Regionalization in Temoa

The current formulation of Temoa does not have a separate index to distinguish different regions. A method was developed in this project to effectively have regional models. The idea is to manipulate the notations used for commodities and technologies of the same region in order to achieve appropriate interregional and intraregional energy flows.

In order to show how the method works, a simple test case was developed. See Figure 1. It consists of 3 regions: R1, R2, R3 and two time slices: day and night. Each region has its own domestic supply and demand of electricity during day and night, see Table 1.

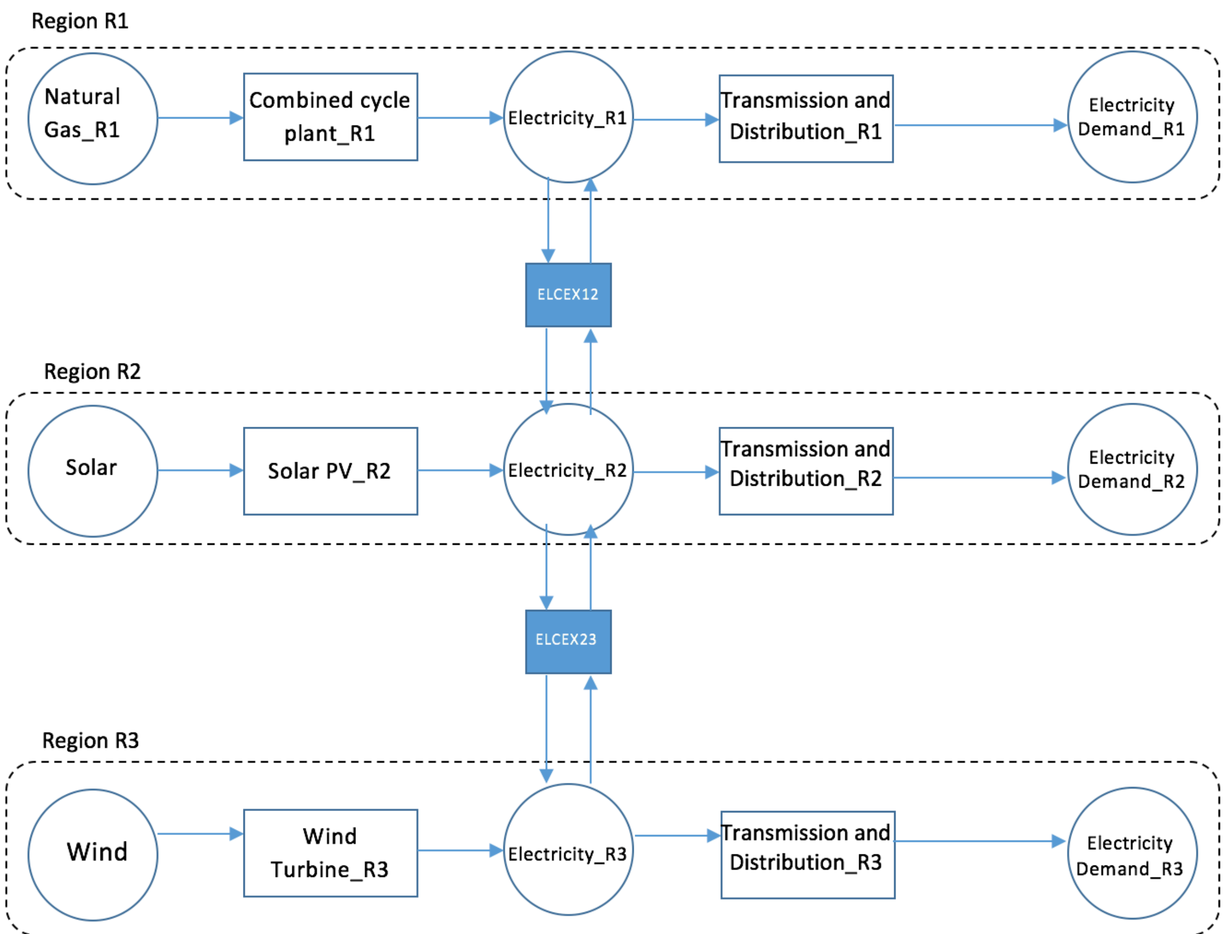

Figure 1| Regional test case consisting of 3 regions. In addition to intraregional energy flows, electricity can also be transferred between regions through technologies ELCEX12 and ELCEX23 if necessary and/or economic. Unlike single region modeling in Temoa, here commodities and technologies, even if they are of the same type, have different notations. This way, in one single database, different regions can be modeled in isolation or with connection.

