



OSeMOSYS Parameters and their Policy Relevance

An Index for Scenario Design

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Additional related resources:

- Building on an OSeMOSYS Starter Data Kit: Exercises 1-5
 - <https://zenodo.org/record/7753832#.ZFEEvXbMJJaR>
 - <https://zenodo.org/record/7758487#.ZFEDd3bMJJaQ>
 - <https://zenodo.org/record/7757227#.ZFEFsNbMJJaQ>
 - <https://zenodo.org/record/7569483#.ZFEGCnbMJJaR>
 - <https://zenodo.org/record/7566315#.ZFEGJnbMJJaS>
 - Video Guidance: <https://www.youtube.com/playlist?list=PLhLN8V8JSUnlw5osZPtOW-U4s87Qey115>
- Niet., Taco., McWhannels, P., Cannone, C. (June 2022), OSeMOSYS Constraints: definition and applications'. *Zenodo*. <https://zenodo.org/record/6617198#.ZFAyVs7MK5c>

Aims and Objectives

This resource provides three key elements.

1. Clearly defines and explains the most important OSeMOSYS parameters used in scenario design.
2. Provides an example of how each parameter could be adjusted and its likely effects on model results.
3. Relates each parameter to a 'real world' policy situation.

List of Parameters



In order of appearance, the parameters discussed in this resource are:

- **SpecifiedAnnualDemand**
- **OperationalLife**
- **ResidualCapacity**
- **CapitalCost**
- **VariableCost**
- **FixedCost**
- **TotalAnnualMaxCapacity**
- **TotalAnnualMinCapacity**
- **TotalAnnualMaxCapacityInvestment**
- **TotalAnnualMinCapacityInvestment**
- **TotalTechnologyAnnualActivityUpperLimit**
- **TotalTechnologyAnnualActivityLowerLimit**
- **TotalTechnologyModelPeriodActivityUpperLimit**
- **TotalTechnologyModelPeriodActivityLowerLimit**
- **ReserveMargin**
- **ReserveMarginTagTechnology**
- **AnnualEmissionLimit**
- **EmissionPenalty**

These parameters are grouped by type; Demands, Performance, Technology Costs, Capacity Constraints, Activity Constrains, Reserve Margin and Emissions.

Parameters in Detail

Demands

SpecifiedAnnualDemand (Unit: MWh or GWh)

Definition: This is how much energy people need to use every year. If people need more energy, we'll need to build more power plants or find better ways to save energy.

Scenario Design: Let's assume that your model's current baseline has an annual electricity demand growth of 5% per year. However, you want to explore a scenario where the government implements energy efficiency measures and policies, resulting in a slower demand growth of 3% per year.



To do this, you would adjust the SpecifiedAnnualDemand parameter in your model to reflect the new growth rate of 3%. This will cause the model to anticipate and plan for a lower increase in electricity demand each year.

Expected Result: Higher demand would require more capacity and/or higher utilization of existing power plants, while lower demand would result in less capacity or lower utilization.

Policy Relevance: This constraint is relevant when considering policies that promote energy efficiency, demand-side management, or other strategies to reduce the growth of electricity consumption. The scenario results would show how the energy system adapts to these changes, the impact on required capacity expansion, and any additional costs or benefits associated with lower demand growth. By exploring such a scenario, policymakers can gain insights into the effectiveness of energy efficiency measures, the potential for reduced investments in new power plants, and the overall implications for energy security and sustainability.

Performance

OperationalLife (Unit: Years)

Definition: This tells you how long a power plant can work before it needs to be replaced. If it lasts a long time, it's better because the model won't need to build new ones often.

Scenario Design: Extend or reduce the operational life of one or more power plants.

Expected Result: A longer operational life would make a power plant more attractive for investment, while a shorter life would make it less attractive, shifting investments to other alternatives.

Policy Relevance: Evaluate the implications of power plant retirements, refurbishments, or life extension programs on the overall energy mix and security of supply.

ResidualCapacity (Unit: Capacity, e.g., MW)

Definition: Residual capacity refers to the existing capacity of a power plant or energy technology that was installed before the starting year of the energy model. It represents the remaining capacity of these assets that can still be used and accounted for within the model. In the context of energy modeling, residual capacity is important because it allows planners and policymakers to include the contribution of pre-existing energy infrastructure in their analyses. This helps them make more accurate assessments of the overall energy system and identify opportunities for improvement, such as replacing old power plants with more efficient ones or investing in new technologies to meet growing demand.

