Energy and Flexibility Modelling

Hands-on 5

Please use the following citation for:

- **This exercise**

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- **clicSAND Software**

Cannone, C., Allington, L., De Wet, N., Shivakumar, A., Goyns, P., Valderrama, C., Howells, M. (2021). clicSAND [computer software]. http://doi.org/10.5281/zenodo.4593100

- **OSeMOSYS Google Forum**

Please sign up to the help Google forum here. If you are stuck, please ask questions here. If you get ahead, please answer questions in the same forum. Please state that you are using the 'clicSAND' Interface.

Learning outcomes

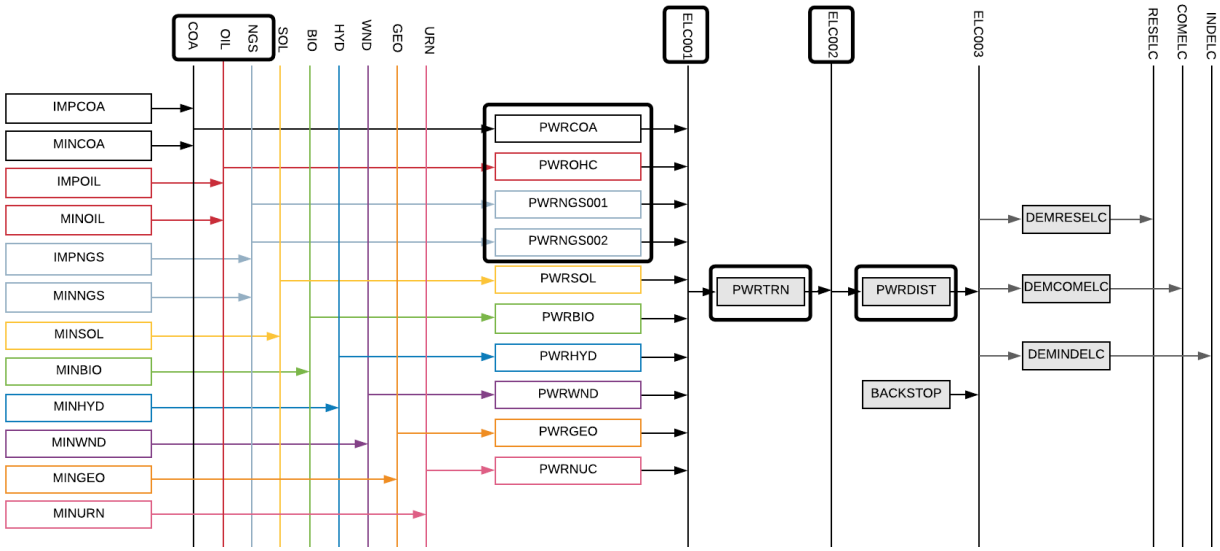
By the end of this exercise, you will be able to:

(1) Define an existing thermal power plant taking in fuel to generate electricity
(2) Define the existing transmission network
(3) Define the existing distribution network
(4) Run the model and check results on production by technology and capacity of each technology

Define an existing thermal power plant taking in fuel to generate electricity

In Lecture 6, we learnt how to represent a technology in OSeMOSYS and which parameters characterize thermal power plants and transmission and distribution technologies.

In this Hands-on, we will add 6 technologies in total: 4 thermal power plants, 1 technology representing the transmission system and 1 for the distribution network. Two new fuels will be added to the model: ELC001 (Electricity coming directly from power plants) and ELC002 (Electricity after transmission). We will build this part of the RES:



In order to represent a thermal power plant, remember that the following **parameters** must be considered:

- **InputActivityRatio**: defines the rate of fuel consumed (i.e. Coal)
- **OutputActivityRatio**: defines the fuel provided (i.e. Electricity)
- **CapacityToAcitivityUnit**: used to convert data related to the Capacity of technology into the Activity it can generate. For primary supply technology, this value should be set to 1.
- **Fixed Cost**: defines the fixed Operation & Maintenance cost ($/kW)

- **CapitalCost**: defines the overnight investment cost of the plant ($/kW)
- **OperationalLife**: defines the lifetime of the technology (in years)
- **ResidualCapacity**: defines the existing capacity of the technology (in GW) and its expected decommissioning.
- **Capacity Factors**: represents the variability in generation at each point in time.

