**Mini-Lecture 1.1 not checked as incomplete**

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**title: Mini-Lecture 1.2 -- Sustainable Development Goals and the global climate agenda.**

keywords:

- Sustainable development

- Sustainable Development Goals (SDGs)

- Paris Agreement

authors:

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## Short description

This mini-lecture will provide a background to sustainable development, the global agendas of the Sustainable Development Goals (SDGs) and an introduction to the role energy systems can play in achieving a range of sustainable development outcomes.

## Learning objectives

- Learn the importance of sustainable development and how it frames

the major global development agendas

- Identify the general principles of the Sustainable Development Goals

# Lecture content

## Introduction

The Sustainable Development Goals (SDGs) are a set of universal goals for every country. The SDGs are focused on ending poverty, improving quality of life and protecting the environment. These goals were agreed on in 2015, with 2030 set as the target year for their achievement. The Sustainable Development Goals aim to tackle multiple issues. Some of the goals are based around poverty, environmental protection, climate action, justice and more. The SDGs can be seen in Figure 1.2.1. These goals are designed to be thought of together, rather than in isolation. There are, therefore, many links between different goals.

![](assets/Fig\_1.2.1.png){width=100%}

\*\*Figure 1.2.1:\*\* The 17 Sustainable Development Goals

[@UnitedNations2015]

In this mini-lecture we will explore these links, global progress on the SDGs and how to factor these goals into national planning and modelling efforts.

## Sustainable Development Goal 7

Sustainable Development Goal 7 (SDG7) specifically focuses on the energy sector. Each SDG has more specific targets. The first target set in SDG7 is universal access to affordable, reliable and modern energy services. This includes electricity and access to clean cooking. Next, SDG7 calls for a substantial increase in the share of renewables in the global energy mix. This is to reduce greenhouse gas emissions and increase the sustainability of energy supplies. Another important element of improving the sustainability of the energy sector is energy efficiency. Therefore, the next SDG7 target requires a doubling of the rate of global improvement in energy efficiency. Finally, SDG7 targets improved cooperation to increase access to clean energy research and technology to promote investment, as well as expanded and improved modern energy infrastructure in developing countries. All of these targets are set in pursuit of reduced poverty and greater sustainability. Whilst SDG7 focuses explicitly on the energy sector, we will see later that all of the goals are strongly interlinked as energy is important for multiple other goals.

![](assets/Fig\_1.2.2.png){width=100%}

\*\*Figure 1.2.2:\*\* Sustainable Development Goal 7

[@UnitedNations2015]

## Progress on SDG7: Access to Electricity and Clean Cooking

According to the tracking SDG7 report, there has been progress in improving access to both electricity and clean cooking in recent years. This report states that electricity access increased from 83% in 2010 to 90% in 2018, whilst clean cooking increased from 56% to 63%. The report finds, however, that the current rates of progress are insufficient to meet the targets set by SDG7 by 2030. There are also key regions where progress has been substantially slower. For example, the population without access to electricity is concentrated in Sub-Saharan Africa -- with an overall access rate of 47%.

There are several ways in which energy modelling can be used to aid with these goals. For instance, geospatial electrification modelling can be used to assess which access solutions are the most economical for different regions or sub-regions. This also includes capacity expansion planning to assess how supply can be increased whilst minimising economic and environmental impacts.

## Progress on SDG7: Renewable Energy and Energy Efficiency

The graph below shows the share of electricity, heat and transport demands met by renewables (such as solar, wind, hydro and geothermal energy) globally. We can see that there has been some progress in increasing the share of renewables in the electricity and transport sectors as well as in the heat sector when traditional biomass use is excluded. According to the SDG7 Tracking Report, the share of renewable energy in Total Final Energy Consumption reached 17.3% in 2017, up from 16.3% in 2010.

The electricity sector has observed the most progress. This is largely due to the growth in solar photovoltaic (PV) and wind energy. However, more progress is required to achieve SDG7, with most scenarios requiring the decarbonisation of end-use sectors: for example, the electrification of transport and heat, sectors which have observed relatively slow progress.

![](assets/Fig\_1.2.4.png){width=100%}

\*\*Figure 1.2.4:\*\* Renewable energy and energy efficiency progress

[@UnitedNations2015]

For energy efficiency, global reductions in primary energy intensity have slowed in recent years. Where energy intensity is the quantity of energy required per unit output or activity, so that using less energy to produce a product reduces the intensity. This is despite progress still being greater than in the period before 2010. The SDG7 Tracking Report analysis shows that the transport sector has seen an increase in energy intensity improvement since 2010, while other sectors have seen a decrease. Differences between regions are observed, with Sub-Saharan Africa having the highest energy intensity and Latin America and the Caribbean having the lowest.

If the SDG7 target of doubling the rate of global improvement in energy efficiency by 2030 is to be met, energy efficiency measures must be prioritised in policy making and investment planning.