Scenario Design: In scenario design, residual capacity can be used to explore the impacts of different assumptions about the remaining life, performance, or retirement of existing power plants or energy technologies. For example, you could model early retirement, creating a scenario where some older power



plants are retired early, before the end of their expected lifetime, to make way for cleaner or more efficient technologies. In this case, you would reduce the residual capacity of these plants in the model to account for their early retirement. The converse is also possible to model the extension of plant life.

Expected outcome: With higher residual capacity, the existing infrastructure might be sufficient to meet a larger portion of the energy demand, which could reduce the need for new investments in capacity expansion for a certain period. If increased for a specific technology (power plant) this can lead to a higher share of that technology in the energy mix, potentially at the expense of other technologies.

Policy Relevance: Adjusting residual capacity allows decision-makers to assess the implications of different strategies related to the management and transition of existing energy infrastructure. It can help inform decisions on whether to phase out or support the continued operation of specific power plants or technologies. It may also inform decisions on investment prioritization. Policymakers can evaluate the costs and benefits of refurbishing or upgrading existing power plants versus investing in new capacity or alternative technologies.

Technology Costs

CapitalCost (Unit: USD/kW)

Definition: This is the money you need to spend to build a new power plant. If it's expensive, the model might not want to build it.

Scenario Design: Let's say you have a coal power plant in your model, and currently, its capital cost in your baseline model is \$2,000 per kW. However, for a new scenario, you want to explore the impact of a policy that increases the capital cost of the coal power plant, due to additional environmental regulations or carbon taxes, raising it to \$3,000 per kW.

To do this, you would adjust the capital cost parameter for the coal power plant to \$3,000 per kW in your model. By increasing the capital cost, the model will have to re-evaluate the cost-effectiveness of the coal power plant and may decide to invest in other, more cost-effective power plants to meet the energy demand.

Expected Result: Higher capital costs would lead to a preference for cheaper alternatives, while lower capital costs might encourage investments in the specific power plant(s) with reduced costs.

Policy Relevance: Assess the impact of subsidies or tax incentives for specific technologies or renewable energy sources, making them more competitive against conventional energy sources. For example, this constraint is relevant when considering policies that aim to discourage investment in certain power generation technologies due to environmental concerns or other reasons. The scenario results would show how the energy system adapts to these changes and how it affects the energy mix and overall costs. It can help policymakers understand the consequences of their decisions and inform them on alternative investments or strategies to meet energy goals.



VariableCost (Unit: USD/kWh)

Definition: This is the money you spend every time you use the power. Think of it like buying gas for a car. If it costs a lot to use, the model might not want to use it as much.

Scenario Design: Increase or decrease the variable cost of one or more power plants.

Expected Result: Higher variable costs would make a power plant less competitive, while lower variable costs could make it more attractive, leading to a change in the energy mix.

Policy Relevance: Analyse the effect of fuel price fluctuations or changes in fuel taxation on the energy mix, and support decision-making for long-term fuel supply contracts or energy import/export strategies.

FixedCost (Unit: USD/kW/year)

Definition: This is the money you need to spend every year to keep the power plant working, like paying for repairs or maintenance. If it's high, it might be expensive to keep using it.

Scenario Design: Increase or decrease the fixed cost of one or more power plants.

Expected Result: A higher fixed cost would make a power plant less competitive, while a lower fixed cost would make it more attractive, affecting the energy mix and possibly the capacity installed.

Policy Relevance: Examine the influence of maintenance costs, labour costs, or regulatory compliance costs on power plant competitiveness and the resulting energy mix.

Capacity Constraints

TotalAnnualMaxCapacity (Unit: Capacity, e.g., MW)

Definition: This parameter sets the maximum amount of new capacity that can be added to the energy system for a specific technology category within a single year. Adjusting this parameter affects how much capacity can be built for that technology in a given year, influencing the energy mix and the overall capacity expansion.

Scenario Design: Let's say your model's current energy mix allows for up to 5,000 MW of solar capacity to be added each year. However, you want to explore a scenario where the government sets a more ambitious annual target for solar capacity addition, raising the annual maximum capacity to 7,000 MW.

To do this, you would adjust the TotalAnnualMaxCapacity parameter for solar power plants to 7,000 MW in your model. This allows the model to invest in more solar capacity each year, potentially shifting the energy mix towards more solar generation.



Expected Result: The model will limit the capacity expansion of the specified power plants, which may affect the overall energy mix.

Policy Relevance: This constraint can be used to simulate the impact of capacity expansion limitations due to factors such as resource availability, infrastructure constraints, or policy decisions. In the example above, this constraint is relevant when considering policies that promote the rapid expansion of renewable energy sources to achieve national energy targets or reduce greenhouse gas emissions. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new targets, and any additional costs or benefits associated with the change.

