Aalto-yliopisto
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The effect of CO2 tax level on the total costs of energy production and renewable energy production share

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Background

- The increase of CO2-emission awareness has lead to a situation where traditional coal-based energy sources are decommissioned and replaced with renewable energy sources.
- Traditional energy production methods generally supply constant power with low variance and dependence on external factors.
- Renewable energy sources, in general, generate less stable and lower quality power that can be highly dependent on extrernal factors and therefore meeting the demand is not as straightforward.

Challenges of renewable energy sources

- Meeting the demand with reliable supply
  - Especially photovoltaics generate power when it's generally less needed
  - High variance of wind results in extremely unstable wind power generation
  - Hydropower can cause environmental issues when used as a storage
  - Storage systems are evolving
- Location of availability
  - Remote locations of production cause more demand for transfer
- Investment issues
  - Usually high investment costs and rapidly developing technology

The chosen topic

- We'll be focusing on meeting the demand and supplying constant power
- This will likely require finding balance between storage-featured sources, like hydro, and highly altering, like PV.

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Methodology

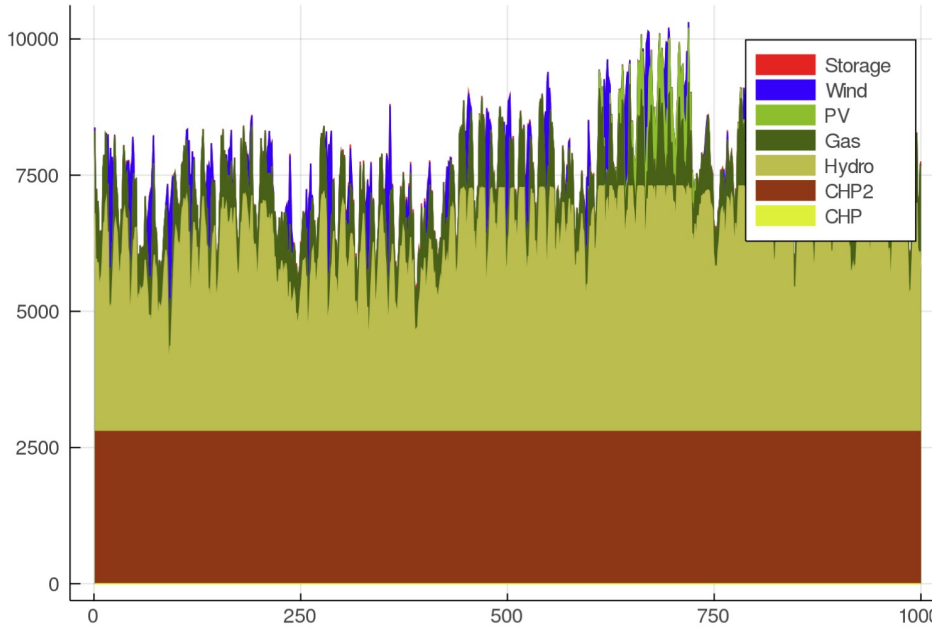
- Generation capacity expansion models are used for determining the costs of generation expansion.
- We'll be building a model like this with some key features
  - Hourly modeling for sufficiently long period, preferably years.
  - Multi-nodal system including multiple countries that buy and sell electricity within each others.
  - CO2 tax level analysis for determining the effect of rising tax to total share of renewables and overall cost.
  - Storage technologies
- The model will be implemented in Julia

The very basic idea of the model and its initial outcome with dummy data

$$\min_x \sum_t \sum_h Vc_t \cdot p_{t,h} + Fc_t \cdot \bar{p_{t,h}}$$
$$+ \sum_t sc \cdot (\bar{d_t} - d_t)$$
$$+ \sum_t \frac{i_t}{y_t} \cdot \bar{p_t}$$
$$+ \sum_s \frac{i_s}{y_s} \cdot \bar{p_s}$$
$$+ \sum_{C^t} \sum_t \frac{p_{t,h} \cdot \tau}{\xi_t}$$

Conditions

$$0 \leq d_h \qquad ,\forall h \in H$$
$$0 \leq \bar{p_t} \leq \hat{p_t} \qquad ,\forall t \in T$$
$$0 \leq \bar{b_s} \leq \hat{b_s} \qquad ,\forall s \in S$$
$$0 \leq \bar{b^+_{s,h}} \leq \hat{Bc^+_s} \qquad ,\forall s \in S, h \in H$$
$$0 \leq \bar{b^-_{s,h}} \leq \hat{Bc^-_s} \qquad ,\forall s \in S, h \in H$$
$$\sum_t p_{t,h} + \sum_s (\bar{b^-_s} - \bar{b^+_s}) = d_h \qquad ,\forall h \in H$$
$$0 \leq p_{t,h} \leq \rho_{t,h} \cdot (\bar{p^0_t} + \bar{p_t}) \qquad ,\forall t \in T, h \in H$$
$$p_{t,h} - p_{t,h-1} \geq -\bar{r^-_t} \cdot (\bar{p^0_t} + \bar{p_t}) \qquad ,\forall t \in T, h \in H \backslash h_1$$
$$p_{t,h} - p_{t,h-1} \leq r^+_t \cdot (\bar{p^0_t} + \bar{p_t}) \qquad ,\forall t \in T, h \in H \backslash h_1$$



These are purely for illustration and will definitely be specified in more detail

Schedule

- Implementing the algorithm: *Mostly done by end the of may*
- Presentation of the topic: Today, 12.6.2020
- Gathering all required data: By the end of June 2020
- Writing the report: By the end on July 2020
- Final presentation: Mid-July or Mid-August
- Thesis ready: by the end August

Literature and references

- Kan et al.: The cost of a future low-carbon electricity system without nuclear power – the case of Sweden (2020)
- Pineda et al.: Chronological Time-Period Clustering for Optimal Capacity Expansion Planning With Storage (2018)
- Yang Gu: Long-term power system capacity expansion planning considering reliability and economic criteria (2011)
- He et al.: Cap-and-trade vs. carbon taxes: A quantative comparison from a generation expansion planning perspective (2011)