Try it: Let's add **PWRCOA** - the technology representing a coal power plant.

1. Go to SETS and in cell B10 change the name from "TEC007" to "**PWRCOA**" and the description to "**Coal Power Plant**". In this way, we added the technology which will be transforming Coal (**COA**) into electricity (**ELC001**) to the model.
2. Now let's add the **Electricity from Power plants** in Cell E7 following the same procedure.
3. Next, go to Parameters Sheet and filter out in Column C for **PWRCOA** (as done previously).
4. Add the data for **PRWCOA** as for the tables below and as given in the DataPrep file.
    a. **InputActivityRatio**: choose the Coal Fuel row (Cell K21514) and add data from 2015 to 2070

	Parameter	TECHNOLOGY	FUEL	variables	2015	2016	2017	2018	2019	2020
21513	InputActivityRatio	PWRCOA	ELC003		0	0	0	0	0	0
21514	InputActivityRatio	PWRCOA	COA		2.7	2.7	2.7	2.7	2.7	2.7
21515	InputActivityRatio	PWRCOA	OIL		0	0	0	0	0	0

    b. **OutputActivityRatio**:

	Parameter	TECHNOLOGY	FUEL	Time indipendent varial	2015	2016	2017	2018	2019	2020	2021	2022	2023
31672	OutputActivityRatio	PWRCOA	ELC003		0	0	0	0	0	0	0	0	0
31673	OutputActivityRatio	PWRCOA	COA		0	0	0	0	0	0	0	0	0
31674	OutputActivityRatio	PWRCOA	OIL		0	0	0	0	0	0	0	0	0
31675	OutputActivityRatio	PWRCOA	NGS		0	0	0	0	0	0	0	0	0
31676	OutputActivityRatio	PWRCOA	ELC001		1	1	1	1	1	1	1	1	1
31677	OutputActivityRatio	PWRCOA	COM006		0	0	0	0	0	0	0	0	0

    c. **CapacityToActivityUnit, CapitalCost and FixedCost** respectively in rows 19571, 19770, and 20971.

	Parameter	TECHNOLOGY	FUEL	Time indipendent variables	2015	2016	2017	2018	2019	2020	2021	2022	2023
19571	CapacityToActivityUnit	PWRCOA		31.536									
19770	CapitalCost	PWRCOA			1600	1600	1600	1600	1600	1600	1600	1600	
20971	FixedCost	PWRCOA			65	65	65	65	65	65	65	65	
21513	InputActivityRatio	PWRCOA	ELC003		0	0	0	0	0	0	0	0	
21514	InputActivityRatio	PWRCOA	COA		2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	

    d. **OperationalLife**

21560	InputActivityRatio	PWRCOA	COM048		0	0
21561	InputActivityRatio	PWRCOA	COM049		0	0
21562	InputActivityRatio	PWRCOA	COM050		0	0
31130	OperationalLife	PWRCOA		35		
31672	OutputActivityRatio	PWRCOA	ELC003		0	0
31673	OutputActivityRatio	PWRCOA	COA		0	0
31674	OutputActivityRatio	PWRCOA	OIL		0	0
31675	OutputActivityRatio	PWRCOA	NGS		0	0
31676	OutputActivityRatio	PWRCOA	ELC001		1	1

e. **Residual Capacity**: defines the existing capacity of the technology (in GW) and its expected decommissioning

f. **Capacity Factors**: represents the variability in generation at each point in time. You need to define capacity factor values for all the modelling years from 2015 to 2070. Therefore, copy-paste the data available in the Data Prep file (**from J48 to J143**) for the year 2015. Then copy paste the **same values** for all the years until column BM correspondent to 2070.

