the different types of technologies used in these sectors. We saw that demand for the industrial sector is expected to rise significantly in non-OECD countries. Finally, we learnt how we can model different technologies in MUSE.

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**title: Mini-Lecture 6.4 -- Sector coupling**

keywords:

- Preset sectors

- Service demand

authors:

- Alexander J. M. Kell

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In this mini-lecture we will investigate the role of electrification in different sectors, as well as find out what sector coupling is.

# Learning objectives

- Understand the importance of sector electrification

- Understand the need for sector coupling

# Sector electrification

Electrification is becoming increasingly important in all sectors of the economy in order to achieve decarbonisation goals. As we saw earlier, electrification can be used to decarbonise the residential, transport, industrial and commercial sectors. However, some sectors are likely to be easier to electrify than other sectors. We have seen rapid progress with electric vehicles in parts of the transport sector, but sectors such as shipping and steel, which are harder to decarbonise, still have a way to go.

However, different options exist for the decarbonisation of steel, for example. This can be done by retrofitting blast furnaces and adding carbon capture and storage (CCS) or scaling up hydrogen-based direct reduced iron. However, this will require innovation and further research on the key technologies, such as CCS.

## Sector coupling

We have seen that we must decarbonise to meet global climate targets. However, this is not a straightforward process. A large reason for this is the inflexibility of intermittent renewable resources such as solar and wind technologies. One method of mitigating this variability and inflexibility is through sector coupling. Sector coupling is where we connect energy demands and processes across differing sectors and increase the efficiency and flexibility of energy use. This would allows us to use renewable energy for all sectors.

One way this could be achieved is through power to gas conversion. When there is a high supply of renewable power, excess electricity could be used to produce hydrogen and methane. This would allow us to store this energy for later use across multiple sectors. This would enable sectors that are difficult to electrify to be based on renewable energy.

It is possible to model this sector coupling process within MUSE and to understand the tipping points which would make sector coupling possible. This could be based on the price and capacity of renewable energy, as well as the price of generating hydrogen or methane compared to the incumbent technologies.

# Summary

In this lecture we have covered the importance of electrifying different sectors to reduce carbon emissions and meet some of the Sustainable Development Goals. We have also learnt of the importance of sector coupling to address hard to decarbonise sectors.