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**UESMO**
**Urban Energy System Modeling using OSeMOSYS**

**Model Specificities.**

OSeMOSYS is an open source energy system optimization model developed by KTH-Desa. OSeMOSYS is designed to find the most cost effective way to meet an energy demand through a system submitted to constraints. Information about the model is available at: http://www.osemosys.org/

Is this project, OSeMOSYS's code has been modified in order to design of a spacial optimization model for urban energy planning. A city is divided into different blocks like suburbs, industrial areas, downtown, residential areas, etc, that have distinct building composition and energetic consumption profiles. Each type of urban form can provide services such housing, employment, industrial activity, agricultural activity. In our model, we consider urban forms as technologies that consume energy and emit $CO_2$ to provide housing related services.

The objective of this model is to find the optimal urban land configuration to meet energetic related demand regarding a set of constraints. This model focus on energy consumed in buildings and in the industrial and agricultural sector. This document outlines the specificities of our model and the modifications made to the code.

# Model specificities

FUELS: There is 2 different type of fuels:

- Energy: electricity, Petroleum, Natural gas, BioFuel, Else (in energy units)
- Demand fuels: for now the only demand we consider is Housing (in habitant)

TECHNOLOGY: OSeMOSYS optimize energetic systems that are composed of different types of machine that transform energy from primaries to consumable form. In my model, there are two types of technologies;

- Urban form technologies: blocks of $1km^2$ of built environment that consume energy to provide a housing service. This represents building energetic consumption.
- Importation technologies: produce energy in order to provide energy to the rest of the model.

EMISSIONS: $CO_2$ are accounted from import technologies.

For import technologies, there are only outputs that are in energy units and variables costs represent energy prices.

## Modifications to the code:

**Salvage value**, **Storage** and **Reserve Margin** are not relevant to our approach. All related parameters, variables and constraints have been removed.

The two following tables list the added parameters and variables.

| New Parameters | Description |
|---|---|
| CapacityConversionOpportunity[r,t,tt,y] | To specify if a technology conversion is possible. =1 if the conversion of t into tt is possible. =0 otherwise. |
| ConversionRate[r,y] | Share of the maximum capacity available for conversion in each region and year. |
| ConversionCost [r,t,tt,y] | Cost for the conversion of one unit of t into tt. |
| TotalSpaceByRegion[r,y] | Total available space by region. |
| TagTechnologyWithSpace[r,t] | To specify which technology are convertible. =1 for urban form technologies. -0 for import technologies. |
| ActivityToCapacityShare[t] | Minimal share that activity can represent compared to capacity. |

| New Variables | Description |
|---|---|
| CapacityConversionGain[r,t,tt,y] | Gained capacity by t from tt. |
| CapacityConversionLoss[r,t,tt,y] | Lost capacity by t from tt. |
| TotalCapacityConversionGain[r,t,y] | Total gained capacity by t from conversion at a given year y. |
| TotalCapacityConversionLoss[r,t,y] | Total lost capacity by t from conversion at a given year y. |
| AccumulatedCapacityConversionGain[r,t,y] | Accumulated gained Capacity by t in conversion at year y. |
| AccumulatedCapacityConversionLoss[r,t,y] | Accumulated lost Capacity by t in conversion at year y. |

### Activity and capacity:

In this model, the capacity of each technology is equal to the surface (in $km^2$) that it occupies. And activity is equal to the surface (in $km^2$) that is used to meet a housing demand. So, for a given technology if you have Capacity =100, Activity=75, and OutputActivityRatio = 200, it means that you have 100 km 2 of this technology, that the 75% of it that is actually used can host 150 (75% of 200) peoples. Capacity and activity are in the same units; $km^2$. To keep this model as realistic as possible, we want to avoid a situation where the activity of a technology would be too low compared to the capacity. Thereof, we have to add a parameter in order to specify the allowed ration of Activity over capacity:

$$\forall_{r,l,t,y} : \mathrm{RateOfTotalActivity}_{r,t,l,y} \geq \mathrm{TotalCapacityAnnual}_{r,t,y} * \mathrm{CapacityFactor}_{r,t,l,y} * \mathrm{CapacityToActivityUnit}_{r,t} * \mathrm{ActivityToCapacityShare}_{t}$$

s.t. CAa4b_Constraint_Capacity{r in REGION, l in TIMESLICE, t in TECHNOLOGY, y in YEAR}: RateOfTotalActivity[r,t,l,y] >= TotalCapacityAnnual[r,t,y] * CapacityFactor[r,t,l,y]*CapacityToActivityUnit[r,t]*ActivityToCapacityFactor[t];

**Space**:

There is a limited amount of space in each region of the model. The sum of Built technologies capacities must not be higher than the space in the region. Therefore we have to add the following constraint to the model.

$$\forall_{r,y} : \sum_{t} \mathrm{TotalCapacityAnnual}_{r,t,y} * \mathrm{TagTechnologyWithSpace}_{r,t} \leq \mathrm{TotalSpaceByRegion}_{r,y}$$

Where $\mathrm{TagTechnologyWithSpace}_{r,t}$ is a parameter that identifies technologies that is to take into consideration in the space accounting (is equal to 1 for every urban form technology, =0 for import technologies).