1	Parameter	TECHNOLOGY	TIMESLICE	2015	2016
69	AvailabilityFactor	PWRCOA		1	1
70	AvailabilityFactor	PWROHC		1	1
71	AvailabilityFactor	PWRNGS001		1	1
72	AvailabilityFactor	PWRNGS002		1	1
73	AvailabilityFactor	PWRTRN		1	1
74	AvailabilityFactor	PWRDIST		1	1
933	CapacityFactor	PWRCOA	S101	0.85	0.85
934	CapacityFactor	PWRCOA	S102	0.85	0.85
935	CapacityFactor	PWRCOA	S103	0.85	0.85
936	CapacityFactor	PWRCOA	S104	0.85	0.85
937	CapacityFactor	PWRCOA	S105	0.85	0.85
938	CapacityFactor	PWRCOA	S106	0.85	0.85
939	CapacityFactor	PWRCOA	S107	0.85	0.85
940	CapacityFactor	PWRCOA	S108	0.85	0.85
941	CapacityFactor	PWRCOA	S109	0.85	0.85
942	CapacityFactor	PWRCOA	S110	0.85	0.85
943	CapacityFactor	PWRCOA	S111	0.85	0.85
944	CapacityFactor	PWRCOA	S112	0.85	0.85
945	CapacityFactor	PWRCOA	S113	0.85	0.85
946	CapacityFactor	PWRCOA	S114	0.85	0.85
947	CapacityFactor	PWRCOA	S115	0.85	0.85
948	CapacityFactor	PWRCOA	S116	0.85	0.85
949	CapacityFactor	PWRCOA	S117	0.85	0.85
950	CapacityFactor	PWRCOA	S118	0.85	0.85
951	CapacityFactor	PWRCOA	S119	0.85	0.85
952	CapacityFactor	PWRCOA	S120	0.85	0.85
953	CapacityFactor	PWRCOA	S121	0.85	0.85
954	CapacityFactor	PWRCOA	S122	0.85	0.85
955	CapacityFactor	PWRCOA	S123	0.85	0.85
956	CapacityFactor	PWRCOA	S124	0.85	0.85
957	CapacityFactor	PWRCOA	S201	0.85	0.85
958	CapacityFactor	PWRCOA	S202	0.85	0.85
959	CapacityFactor	PWRCOA	S203	0.85	0.85
960	CapacityFactor	PWRCOA	S204	0.85	0.85
961	CapacityFactor	PWRCOA	S205	0.85	0.85
962	CapacityFactor	PWRCOA	S206	0.85	0.85
963	CapacityFactor	PWRCOA	S207	0.85	0.85
964	CapacityFactor	PWRCOA	S208	0.85	0.85
965	CapacityFactor	PWRCOA	S209	0.85	0.85
966	CapacityFactor	PWRCOA	S210	0.85	0.85
967	CapacityFactor	PWRCOA	S211	0.85	0.85
968	CapacityFactor	PWRCOA	S212	0.85	0.85
969	CapacityFactor	PWRCOA	S213	0.85	0.85
970	CapacityFactor	PWRCOA	S214	0.85	0.85
971	CapacityFactor	PWRCOA	S215	0.85	0.85

Naming | SETS | Parameters | ToDataFil ...

For **PWRCOA,** only in this specific exercise, **ResidualCapacity** will be 0 because it was assumed that in this ideal region there were no existing coal power plants installed before 2015.

Watch out: this is not true for **PWROHC** (Oil power plant technology that we will add next), be sure to add Residual Capacity for this technology in your model!

Repeat the same steps for

1) **PWROHC** - Light Fuel Oil Power Plant
2) **PWRNGS001** - Gas Power Plant (CCGT)
3) **PWRNGS002** - Gas Power Plant (SCGT)

Using the data provided in the DataPrep file.

Voilà: you now have added 4 thermal power plants (**PWRCOA, PWROHC, PWRNGS001, PWRNGS002**) and 1 fuel (**ELC001**) to your model.

Define the existing transmission network

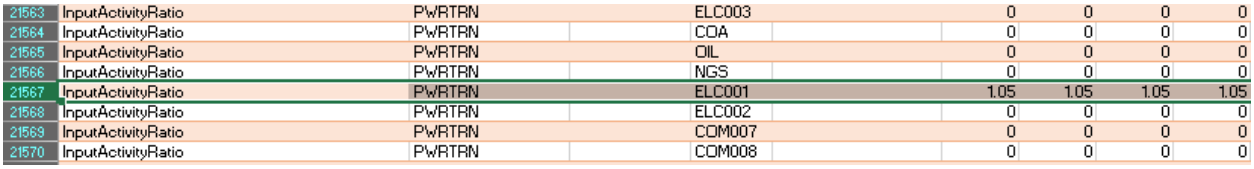
We will repeat the exercise once more giving the example of a technology which represents the **transmission network (PWRTRN)**. When representing the transmission technology, the following parameters must be considered:

