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Homework 2

EW-Mod
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Task 1 Commercial Exchange

1. In the lecture we discussed three types of pricing mechanisms in electricity markets. Name all three, state an example where markets are designed with this pricing mechanism and name at least two advantages and disadvantages for each:

Uniform Pricing

Example: Germany

Advantages:

- Increase of competition, since location in the zone is not important and all electricity producer compete against each other
- Tecchnologies with low marginal cost, such as renewable energies, will dispatch first, hence increasing the overall share of renewables at the electricity mix

Disadvantages:

- High cost for redispatch since transmission constraints are neglected and market assume a "copper plate".
- The higher cost for congestion management can cause higher cost for grid usage (Netzentgelte) especially in those areas, where large amounts of renewable energy is produced to the loweset price.

Zonal Pricing

Example: Norway

Advantages:

- Zones with high electricity generation offer lower prices, resulting in locational incentives for high electricity consumer. High consumption is getting geographically closer to production.
- Zones can split the market at points of large redispatch volumes in the grid, which makes it easier to manage congestion, since specific exchange volumes can be established.

Disadvantages:

- Reduction of market participants, since they split into two electricity market (in comparison to one zone). This results in a reduction of competition.
- Price zones may decrease incentives for further grid extensions, which are necessary to cope with changes in electricity production, i.e the decentralised character of renewable energies.

Locational Marginal Pricing (Nodal Pricing)

Example: PJM

Advantages:

- Good representation of both financial and physical parameter of electricity markets, since grid constraints are part of actual prices in the nodes.
- Nodes with high electricity generation, can offer lower prices, yet high consumption has incentives to be in spatial proximity.

Disadvantages:

- Possible market power at some nodes by a few market participants.
- Grids after extensions, may connect nodes in such an efficient way, that nodal prices are equal anyway, in retrospect that also means, that prices for consumer especially depend on available grid capacities attached to their node.

2. Zonal pricing with implicit auctioning is used across Europe. Describe what this means in terms of balancing load and generation, exchange between market areas and the concept of an Energy-only-market

In Europe electricity markets are divided in several zones. Each zone provides one market. In general, these zones are similar to national borders. Zones are connected to each other by interconnectors which enable cross border trading. The amount of trading capacities between zones are specified by system operators. In each zone, an implicit auctioning mechanism is chosen. This means that every electricity producer is able to offer his/her electricity volume to the whole zone, hereby neglecting physical constraint inside the zonal market. As a result of market clearing in a uniform pricing auction, the producer is paid only for the amount of produced energy with the market clearing price, without any additional cost for using capacity in the grid to transport the generated electricity. This is also known as energy-only market (EOM) since prices do not cover any grid related costs such as capacities. However, transmission constraints (like capacity) do play a role for physical delivery, resulting in cost for the balancing between market results and grid constraints i.e. spatial and temporarily balancing of load and demand. These ancillary services are provided by system operators. Expenditures for balancing are divided between all grid users.

Task 2 Data preprocessing

1. In contrast to our previous examples, in the provided template all data are loaded from files instead of hard coding them in the script. Why is it usefull to separate the input data from the script?

It is useful to exclude the input data from the source code because then one can easily adapt the source code to another example with different timeseries by simply changing the input data. In addition, the code becomes more clean since there are only read in statements instead of large declarations of input vectors and matrices.

2. What do the functions ‘dictzip‘ and ‘coldict‘ do? Why is it efficient to define a custom function here?

The function "dictzip" creates a dictionary using a dataframe and a pair value as arguments. With this function it is easy to create a dictionary which can be then used to look up certain values like the marginal costs of power plants. Without the function one would always need to index the corresponding input dataframe. Thus the code would be more complicated.
As all timeseries include values for all given zones it would be handy to create a dictionary to look up for example the load timeseries for a specific zone. This is done by using the function "coldict" which takes a dataframe as an argument.

3. Why does the net transfer capacity between zones need to be limited in both directions?

A limited net capacity splits the market into zones. Otherwise we would have one market with one merit order curve since all electricity could be distributed through the lines. Although there is only one line between the zones it is still important to set the net capacity in both directions since the model takes the imports and exports of a node into account.

4. Based on the given program it is possible to change the topology solely by changing the data. List the steps necessary to extend to problem to three zones and state what additional information/data is needed.

In order to implement a case with three zones one would just need to extend all input data by adding all relevant information for zone 3 which are:

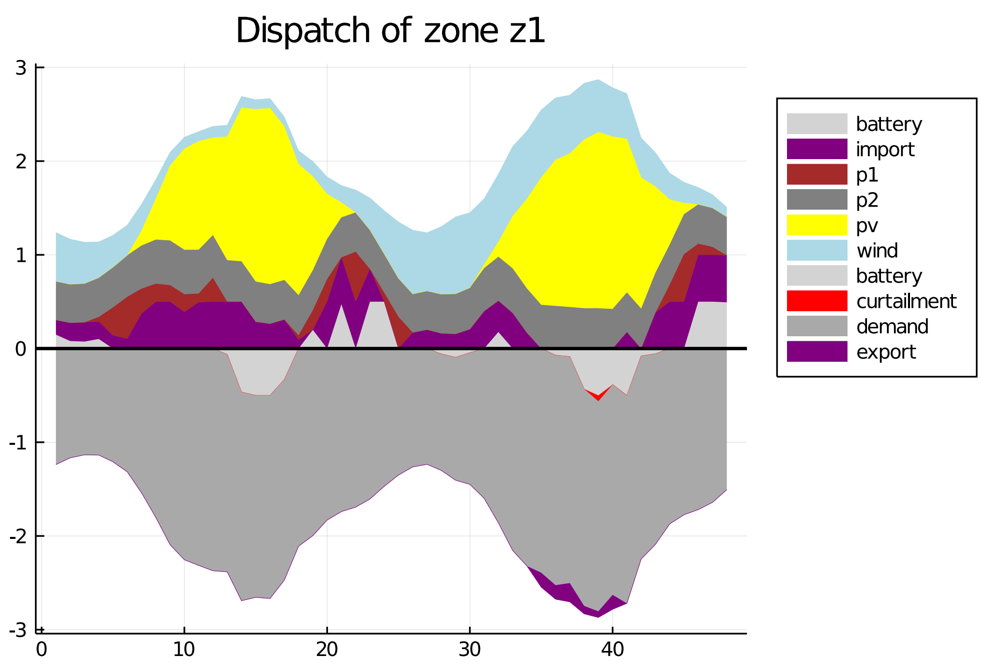
1. If there is a new technology one would need to add this technology to the input data set technologies.
2. In the input data set zones one would need to declare which technologies are available in zone 3 along with the information about the generation or the storage capacity.
3. Adding a third zone means that there are two more lines connecting zone 3 with zone 1 and 2. Therefore these lines need to be added to the input data set lines along with the information about the net capacity.
4. As a last step, one would have to determine the timeseries for heat, load, pv and wind in zone 3 and add these information to the corresponding input data sets.

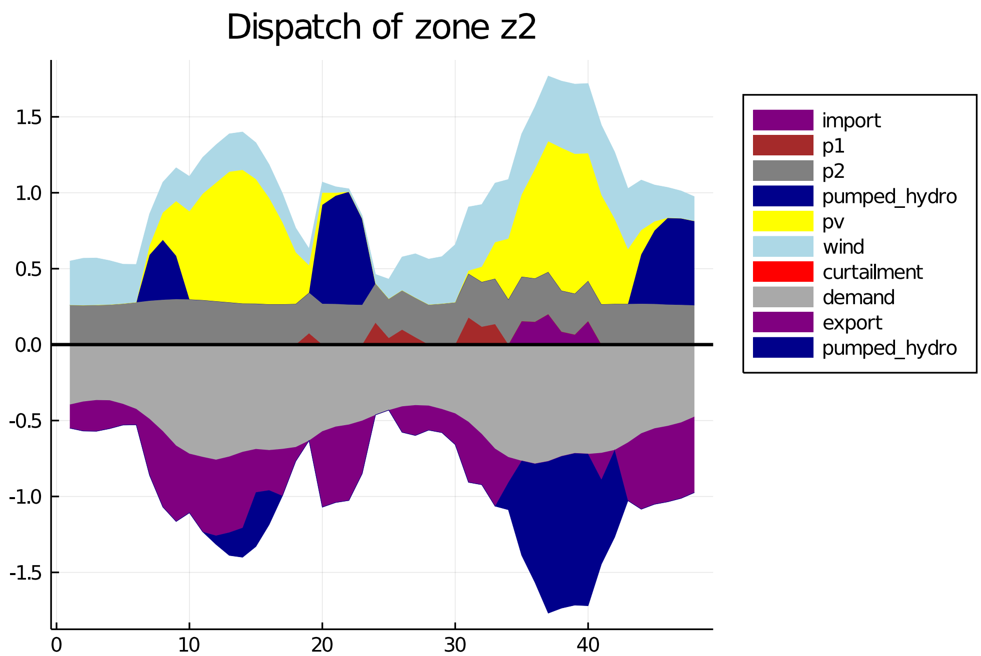
Task 3

For no. 1, 2, 3 see code below

```
...

### Building dataframe for import and export
result_F = value.(FLOW)
# import
importFlow = DataFrame(
        (zone=z,
        technology="import",
        hour=t,
        value = sum(result_F[zz,z,t] for zz in Z))
    for z in Z, t in T)

# export
exportFlow = DataFrame(
        (zone=z,
        technology="export",
        hour=t,
        value = sum(result_F[z,zz,t] for zz in Z))
    for z in Z, t in T)

# vcat importFlow and exportFlow to generation and demand
```

```
result_generation = vcat(result_generation, importFlow)
result_demand = vcat(result_demand, exportFlow)

### Plotting
colordict = Dict("pv" => :yellow,
    "wind" => :lightblue,
    "pumped_hydro" => :darkblue,
    "battery" => :lightgrey,
    "p1" => :brown,
    "p2" => :grey,
    "demand" => :darkgrey,
    "curtailment" => :red,
    "import" => :purple,
    "export" => :purple)
...
```





4. Describe the resulting exchange between the two zones. What is the direction of the commercial exchange, what is the resulting average load of the interconnector and how often is the interconnector fully utilized.

In general an export of excess electricity from Zone 2 to Zone 1 can be observed most of the time except for hours 35 to 40. This is due to the lower load in Zone 2 and the relatively high share of renewable energy sources that generate at lower marginal costs. The average load of the interconnector is 0.283 MW - calculated with the dataframe. The interconnector is used at maximum capacity in 13 hours or 27 % of the time.