**Capacity conversion**:

Because of residual capacities, all the available space if fully occupied from the 1st to the last modeling year. Therefore it’s impossible to build new capacity. However, it is made possible to the model to convert capacity from a certain technology to another technology. First, when an amount of technology is converted from t to tt the gained capacity of tt must be equal to the lost capacity of t.

$$\forall_{r,t,tt,y} : \mathrm{CapacityLoss}_{r,t,tt,y} = \mathrm{CapacityGain}_{r,tt,t,y}$$

Different conversions could occur during the same year for a given technologies and are summed as follow:

$$\forall_{r,t,y} : \sum_{tt} \mathrm{CapacityConversionGain}_{r,t,tt,y} * \mathrm{CapacityConversionOpportunity}_{r,tt,t,y} = \mathrm{TotalCapacityConversionGain}_{r,t,y}$$

$$\forall_{r,t,y} : \sum_{tt} \mathrm{CapacityConversionLoss}_{r,t,tt,y} * \mathrm{CapacityConversionOpportunity}_{r,t,tt,y} = \mathrm{TotalCapacityConversionLoss}_{r,t,y}$$

$\mathrm{CapacityConversionOpportunity}_{r,t,tt,y}$ =1 when the conversion from t to tt is allowed (t loses capacity and tt win capacity) and 0 otherwise.

When a certain amount of technology capacity units are converted at year t it should be accounted for all following years. Therefore technology conversion has to be accumulated:

$$\forall_{r,t,y} : \sum_{yy \le y} TotalCapacityConversionGain_{r,t,y} = AccumulatedCapacityConversionGain_{r,t,y}$$

$$\forall_{r,t,y} : \sum_{yy \le y} TotalCapacityConversionLoss_{r,t,y} = AccumulatedCapacityConversionLoss_{r,t,y}$$

For each region and year only a defined share of the total capacity is available for conversion:

$$\forall_{r,t,y} : TotalCapacityConversionLoss_{r,t,y} = TotalCapacityAnnual_{r,t,y\text{-}1} * ConversionRate_{r,t}$$

Technology conversions also have to be taken into account in the capacity adequacy constraints. So the following constraint (s.t. CAa2_TotalAnnualCapacity):

$$\forall_{r,t,y} : AccumulatedNewCapacity_{r,t,y} + ResidualCapacity_{r,t,y} = TotalCapacityAnnual_{r,t,y}$$

Has to be replaced by this new one:

$$\forall_{r,t,y} : AccumulatedNewCapacity_{r,t,y} + ResidualCapacity_{r,t,y} + AccumulatedCapacityConversionGain_{r,t,y}$$
$$- AccumulatedCapacityConversionLoss_{r,t,y} = TotalCapacityAnnual_{r,t,y}$$

Where Capacity conversion losses and capacity conversion gains would be taken into account.

**Capacity conversion pricing**:

A cost is associated with the conversion of a technology from t to tt and is accounted as follow:

$$\forall_{r,t,y} : \sum_{tt} (CapacityConversionGain_{r,t,tt,y} * TransferCost_{r,tt,t,y} * CapacityConversionOpportunity_{r,tt,t,y})$$
$$= ConversionCostByTechnology_{r,t,y}$$

Where ConversionCost is the price of converting a technology from tt to t. Note that conversion prices are accounted only for ConversionGain. This price has to be added the calcul of Total Discounted Cost By Technology. So the following constraints (s.t.TDC1_TotalDiscountedCostByTechnology) :

$$\forall_{r,t,y} : DiscountedOperatingCost_{r,t,y} + DiscountedCapitalInvestment_{r,t,y}$$
$$+ DiscountedTechnologyEmissionPenalty_{r,t,y} + DiscountedSalvageValue_{r,t,y}$$
$$= TotalDiscountedCostByTechnology_{r,t,y}$$

is replaced by

$$\forall_{r,t,y}: \text{DiscountedOperatingCost}_{r,t,y} + \text{DiscountedCapitalInvestment}_{r,t,y}$$
$$+ \text{DiscountedTechnologyEmissionPenalty}_{r,t,y} + \text{ConversionCostByTechnology}_{r,t,y}$$
$$= \text{TotalDiscountedCostByTechnology}_{r,t,y}$$

Note that DiscountedSalvageValue has been removed. And because there is no storage, the following constraint (s.t. TDC2_TotalDiscountedCost):

$$\forall_{r,y}: \sum_{t} \text{TotalDiscountedCostByTechnology}_{r,t,y} + \sum_{s} \text{TotalDiscountedStorageCost}_{r,s,y} = \text{TotalDiscountedCost}_{r,y}$$

Is replaced by this one:

$$\forall_{r,y}: \sum_{t} \text{TotalDiscountedCostByTechnology}_{r,t,y} = \text{TotalDiscountedCost}_{r,y}$$