- **InputActivityRatio**: defines the rate of fuel consumed (i.e. Electricity from power plants)
- **OutputActivityRatio**: defines the fuel provided (i.e. Electricity)
- **CapacityToAcitivityUnit**: It is used to convert data related to the Capacity of technology into the Activity it can generate. For primary supply technology, this value should be set to 1.
- **Fixed Cost**: defines the fixed Operation & Maintenance cost ($/kW)
- **CapitalCost**: defines the overnight investment cost of the plant ($/kW)
- **OperationalLife**: defines the lifetime of the technology (in years)

- **ResidualCapacity**: defines the existing capacity of the technology (in GW) and its expected decommissioning

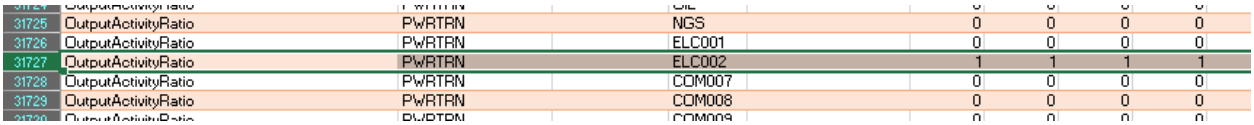
Try it: Let's add **PWRTRN** - the technology representing the transmission grid

1. Go to SETS and in cell B14 change the name from "TEC00" to "**PWRTRN**" and the description to "**Electricity Transmission"**. In this way, we added the technology that will be transmitting Electricity from Power Plants (**ELC001)** into a fictitious fuel that is the Electricity After Transmission (**ELC002**). This is done to account for the transmission grid losses.
2. Now let's add the **Electricity after transmission (ELC002)** in Cell E8 following the same procedure.
3. Next, go to Parameters Sheet and filter out in Column C for **PWRTRN** (as done previously).
4. Add the data for **PWRTRN** as for the tables below and as given in the DataPrep file.
    a. **InputActivityRatio**: choose the ELC001 row (Cell K21567) and add data from 2015 to 2070



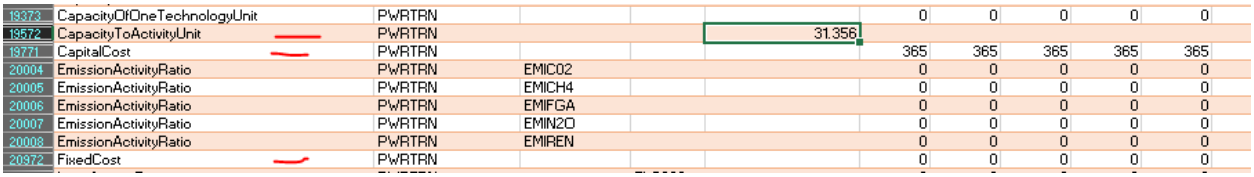
21563	InputActivityRatio	PWRTRN	ELC003	0	0	0	0
21564	InputActivityRatio	PWRTRN	COA	0	0	0	0
21565	InputActivityRatio	PWRTRN	OIL	0	0	0	0
21566	InputActivityRatio	PWRTRN	NGS	0	0	0	0
21567	InputActivityRatio	PWRTRN	ELC001	1.05	1.05	1.05	1.05
21568	InputActivityRatio	PWRTRN	ELC002	0	0	0	0
21569	InputActivityRatio	PWRTRN	COM007	0	0	0	0
21570	InputActivityRatio	PWRTRN	COM008	0	0	0	0

    b. **OutputActivityRatio**:



31725	OutputActivityRatio	PWRTRN	NGS	0	0	0	0
31726	OutputActivityRatio	PWRTRN	ELC001	0	0	0	0
31727	OutputActivityRatio	PWRTRN	ELC002	1	1	1	1
31728	OutputActivityRatio	PWRTRN	COM007	0	0	0	0
31729	OutputActivityRatio	PWRTRN	COM008	0	0	0	0

    c. **CapacityToActivityUnit, CapitalCost and FixedCost** respectively in rows 19572, 19771 and 20972. Fixed cost for transmission tech will be 0.



