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**title: Mini-Lecture 4.1 -- Timeslicing in energy systems modelling**

**keywords:**

- Timeslices

- Energy modelling

- Energy demands

authors:

- Alexander J. M. Kell

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This mini-lecture provides an overview of timeslicing in energy systems modelling.

# Learning objectives

- Learn why we use timeslices in energy systems models

- Understand the importance of representative days

# Introduction

With energy systems models we must model how demand is met by supply. However, over the course of a year, or even over the course of 30 years we have large variations in demand and supply. For instance, the weather changes between years, seasons, and days. This all has an effect on the amount of energy that can be supplied by renewable energy sources such as solar and wind.

It is also true that this variation in demand has a large impact on the demand. In a particularly cold year, or on a particular cold day, energy demand may significantly increase as consumers use more energy for heating. The same may be true during a particularly warm period if people need energy for cooling systems. We therefore need to model this variability.

## Representative days

As you can probably imagine, matching supply and demand for every 30 minutes in a year is very costly in terms of computation time. If we must match supply and demand for every 30 minutes for 30 years (or more), we may end up with a very slow model in return for some gains in accuracy.

However, it may be the case that we do not need to model a year in such high detail. In most cases, for long-term energy systems models, we can reduce the amount of detail to significantly increase the speed of the model, without losing significant accuracy [@Kell2020].

A common approach is to model 4 days for each year. Each day corresponds to a season of the year and is split into 24 timeslices (which equates to a timeslice representing one hour). Therefore, we maintain the variability within a day, but also within seasons. We will lose some of the extremely hot or cold days, but that matters less when we're considering the long-term planning horizon.

We do not always have to take into account entire days, to reduce the complexity further. For instance, we could have 8 days, but with only 2 timeslices (day and night). This will make the model run quickly, but may lose some detail. It is up to you, as the modeller, to find a sweet spot between accuracy and speed of computation. Various papers have been published to find this sweet spot, which you can look into in your own time [@Poncelet2017].

# Summary

In this mini-lecture we discovered why long-term energy models consider timeslices and representative days. Through this approach we are able to maintain high accuracy whilst also reducing computation time.

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**title: Mini-Lecture 4.2 - Technologies by timeslice**

keywords:

- Energy technologies

- Energy modelling

- Timeslices

authors:

- Alexander J. M. Kell

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In this mini-lecture we describe how different technologies can have different characteristics by timeslices.

# Learning objectives

- Understand the different characteristics of technologies by timeslice

- Understand how to characterise technologies by timeslice

# Introduction

In the previous lecture we discovered the importance of timeslices. In this mini-lecture we will learn about how different technologies have different characteristics when it comes to timeslices, and how this can be modelled within MUSE.

# Technologies by timeslices

Different technologies and supply sectors have different characteristics when it comes to timeslices. For instance, solar photovoltaics do not produce any energy when it is dark (for instance, at night) and produce less in the winter. Wind, on the other hand, has a completely different profile and is largely dependent on geography. Therefore, it would make sense to provide a maximum output of the technologies at different times. For instance, it would be useful if the model limited solar output at night time in the form of a maximum utilization factor. Where utilization factor is the ratio of average amount of energy output to total possible output of an energy technology if it were to run 100% of time.

However, it can be very difficult to turn off some technologies, such as a nuclear power plant. Nuclear power plants are expensive to turn on and can be unsafe if constantly varying their power. Also, their marginal cost, or the cost to produce 1MWh of electricity excluding capital costs, is usually much lower than other power plants such as gas or coal plants. It, therefore, makes sense that we place a minimum service factor, or minimum output allowed, on nuclear, to ensure their output does not fall below a certain level.

Other technologies, however, such as gas power plants, can be turned on and off readily; therefore we can simply leave an average utilization factor for all the timeslices.

All of these features exist in MUSE, and during this lecture's hands-on, we will show you how to do this within MUSE.

