



DER-CAM

DECISION SUPPORT TOOL FOR
DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Modeling Workflow

Completing a DER-CAM analysis in 7 steps

Mar. 7th, 2018



Before we begin...

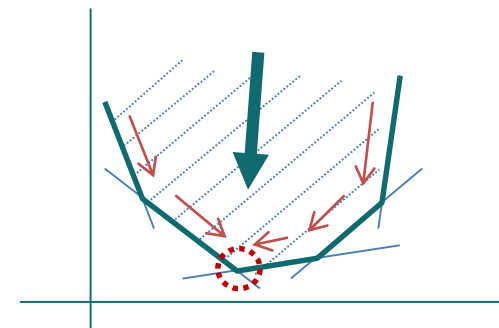
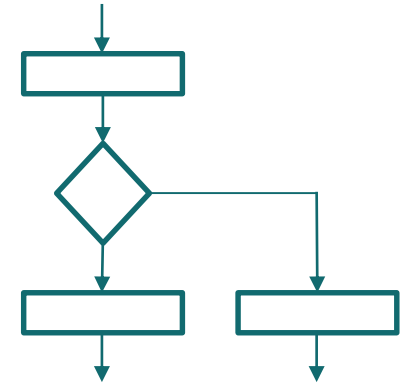
Simulation vs Optimization

Simulation:

- Pre-defined set of rules
 - if *PV output* < *Load*:
 - if *Battery SOC* > *Min*: Decrease *Battery SOC*
- One possible output per input (not optimal)
- Very fast

Optimization (DER-CAM):

- Define boundaries for each variable
 - $Min \leq Battery\ SOC \leq Max$
- Entire feasible region of possible output
- Define an objective function
 - $Total\ Cost = DER\ Inv.\ Cost + DER\ Op.\ Cost + Util.\ Cost$
- Find the solution in the feasible region that optimizes the objective
- Problems may become very large and take time to solve



DER-CAM

DER-CAM is a *decision support tool* for decentralized energy systems

Finds optimal *portfolio*, *sizing*, *placement*, and *dispatch* of **DER** in buildings and microgrids



Energy loads



Electricity & fuel prices



DER technologies



Local weather



Topology

Many variables!