19572	CapacityToActivityUnit	PWRTRN		31.356					
19771	CapitalCost	PWRTRN			365	365	365	365	365
20004	EmissionActivityRatio	PWRTRN	EMIC02		0	0	0	0	0
20005	EmissionActivityRatio	PWRTRN	EMICH4		0	0	0	0	0
20006	EmissionActivityRatio	PWRTRN	EMIFGA		0	0	0	0	0
20007	EmissionActivityRatio	PWRTRN	EMIN2O		0	0	0	0	0
20008	EmissionActivityRatio	PWRTRN	EMIREN		0	0	0	0	0
20972	FixedCost	PWRTRN			0	0	0	0	0

    d. **OperationalLife**

21611	InputActivityRatio	PWRTRN	COM049		0	0
21612	InputActivityRatio	PWRTRN	COM050		0	0
31131	OperationalLife	PWRTRN		50		
31722	OutputActivityRatio	PWRTRN	ELC003		0	0
31723	OutputActivityRatio	PWRTRN	COA		0	0

e. **ResidualCapacity**: defines the existing capacity of the technology (in GW) and its expected decommissioning.

Define the existing distribution network

We will repeat the exercise once more giving the example of a technology which represents the **distribution network (PWRDIST)**. (Very similar to **PWRTRN**)

Try it: Let's add **PWRDIST** - the technology representing the distribution network

1. Go to SETS and in cell B15 change the name from "TEC009" to "**PWRDIST**" and the description to "**Electricity distribution**". In this way, we added the technology which will convert the Electricity After Transmission (**ELC002**) into Electricity after distribution (**ELC003**).
2. We don't need to add **Electricity after Distribution as we had that already defined in Cell E1.**
3. Next, go to Parameters Sheet and filter out in Column C for **PWRDIST** (as done previously).
4. Add the data for **PWRDIST** as for the tables below and as given in the DataPrep file.
   a. **InputActivityRatio**: choose the Electricity After transmission row (Cell K21618) and add data from 2015 to 2070

21615	InputActivityRatio	PWRDIST	OIL	0	0	0	0
21616	InputActivityRatio	PWRDIST	NGS	0	0	0	0
21617	InputActivityRatio	PWRDIST	ELC001	0	0	0	0
21618	InputActivityRatio	PWRDIST	ELC002	1.17	1.16733	1.16467	1.162
21619	InputActivityRatio	PWRDIST	COM007	0	0	0	0
21620	InputActivityRatio	PWRDIST	COM008	0	0	0	0
21621	InputActivityRatio	PWRDIST	COM009	0	0	0	0

b. **OutputActivityRatio**:

21662	InputActivityRatio	PWRDIST		COM050	0	0	0	0
31132	OperationalLife	PWRDIST			1			
31772	OutputActivityRatio	PWRDIST		ELC003	1	1	1	1
31773	OutputActivityRatio	PWRDIST		COA	0	0	0	0
31774	OutputActivityRatio	PWRDIST		OIL	0	0	0	0

c. **CapacityToActivityUnit, CapitalCost and FixedCost** respectively in rows 19573, 19772 and 20973. Fixed costs will be zero.

1220	CapacityFactor	PWRDIST			1	1	1	1
19374	CapacityOfOneTechnologyUnit	PWRDIST			0	0	0	0
19573	CapacityToActivityUnit	PWRDIST		31.536				
19772	CapitalCost	PWRDIST			2502	2502	2502	2502
20009	EmissionActivityRatio	PWRDIST	EMIC02		0	0	0	0
20010	EmissionActivityRatio	PWRDIST	EMICH4		0	0	0	0
20011	EmissionActivityRatio	PWRDIST	EMIFGA		0	0	0	0
20012	EmissionActivityRatio	PWRDIST	EMIN2O		0	0	0	0
20013	EmissionActivityRatio	PWRDIST	EMIREN		0	0	0	0
20973	FixedCost	PWRDIST			0	0	0	0

