University of Basel

Exploring Possible Futures

Video Transcript

Optimization models

Let us now familiarise ourselves with the basic principles of optimisation problems. If we want to set up a model, we need only two ingredients. First, we need something that we actually can optimise, the objective of our model. Second, our model requires side constraints that we need to take into account while looking for the optimum. Let's use a little example first to get an idea how such an optimisation looks before we address the more general aspects. We have a simple energy market outlet and want to analyse which power plants ensure cost optimal supply of our demand. The objective naturally is the costs we want to minimise.

The costs are given by the generation costs of the different power plants, k, indicated by the ck, and the actual output of those plants indicated by the qk. Now, for the side constraints, you have to consider the different power plants won't be able to produce infinite energy. You will need a production constraint for the plants that ensures that the output of a plant cannot exceed its installed capacity, the q max. Finally, we need to ensure that our total output of all power plants is sufficient to cover consumer demand. And that's it. This is how a simple little optimisation model looks like. Not that complicated, is it?

In a more general sense, the two elements, objective and constraints, follow some basic structures that allow you to easily design and combine different elements into sophisticated optimisation models. First and foremost, an optimisation model will need one and only one objective that it can either minimise or maximise. In economic models, this mainly boils down to minimising costs or negative impacts like emissions, environmental damage or health effects. Or to maximise profits, social benefits, welfare, happiness or some other value indicator. They do not necessarily need to be money. But in many economic models, we rely on monetary indicators. The side constraints ensure that our model captures the underlying system aspects and defines the solution space of our model.

For optimisation problems, these can either be inequality or equality constraints. The most common formulation of inequality constraints are lower equal formulations to define some upper limits. These normally represent capacity constraints like maximum production possibilities. Greater equal constraints capture lower limits. These can define minimum output restrictions or demand and input requirements. Mathematically, upper and lower bounds can be transferred into each other. But the distinction helps to link the real world setting with our model. Finally, there are equality constraints that capture definitions. In order to keep a model readable, it often helps to define specific variables where equalities are used in newly defined variable and other equations.

Another important form of equality constraints are balances that link different time periods with each other or input and output side. Summing up, the basic concepts of optimisation models are simple and straightforward. Nevertheless, they are powerful tools that can help you model even highly complex systems. Many large scale energy system models are based on optimisation formulations. The main challenge is to translate your problem into something with a single objective.