DER-CAM



Optimal DER Portfolio



Optimal DER Sizing

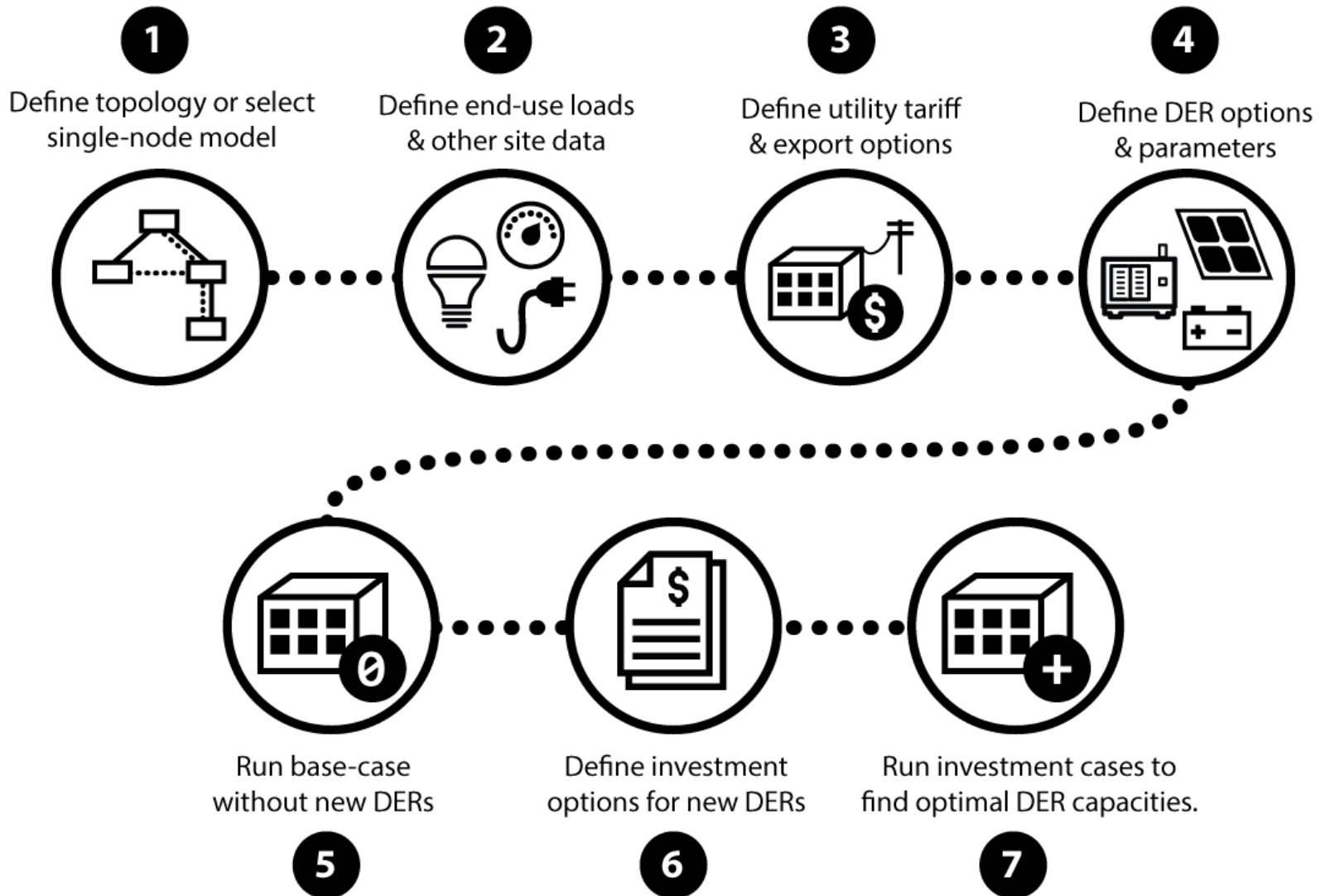


Optimal DER Placement



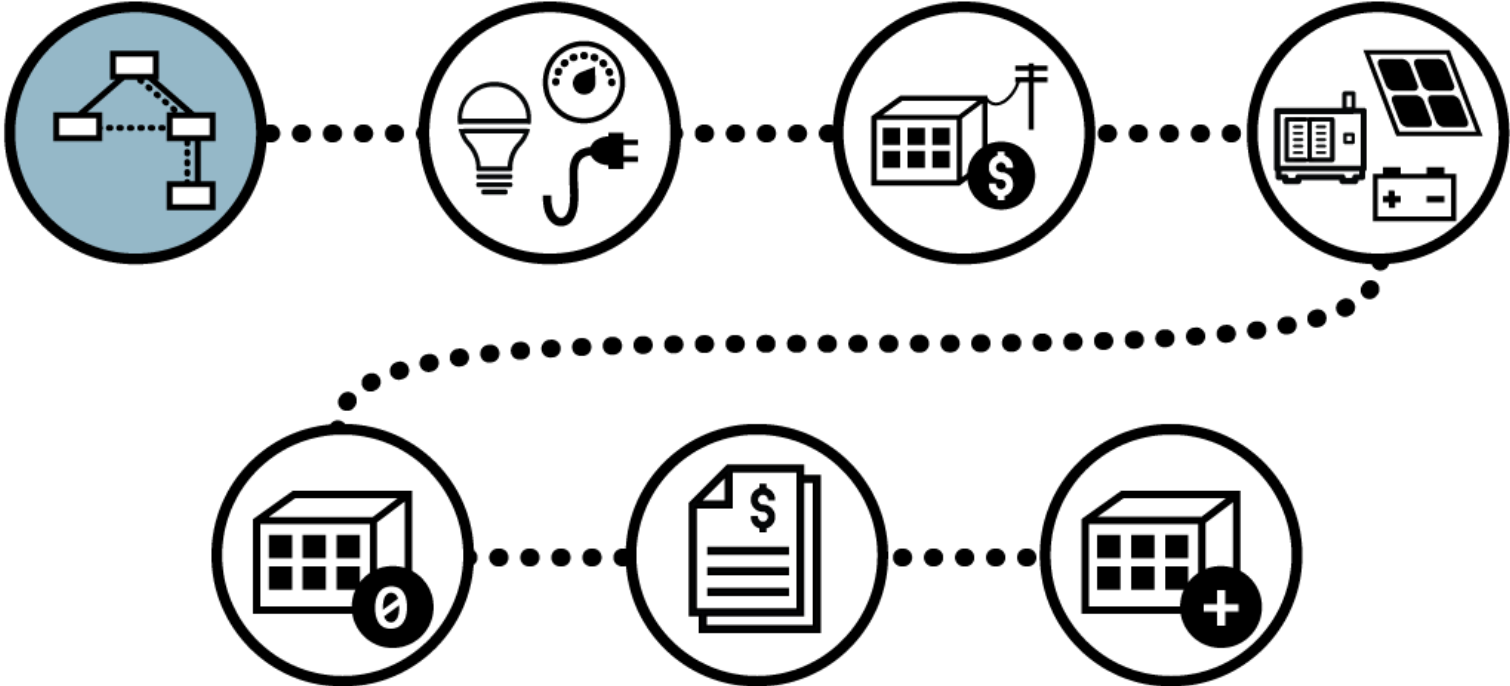
Optimal DER dispatch

DER-CAM Project Workflow:



1

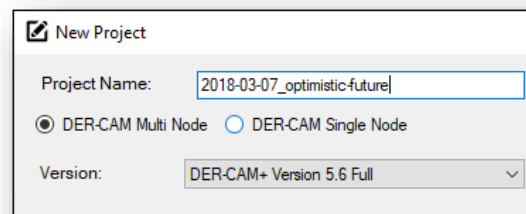
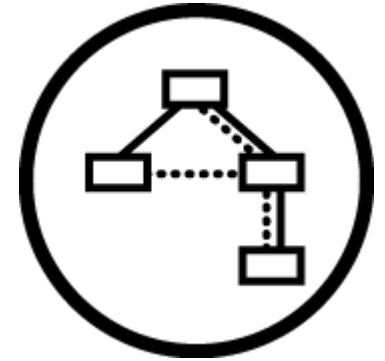
Define topology or select single-node model



1 – Define Topology

Start by deciding between single or multi-node

- Single node models can be a good first approach
- Faster to solve, less data required
- Ideal if loads can be aggregated:
 - Strong network, no loss or voltage concerns
 - Optimal DER placement not required
- Multi-node models provide additional depth
- (Optimal) power flow and heat flow is integrated in the analysis
- Optimal DER placement is provided
- Choosing between single or multi-node happens when creating a new project
- This decision cannot be changed later on

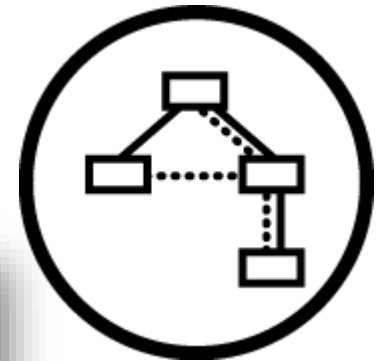
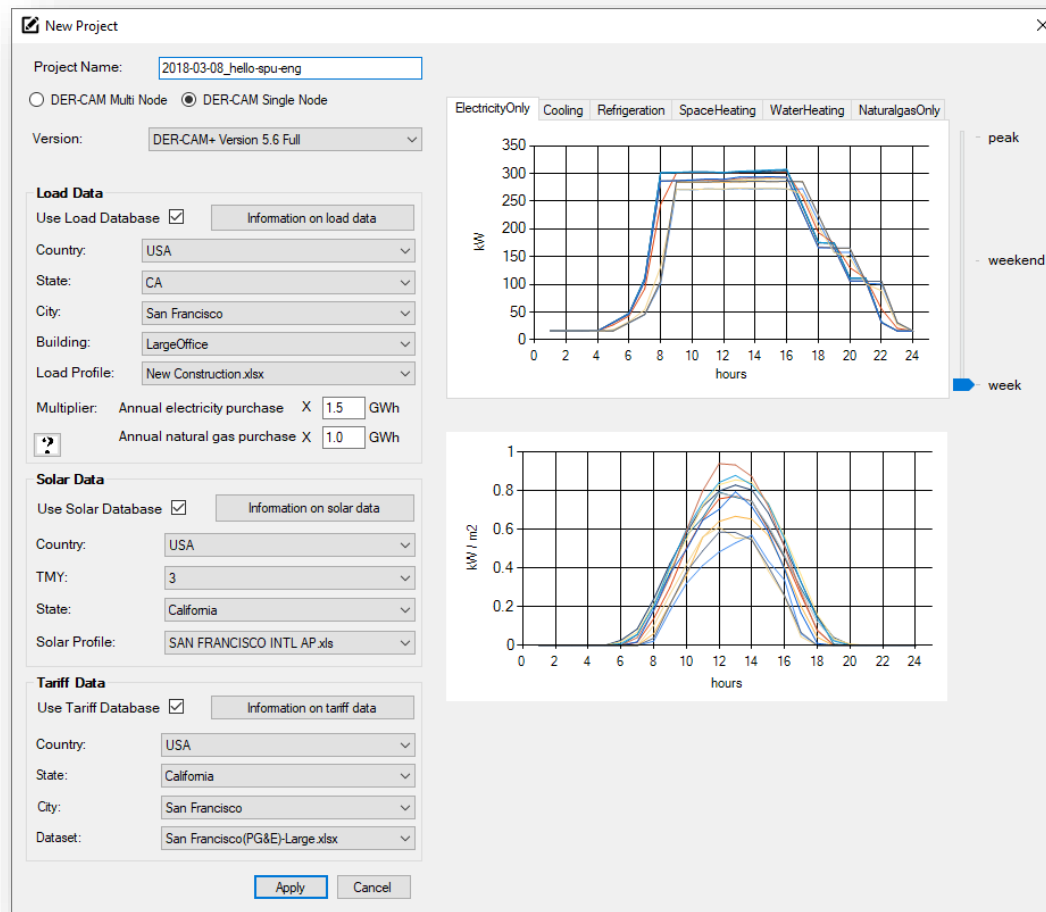
A screenshot of a software dialog box titled "New Project". It contains the following fields and options:

- Project Name: 2018-03-07_optimistic-future|
- Radio buttons: DER-CAM Multi Node and DER-CAM Single Node
- Version: DER-CAM+ Version 5.6 Full (with a dropdown arrow)

1+2+3 – Using the databases

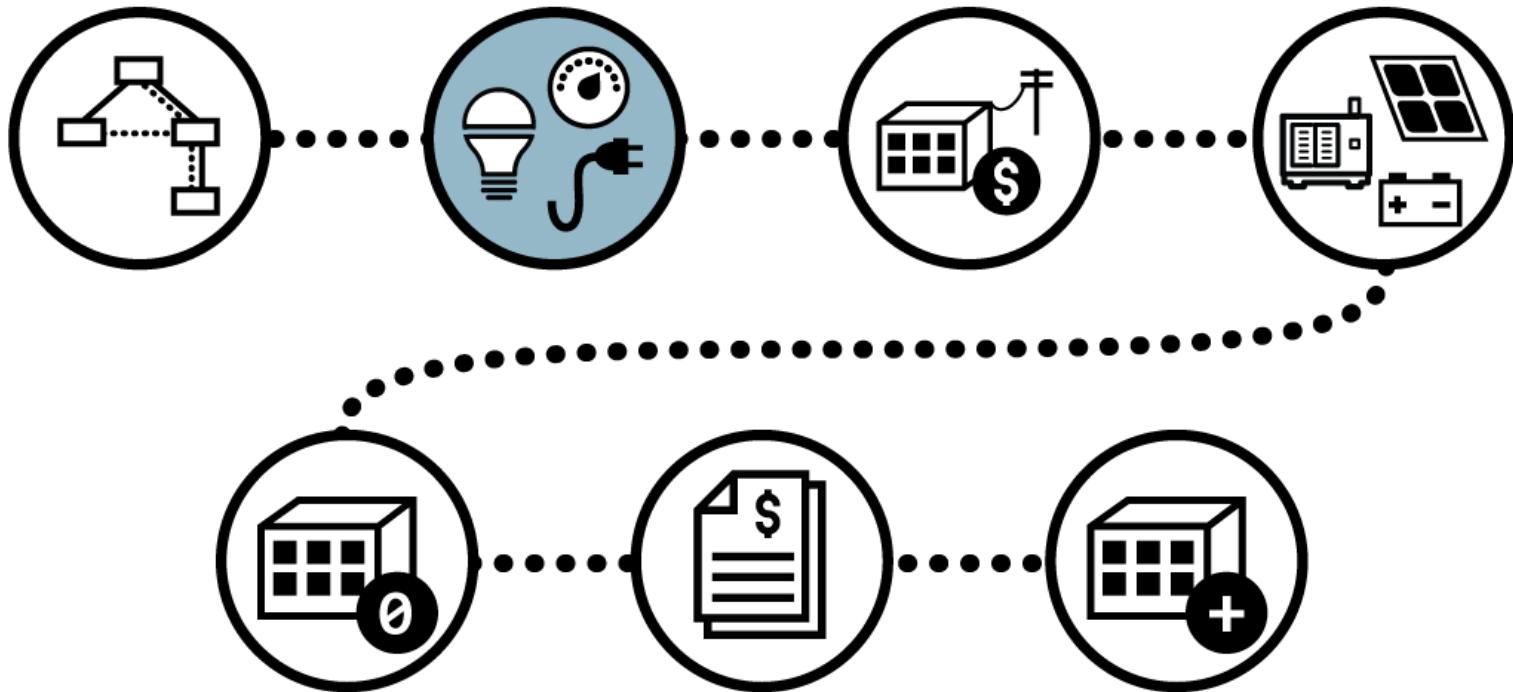
Single node example...