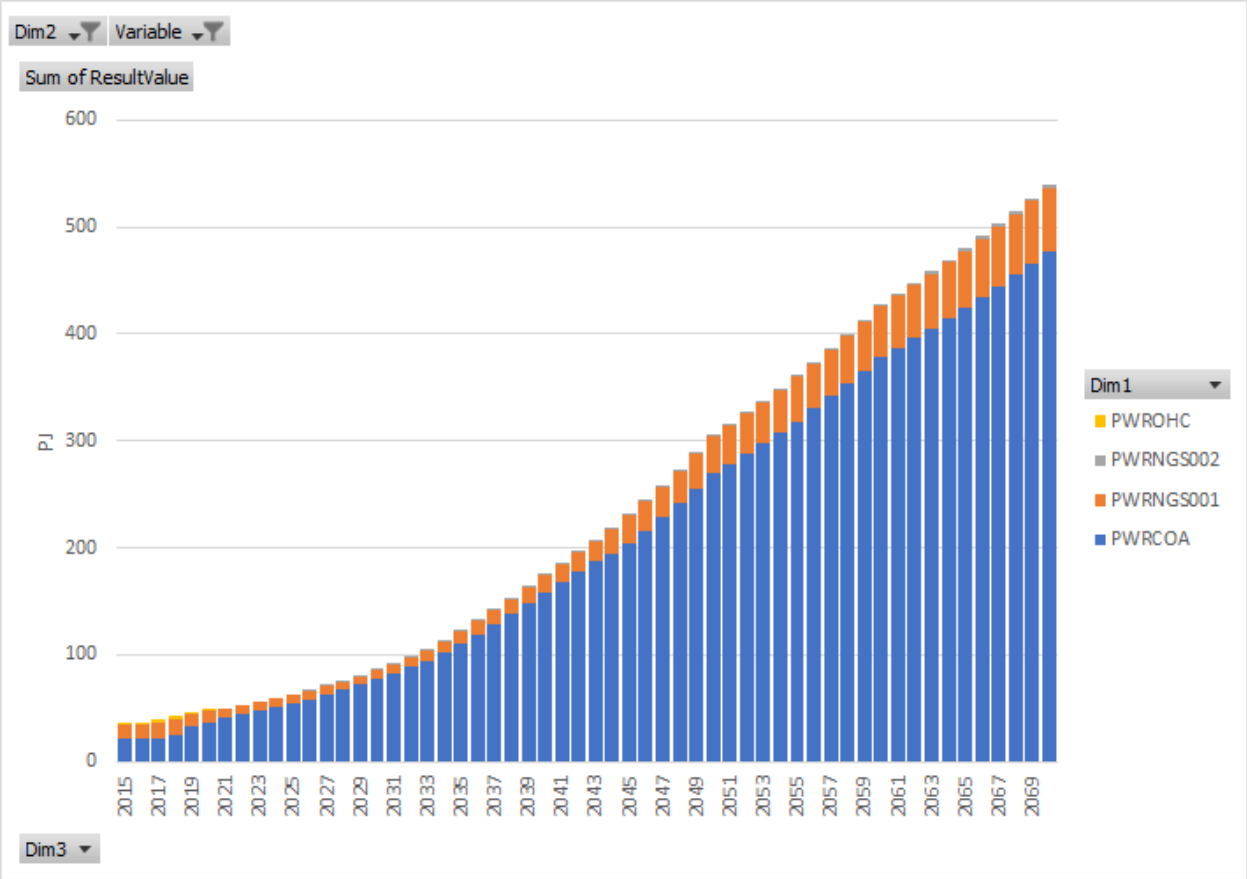
d. **OperationalLife**

21661	InputActivityRatio	PWRDIST		COM049		0
21662	InputActivityRatio	PWRDIST		COM050		0
31132	OperationalLife	PWRDIST			70	
31772	OutputActivityRatio	PWRDIST		ELC003		1
31773	OutputActivityRatio	PWRDIST		COA		0
31774	OutputActivityRatio	PWRDIST		OIL		0

e. **ResidualCapacity**: defines the existing capacity of the technology (in GW) and its expected decommissioning

Run the model and check results on production by technology and capacity of each technology

This is the graph showing the Annual Electricity Production (PJ) results for this exercise. You should obtain this in Results_Template_HO5 after running the model and following the steps explained in **Hands-on 3**.


Dim2
Variable
Sum of ResultValue
600
500
400
300
200
100
0
PJ
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
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2051
2053
2055
2057
2059
2061
2063
2065
2067
2069
Dim3
Dim1
PWROHC
PWRNGS002
PWRNGS001
PWRCOA