## Links between SDGs

The SDGs are highly interlinked, with synergies and trade-offs between these targets. It is important that these interactions are understood so that policymakers can make plans to maximise synergies and minimise trade-offs. Modelling can help in the making of informed decisions by providing a better understanding of these interactions. This is because models can be used to develop cross-sectoral scenarios and can help project the impacts of decisions.

As an example, let us explore the links between the energy system and the SDG targets. One study [@nerini2018mapping] found that at least 113 of the 169 SDG targets require changes in energy systems. Examples of this include targets in SDG13, which focus on climate change action. This requires decarbonisation of the energy system. In addition SDG1, which focuses on ending poverty, requires improved energy infrastructure to increase modern energy access. Nerini et al. (2018) highlight that we cannot think in silos and must use integrated planning approaches with a long-term perspective. Energy modelling tools are a key enabler of such approaches.

## Summary

In this mini-lecture we have explored the Sustainable Development Goals and how these apply to the energy systems and energy modelling domain. We discovered that the Sustainable Development Goals are highly interlinked, with the existence of different synergies and trade-offs between these different goals.

While much progress has been made, significant further progress is required to meet many of these goals. Modelling approaches can be utilised to aid this aim by exploring integrated planning approaches with a long-term perspective.

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**title: "Mini-Lecture 1.3 -- Energy planning"**

keywords:

- Energy planning

- Energy modelling

authors:

- Alexander J. M. Kell

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## Short description

In this mini-lecture we will explore the benefits of energy planning and why energy modelling is needed. We will discover why different countries require different solutions and how a continuous, iterative process is required to perform analyses.

## Learning objectives

- Learn the principles of energy planning

- Learn why energy modelling is needed

# Lecture content

## Introduction

Energy has become a fundamental commodity over the last 100 years. It has allowed society to make significant progress in some of the Sustainable Development Goals. For instance, it has brought millions out of poverty across the world. However, it has required the development of other development goals such as SDG13, which focuses on climate action. In addition, economic and sustainable development have grown in an inequitable manner, with certain regions prospering more than others.

This mini-lecture will introduce the concepts of energy planning in the context of the Sustainable Development Goals. In particular, we will explore how energy planning can be used to tackle some of the most difficult issues humanity faces.

## Why plan an energy system?

The traditional methods of supplying energy come with some major pitfalls. One of the most significant issues is the emissions of carbon emissions, leading to climate change. However, we require energy to sustain the current global population; no energy would lead to mass starvation and population decline.

Thus, a fundamental transformation of the energy system is required. Energy systems, however, are highly complex and capital intensive. In addition, these systems are constantly interacting with many other critical systems, such as the environment, natural resource systems and infrastructure. Thus, comprehensive, systematic analyses are required to avoid expensive stop-gap measures and long-term "lock-in" [@rodriguez2017energy].

## Importance of energy planning

An additional complication is that there is no single solution that can be applied to all energy systems. Different geographies have differing needs and resources. For instance, the UK has access to lots of offshore wind, whilst Kenya has access to lots of geothermal energy. The energy demand profiles and challenges of these two countries are also very different.

In developing countries, access to affordable energy services is important to combat energy poverty. This is especially true for rural areas, but it is becoming increasingly true for large metropolitan areas as urbanisation accelerates.

In contrast, developed countries, such as those in Europe, North America and Asia, struggle with the replacement of ageing plants and equipment. It is estimated that 40% of existing capacity stock is scheduled for retirement by 2040.

Therefore, investment decisions are required to alleviate these different issues. However, due to the long-term nature of these investments, these private sector dominated energy markets rely on clear and consistent government energy-environment policy to reduce uncertainty.

## What is energy planning?

Energy planning is the act of assessing the ability of a local, national or regional system to provide dependable energy services under constantly changing conditions. For example, variables such as the cost of materials and fuels, investment costs in technologies, demand levels and distribution requirements may all change.

Drawing on the field of operations research, electricity planning applies advanced analytical methods and tools to make better decisions when faced with complex decisions. This process, however, must be done iteratively due to the fast transformations that can take place over a very limited time period.

Energy planning models help discern the most cost-effective way of delivering energy to the final consumer. Of course, the most effective way of providing energy is different in different parts of the world. However, quantitative energy modelling offers a promising tool to make better decisions under uncertain conditions.

There is a requirement in developing countries for energy planning

due to growing populations and a lack of access to electricity. However, the main barriers to energy models in developing countries are the lack of adequate data and a shortage of skilled human resources to perform the analyses. As a result, investment decisions are often based on ill-informed policy targets and the need for ad-hoc stop-gap measures. These measures, therefore, tend to focus on cheap and quick-to-build technologies. This can result in higher environmental and operating costs. It is often the case that such actions serve the supply shortfalls of already-connected consumers, and so, increasing access to energy is rarely part of the strategy.