Table 1| Techno-economic characteristics of the energy system show in Figure 1

Regions	Regional generation costs (cents/kWh)	Regional efficiencies		generation capacities (GW)		Electricity demand (GWyr)	
		Power Plants	T&D lines	day	night	day	night
R1	20	55%	95%	222	222	50	50
R2	0	-	96%	200	0	50	50
R3	0	-	94%	0	200	50	50

Two other technologies in Figure 1 are ELCEX12 and ELCEX23. These two technologies serve as the transmission lines from region 1 to 2, and 2 to 3 respectively. Electricity can flow either way through ELCEX12 and ELCEX23. They both have an assumed efficiency equal to 90%. The reason for assuming an efficiency for ELCEX12 and ELCEX23 less than those of intraregional T&D lines, is to give the model higher priority to satisfy the domestic demands, and lower priority to transfer electricity to other regions.

During the day (night), there is no internal source of generation in region R3 (R2). Therefore, it's essential for the combined cycle plant in region R1 to generate enough electricity to first satisfy domestic demand and then transfer the additional electricity to the neighboring regions.
The "Efficiency" table for this model in Temoa is given in Table 2.

Table 2| Efficiency table of the energy system shown in Figure 1 in Temoa. The optimization is done only for 2017. Technologies ELCEX12 and ELCEX23 represent the bidirectional flow of electricity (see the inputs and outputs).

input_comm	tech	vintage	output_comm	efficiency
ethos	NGAIMP_R1	2017	NG_R1	1
NG_R1	CC_R1	2016	ELC_R1	0.5
ELC_R1	TD_R1	2017	DEM_R1	0.95
SOL	SOLPV_R2	2016	ELC_R2	1
ELC_R2	TD_R2	2017	DEM_R2	0.96
WND	WND_R3	2016	ELC_R3	1
ELC_R3	TD_R3	2017	DEM_R3	0.94
ELC_R1	ELCEX12	2017	ELC_R2	0.9
ELC_R2	ELCEX12	2017	ELC_R1	0.9
ELC_R2	ELCEX23	2017	ELC_R3	0.9
ELC_R3	ELCEX23	2017	ELC_R2	0.9

To verify Temoa outputs, energy flows during day, when wind power plant is off, are examined. Intuitively, since solar-electricity comes with zero cost, the model has higher tendency to the solar power plant in region R2 than to the combined cycle in region R1. On the other hand, as mentioned before regional generations are first allocated to domestic demands. Having said that, now we can calculate the electricity that goes from R2 to R3 in the day time (Elec-R2-to-R3). It is calculated by subtracting R2 electricity demand (including losses) from maximum generation of the solar power plant during day time:

Elec-R2-to-R3=200 GW*0.5 yr -50 GWyr/0.96= 47.9166 GWyr

However, due to transmission losses, not all 47.9166 GWyr is used to meet R3 demand. There are two technologies in the way: ELCEX23 (efficiency=0.9) and R3_TD (efficiency=0.94). So:
Useful contribution of R2 to demand satisfaction in R3= 47.9166 GWyr*0.9*0.94=40.5375 GWyr

Since electricity demand in R3 is 50 GWyr during the day, there is 50-40.5375=9.4625 GWyr of unmet electricity demand, which inevitably must come from region R1. Taking into account the transmission losses (ELCEX23 and ELCEX12), total electricity transfer from region R1 to R2 would be:

9.4625 GWyr/0.9/0.9=12.427764 GWyr. This value is equal to the value Temoa generates.