TotalAnnualMinCapacity (Unit: Capacity, e.g., MW)

Definition: This parameter sets the maximum amount of new capacity that can be added to the energy system for a specific technology category within a single year. It ensures that the powerplant maintains a certain level of energy production to meet demand and policy requirements.

Scenario Design: Let's say the baseline model currently has no minimum annual capacity additions for wind power plants. In a new scenario, you want to explore the impact of a policy that mandates adding at least 1,000 MW of wind capacity each year.

To do this, you would adjust the TotalAnnualMinCapacity parameter for wind power plants to 1,000 MW in your model. This ensures that the model will invest in a minimum of 1,000 MW of wind capacity annually, changing the energy mix accordingly.

Expected Result: The model will ensure that the specified power plants expand their capacity at least by the required amount, which may affect the overall energy mix.

Policy Relevance: This constraint can be used to simulate minimum capacity expansion requirements for specific power plants or technologies, as part of energy security, diversity policies, or renewable energy targets. In the example above, the scenario results would show how the energy system adapts to these changes, the cost of meeting the minimum capacity addition targets, and the potential impact on energy security and emissions. This information can help policymakers evaluate the effectiveness of their policies and make informed decisions about future energy strategies.

TotalAnnualMaxCapacityInvestment (Unit: Currency, e.g., USD)

Definition: This is the maximum amount of investment allowed for expanding the capacity of power plants within a single year. It sets a budget constraint on how much can be spent on new infrastructure or upgrades.

Scenario Design: Let's assume your model's current energy mix allows for up to \$500 million to be invested in new solar capacity each year. However, you want to explore a scenario where the government sets a



more ambitious annual investment target for solar capacity addition, raising the annual maximum investment to \$700 million.

To do this, you would adjust the TotalAnnualMaxCapacityInvestment parameter for solar power plants to \$700 million in your model. This allows the model to allocate more funds for solar capacity expansion each year, potentially shifting the energy mix towards more solar generation.

Expected Result: The model will limit the capacity expansion of the specified power plants based on the investment constraint, which may affect the overall energy mix.

Policy Relevance: This constraint can be used to simulate the impact of budget constraints or investment limitations on the capacity expansion of specific power plants or technologies, as a result of policy decisions or financial limitations. In the example above, this constraint is relevant when considering policies that promote increased financial support for renewable energy sources to achieve national energy targets or reduce greenhouse gas emissions. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new investment targets, and any additional costs or benefits associated with the change.

TotalAnnualMinCapacityInvestment (Unit: Currency, e.g., USD)

Definition: This is the minimum amount of investment required for expanding the capacity of power plants within a single year. It ensures that the system continues to grow and evolve to meet future energy demand and policy objectives.

Scenario Design: In the baseline model, let's say we have a mix of power plants, including coal, natural gas, solar, and wind. The government wants to encourage the development of renewable energy sources to reduce greenhouse gas emissions and reach its climate targets. To achieve this, they introduce a policy that requires a minimum annual investment of \$100 million in renewable energy projects.

Let's take a solar power plant as an example. In this scenario, you would set the TotalAnnualMinCapacityInvestment parameter for solar power plants to \$100 million, which means that the model must allocate at least \$100 million to solar power capacity expansion each year.

Expected result: With this minimum investment constraint, the model will be more likely to allocate resources to build new solar power plants or expand the capacity of existing ones, even if it might not be the most cost-effective solution in the short term. As a result, the share of solar power in the energy mix will increase compared to the baseline scenario. This transition to renewable energy sources will contribute to the country's climate goals and the long-term sustainability of the energy system.

Policy Relevance: By introducing a minimum investment requirement for renewable energy projects, policymakers can promote the growth of the renewable energy sector, reduce dependency on fossil fuels, and create new job opportunities in the renewable energy industry. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new minimum investment targets, and any additional costs or benefits associated with the change. This policy can also encourage



innovation and investment in clean energy technologies, ultimately contributing to the nation's energy security and climate goals.

Activity Constraints

TotalTechnologyAnnualActivityUpperLimit (Unit: Energy output per year, e.g., GWh)

Definition: This is the maximum amount of energy that a specific power plant can produce annually. It puts a cap on the energy output to account for technical or operational constraints.

Scenario Design: Let's say you have a solar power plant in your model, and currently, there is no limit to how much energy it can produce annually in your baseline model. However, for a new scenario, you want to explore the impact of limiting the solar power plant's annual energy production to a specific value, such as 1,000 GWh.