# Summary

In this mini-lecture we have explored the importance of characterising technologies not just by their economic data, but also by their physical characteristics. We discovered that different technologies have different outputs at different times, such as solar and wind. We also found out that nuclear power, for instance, must output a certain level to remain within a safety range.

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**title: Mini-Lecture 4.3 - Different energy demands by timeslice**

keywords:

- Energy demands

- Timeslice

- Energy modelling

authors:

- Alexander J. M. Kell

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This mini-lecture will continue exploring the importance of timeslices in energy modelling; however, it will have a particular focus on energy demands, and how these can change by timeslice and over the years.

In the previous lecture we explored energy demands and timeslices. In this lecture we will have a brief recap of this, and explore how energy demand can be represented within MUSE.

# Learning objectives

- Understand how energy demand can change by timeslice

- Learn how energy demand is represented in MUSE

# Energy demand

Energy demand can come in various forms. For instance, the demand we model can be for heating or cooling in the residential sector. It is the case that these demands have different characteristics. For instance, they may have different magnitudes and different technologies which serve these demands as well as they may be able to run at different times.

Within MUSE, similarly to the supply sectors, we can model this time varying capability with timeslices. For instance, if we have 4 representative days which refer to the different seasons, we can model the high heating demand in winter and cooling demand in summer. On top of this we can vary these demands by time of day.

To do this, we must edit the demand in the `preset/Residential2050Consumption.csv` sector. An example of which is shown in Figure 4.3.1.

![](assets/Figure\_4.1.1.png){width=100%}

\*\*Figure 4.3.1:\*\* Example input for the preset sector.

In this small example we see that there is only a demand for `heat` in the residential sector. However, this demand changes per timeslice (which are listed in the leftmost column). For instance, there is low demand for heat in timeslice 0 and a high demand for heat in timeslice 4. These timeslices refer to a single representative day, and therefore timeslice 4 has the highest demand for heat as it is in the late-evening, when people generally come home from work and turn on their radiators.

In your models you can use datasets to disaggregate the demand into different types, or you can aggregate demand to include all gas or electricity utilised in the residential sector. This is largely dependent on the data available and the complexity of the model you would like.

# Summary

In this mini-lecture, we explored the importance of timeslicing for modelling demand in energy models. We also covered how this can be done within MUSE using the preset sector.

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**title: Mini-Lecture 4.4 -- Timeslicing and climate policy**

keywords:

- Climate policy

- Timeslicing

authors:

- Alexander J. M. Kell

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This mini-lecture explores the relevance of timeslicing to climate policy. We will explore how different timeslicing can affect modelling results, why it is important to consider realistic timeslicing and how these can affect policy decisions.

# Learning objectives

- Understand the impact of timeslicing on modelling outputs

- Learn how timeslicing can affect policy decisions

# Timeslicing and policy

Timeslicing is a core component of an energy systems model as we have previously discussed. If one were to use an inappropriate number of timeslices in an energy systems model, it is likely that this would have major implications on the model outputs.

Let's look at an example: if we were to model solar panels with an average capacity factor for the entire time horizon of the model this would assume that the solar panels can be used at night and could displace other technologies, such as gas turbines. However, in reality, solar panels contribute to the grid during the day and produce nothing at night. Therefore, we need some sort of flexibility in the system to ramp up after the sun sets. This needs to be modelled explicitly within MUSE, so to allow gas (or other technologies) to fill this gap in supply.

If we take this conclusion further, it is possible to see scenarios where the intermittency of solar and wind are not modelled, and therefore we observe scenarios with a majority in solar or wind. With current technologies this is not possible, and this therefore underscores the importance of timeslicing.

If we do not use accurate timeslicing then the model outputs can skew resulting policy, and so due care must be taken for sourcing data from different geographies.

# Summary

In this lecture we have looked into the implications of different timeslicing decisions made when creating an energy systems model. We learnt that if we do not get this right, the investments made could be skewed and unrealistic.