## Acting on energy planning

Energy planning is not an end in itself. Energy planning requires more than solely the mastering of energy modelling tools. Implementation based on the information provided by energy planning models is required. However, implementation requires a functional institutional framework to ensure the availability of funding, the timely readiness of energy infrastructure investments and a mechanism to oversee progress and quality control.

However, sound project economics can mobilise the necessary finance, which is particularly true for large infrastructure investments. Finally, the physical deployment of infrastructure needs to match schedule logistics. For example, the introduction of a large hydropower plant may exceed current electricity demand. This may make it difficult to pay dividends and service debt. However, shortages may also results when electricity demand grows faster than supply, which leads to stop-gap measures and delayed economic development. Energy planning and energy modelling can help ensure the right level of investment in energy systems takes place.

## Benefits of energy systems models

Quantitative models of complex systems can help decision makers in multiple ways. From a technical perspective, they allow analysts to compare different system configurations without incurring the upfront costs of building them. This allows for the mitigation of uncertainty.

From a practical perspective, quantitative models facilitate the design of systems in a way that accounts for local resources, demands and the constraints that are placed upon real-life electricity systems. This enables the minimisation of consumer electricity bills by allowing governmental institutions to structure tariffs optimally.

The development of scenarios can serve as an effective communication tool for non-partisan political commitment, which will help both to garner and mobilise private sector support, and to solicit agreement from society at large.

For developing countries, the impact of even minor system improvements often can have disproportionally high positive economic and environmental returns.

## Summary

In this mini-lecture we have covered the reasons that energy planning is important, how it can help with the Sustainable Development Goals and the various pitfalls that could occur without energy planning. We discovered that with sound energy planning, uncertainty can be reduced and greater stability can be provided to private sector investments. This can lead to sustainable economic growth if done in an optimal manner.

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**title: "Mini-Lecture 1.4 -- Energy systems model classifications"**

**keywords:**

- Energy systems model classifications

- Energy systems analysis

- Optimisation models

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## Short description

Energy systems models can take many different forms, as they can be designed for global long-term energy markets, short-term energy dispatch markets or local markets. In this mini-lecture we will explore the different types of models that fit into different classifications.

## Learning objectives

- Classify different types of energy systems models

- Identify the pros and cons of selected energy systems models

# Lecture content

## Introduction: Typical classifications

Energy systems models can be broken down into four different categories in a typical classification. These include the time scales in which they model, the geographies in which they model, the analytical approach and the methodology [@Pfenninger2014]. The different classifications are shown below:

- Time Scale

- Short

- Medium

- Long

- Geography

- Global

- National

- Sub-national

- Analytical Approach

- Top-down

- Bottom-up

- Methodology

- Optimisation

- Simulation

## Time

The classification of time leads to models used for different applications. For instance, a model which takes into account short-term timesteps may be able to look at weather conditions every 30 minutes or less for a single year. This means that the output, or dispatch of a particular system can be investigated for the short-term. A long-term model which models 50 years into the future, however, needs to make assumptions as it will not be able to go into the same level of detail regarding timeslices. These types of models, however, are better at considering the performance of long-term investments.

## Geography

Different models take into account different geographies. Models which take into account the global system need to make assumptions and reduce complexity in other ways. This could be, for example, by reducing the amount of energy demand data that is modelled. However, models which only consider national or even sub-national geographies are able to incorporate more detail.

## Analytical approach

Different models can take different approaches when modelling energy systems. These largely fall into the bottom-up or top-down methodologies. Bottom-up methodologies capture the technological details of the energy system, which allow for the modelling of competition between different technologies and technological progress. An example of this is the modelling of falling costs of solar photovoltaics when compared to coal power plants. Over time, competition between these technologies can be modelled to better understand the costs required to increase solar photovoltaics in the energy system. For example, if an energy planner only considers current costs, they may conclude that a coal power plant is more cost-effective. However, over a 20-year time period, if solar PV energy costs are projected to fall relative to coal power, then the most economic option may be to install solar PV in the future.

A different, top-down perspective can be taken, however. Rather than looking at the technoeconomic details of technologies, economic relationships between energy systems and the economy can be explored. This covers the interactions across sectors and regions through the calibration of historical data.

## Methodology

Within energy systems models there exist at least two broad methodologies which underpin the models. The first is optimisation. This is where an energy system is minimised or maximised by a certain metric. For example, we can find the energy system which has the lowest cost, or a system which maximises welfare of consumers.

Simulations, on the other hand, are computer programs which describe system evolutions. These represent the behaviour of the main players in the energy system. This does not necessarily lead to a minimisation or maximisation of an objective, and it can take into account different uncertainties of what may occur as opposed to what should occur.

## Summary

This mini-lecture has covered the different classifications that energy models can fit into. We have seen that a range of different models are required to cover the whole requirements of different energy systems, with models suited for different needs.