To do this, you would set the TotalTechnologyAnnualActivityUpperLimit for the solar power plant at 1,000 GWh. By imposing this constraint, the model will need to balance the energy system by possibly increasing the production of other power plants or investing in new capacities to meet the demand.

Expected Result: The model may reallocate generation among power plants or bring new power plants into the mix to comply with the constraint. This could lead to a different energy mix.

Policy Relevance: This constraint could be relevant if the government wants to diversify the energy mix and avoid over-reliance on a particular power source. It could also reflect a real-world limitation, such as land availability or transmission constraints, that might limit the expansion of solar power. The scenario results would provide insights into alternative investments and the impact on the overall energy system.

TotalTechnologyAnnualActivityLowerLimit (Unit: Energy output per year, e.g., GWh)

Definition: This is the minimum amount of energy that a specific power plant must produce annually. It ensures that certain technologies are utilized to a specific extent, which might be necessary for energy security or meeting policy goals.

Scenario Design: Let's say your model's current energy mix allows coal power plants to operate at any level of electricity generation. However, you want to explore a scenario where the government sets a minimum annual electricity generation target for coal power plants, ensuring that they generate at least 10,000 GWh of electricity each year.

To do this, you would adjust the TotalTechnologyAnnualActivityLowerLimit parameter for coal power plants to 10,000 GWh in your model. This ensures that the model keeps coal power plants operating at or above the specified minimum level of electricity generation each year.



Expected Result: The model will ensure that the specified power plants generate at least the required minimum energy output, which may affect the overall energy mix and the operation of other power plants.

Policy Relevance: This constraint can be used to simulate minimum generation requirements or quotas for specific power plants or technologies, as part of energy security or diversity policies. The above example, is considering policies that maintain a minimum level of operation for specific energy sources, ensuring their continued contribution to the energy mix. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new minimum generation targets, and any additional costs or benefits associated with the change.

TotalTechnologyModelPeriodActivityUpperLimit (Unit: Energy output over the entire model period, e.g., GWh)

Definition: This sets a limit on the total energy output of a specific power plant over the entire model period. It takes into consideration long-term constraints, such as resource availability or emissions targets.

Scenario Design: In your model's current energy mix, there is no limit on the total amount of electricity that can be generated by natural gas power plants throughout the entire model period. However, you want to explore a scenario where the government sets a cumulative limit on natural gas electricity generation, limiting it to 200,000 GWh throughout the model period.

To do this, you would adjust the TotalTechnologyModelPeriodActivityUpperLimit parameter for natural gas power plants to 200,000 GWh in your model. This ensures that the model keeps the total electricity generation from natural gas power plants within the specified limit throughout the entire model period.

Expected Result: The model may reallocate generation among power plants or bring new power plants into the mix to comply with the constraint, affecting the overall energy mix across the model period.

Policy Relevance: This constraint can be used to simulate long-term limitations on specific power plants or technologies due to resource depletion, environmental concerns, or regulatory reasons. The above example is considering policies that control the overall contribution of specific energy sources to achieve long-term energy goals or emissions targets. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new cumulative generation targets, and any additional costs or benefits associated with the change.

TotalTechnologyModelPeriodActivityLowerLimit (Unit: Energy output over the entire model period, e.g., GWh)

Definition: This is the minimum amount of energy that a specific power plant must produce over the entire model period. It guarantees a certain level of utilization for technologies that are crucial to long-term planning or policy commitments.



Scenario Design: Let's assume your model's current energy mix has no minimum requirement for the total amount of electricity generated by hydropower plants throughout the entire model period. However, you want to explore a scenario where the government sets a cumulative minimum target for hydropower electricity generation, ensuring that it generates at least 50,000 GWh throughout the model period.

To do this, you would adjust the `TotalTechnologyModelPeriodActivityLowerLimit` parameter for hydropower plants to 50,000 GWh in your model. This ensures that the model keeps the total electricity generation from hydropower plants at or above the specified minimum level throughout the entire model period.

Expected Result: The model will ensure that the specified power plants generate at least the required minimum energy output, which may affect the overall energy mix and the operation of other power plants across the model period.

Policy Relevance: This constraint can be used to simulate long-term minimum generation requirements or quotas for specific power plants or technologies, as part of energy security or diversity policies. The above example is considering policies that maintain a minimum level of contribution from specific energy sources over the long term to support their growth and development. The scenario results would show how the energy system adapts to these changes, the feasibility of meeting the new cumulative minimum generation targets, and any additional costs or benefits associated with the change.

Reserve Margin

ReserveMargin (Unit: Percentage: 1.15 = 115 %)

Definition: Reserve Margin is like having extra seats in a movie theatre. It's the extra energy a power plant can produce if needed, just in case there's a sudden increase in people wanting to watch the movie (energy demand) or another theatre (power plant) has a problem and can't show the movie. By having this extra energy on hand, we can make sure everyone gets to watch the movie without any interruptions (keep the power supply stable and reliable). In other words, it represents the percentage of extra capacity that the system as a whole must have to maintain reliability and stability. Usually, 15% in the Sand starter data kits.

Scenario Design: Reserve Margin refers to the unused capacity of a power plant that can be utilized in case of unexpected surges in demand or failures of other power plants. So let's say the baseline model assumes a fixed reserve margin for all power plants. However, the government wants to increase the resilience of the energy system by having more backup capacity available in the case of power shortages.

To demonstrate this in a scenario, let's take a natural gas power plant as an example. In the baseline model, the residual capacity of the natural gas plant might be set at 20% of its total capacity. In the new scenario, you could increase the residual capacity requirement to 30% for the natural gas power plant, ensuring that more backup capacity is available in case of emergencies or sudden increases in energy demand.



Expected result: With a higher reserve margin requirement, the model will allocate more resources to maintaining and managing the additional backup capacity of the natural gas power plant. This might lead to a slight increase in the total capacity of the plant, as well as higher operating costs due to the need to keep the additional capacity ready for use. However, the energy system will be more resilient, with a greater ability to handle unexpected situations and ensure a reliable supply of power.

Policy Relevance: Adjusting the Reserve Margin parameter allows policymakers to explore the implications of different reserve requirements on the energy system, such as the cost of maintaining system reliability, the potential for blackouts, and the role of various technologies in providing backup capacity. In the scenario outlined above, the results would show how the energy system adapts to the higher reserve margin requirement, the feasibility of meeting the new target, and any additional costs or benefits associated with the change.

ReserveMarginTagTechnology (Unit: yes or no i.e. 1 or 0)

Definition: This tells us if a power plant or energy machine can be used as a backup when other machines can't make enough energy. If we have enough backups, we won't run out of power when we need it. Typically, renewable energies like wind are intermittent so cannot be used as backup i.e., 'reserve'.

Emissions

Annual Emission Limit (Unit: ton/year)

Definition: This is like a rule that says power plants or energy machines can only make a certain amount of pollution each year. If they make more pollution than allowed, they might have to pay a fine or find cleaner ways to make energy.

Scenario Design: Let's say your model's current energy mix does not include any limit on the greenhouse gas emissions from power plants. However, you want to explore a scenario where the government sets an annual emission limit of 100,000 tonnes of CO₂ for the whole energy system.

To do this, you would adjust the Annual Emission Limit parameter for CO₂ in your model to 100,000 tonnes per year. This sets a cap on the total amount of emissions allowed, encouraging the use of cleaner power plants and technologies to stay within the limit.

Expected Result: Introducing an annual emission limit would make polluting power plants less competitive, pushing the energy mix towards cleaner power plants and technologies to stay below the limit.

Policy Relevance: Assess the effectiveness of emission limit policies, such as national or sector-specific emission caps, in reducing overall emissions and encouraging a shift to cleaner energy sources. In the scenario outlined above, the results would show how the energy system adapts to the new emission limit,



the potential reduction in greenhouse gas emissions, and any additional costs or benefits associated with the change.

EmissionPenalty (Unit: USD/ton)

Definition: This is like a fine people have to pay if their power plant or energy machine makes too much pollution. If the fine is high, people might try to find cleaner ways to make energy.

Scenario Design: Let's say your model's current energy mix does not include any penalty for greenhouse gas emissions from power plants. However, you want to explore a scenario where the government introduces a carbon pricing policy, imposing a penalty of \$50 per tonne of CO2 emitted by power plants.

To do this, you would adjust the emission penalty parameter for CO2 in your model to \$50 per tonne. This introduces an additional cost associated with emissions, making it more expensive to operate power plants with high emission rates and incentivizing investments in cleaner technologies.

Expected Result: A higher emission penalty would make polluting power plants less competitive, encouraging the use of cleaner power plants in the energy mix.

Policy Relevance: Evaluate the effectiveness of carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, in driving investments towards cleaner energy sources and reducing overall emissions. In the scenario outlined above, the results would show how the energy system adapts to the new emission penalty, the potential reduction in greenhouse gas emissions, and any additional costs or benefits associated with the change.