- Large Office Building in San Francisco



2

Define end-use loads & other site data



2 – End-use loads and site data

End-use loads...

- Up to 3(+3) “design days” per month



2018-03-08_hello-spu-eng

DER-CAM+ DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
TOPOLOGY | ANALYTICS | PLANNING | OPERATIONS

Parameters Load1

Load Data Loaded Data: n/a/n/a/n/a: n/a

	type	month	daytype	1	2	3	4	5	6	7	8	9
1	electricity-only	January	week	17.4548	15.8272	17.4548	15.8593	17.4548	30.0526	45.0971	100.9922	271.6
2	electricity-only	February	week	15.8272	15.8272	15.8272	15.8272	15.8272	30.7234	45.8339	105.4126	284.1
3	electricity-only	March	week	15.8272	15.8272	15.8272	15.8272	26.9063	42.9193	92.0206	243.9604	300.9
4	electricity-only	April	week	15.8272	15.8272	15.8272	15.8631	31.6545	47.703	111.0116	300.9958	301.2
5	electricity-only	May	week	15.8272	15.8272	15.8272	15.8272	30.8631	46.1718	106.2527	287.6103	287.8
6	electricity-only	June	week	15.8272	15.8272	15.8272	15.8272	31.6545	47.8159	111.0116	301.6366	302.3
7	electricity-only	July	week	15.8272	15.8272	15.8272	15.8272	30.7752	46.057	106.4488	285.743	287.4
8	electricity-only	August	week	15.8272	15.8272	15.8272	15.8272	31.6545	47.8918	111.0116	301.8464	302.6
9	electricity-only	September	week	15.8272	15.8272	15.8272	15.8272	30.7752	46.1359	105.7236	286.1007	287.0
10	electricity-only	October	week	15.8272	15.8272	15.8272	15.8272	30.8215	46.1792	106.0019	286.4792	287.1
11	electricity-only	November	week	15.8272	15.8272	15.8272	15.8593	18.3263	32.6214	54.3435	131.0936	271.1
12	electricity-only	December	week	15.8272	16.0303	15.8272	16.0755	15.8272	31.046	45.9319	105.7913	285.0
13	electricity-only	January	peak	15.8272	15.8272	15.8272	15.8272	15.8272	31.8576	47.7027	111.0116	300.9
14	electricity-only	February	peak	15.8272	15.8272	15.8272	15.8272	15.8272	31.6545	47.7374	111.0116	301.0
15	electricity-only	March	peak	15.8272	15.8272	15.8272	15.8272	21.103	37.0039	68.8057	174.3222	301.2
16	electricity-only	April	peak	15.8272	15.8272	15.8272	15.8272	31.6545	47.9134	111.0116	302.7732	304.4
17	electricity-only	May	peak	15.8272	15.8272	15.8272	15.8272	31.6545	47.8554	111.0116	302.2757	303.7
18	electricity-only	June	peak	15.8272	15.8272	15.8272	15.8272	31.6545	48.0074	111.0117	304.0514	306.0
19	electricity-only	July	peak	15.8272	15.8272	15.8272	15.8272	31.6545	48.0335	111.1188	303.7037	305.2
20	electricity-only	August	peak	15.8272	15.8272	15.8272	15.8272	31.6545	47.9968	111.0116	302.7867	304.5
21	electricity-only	September	peak	15.8272	15.8272	15.8272	15.8272	31.6545	48.2817	111.0116	304.5556	308.0
22	electricity-only	October	peak	15.8272	15.8272	15.8272	15.8272	31.6545	47.9199	111.0116	301.8581	303.0
23	electricity-only	November	peak	15.8272	15.8272	15.8272	15.8272	15.8272	31.6545	47.7086	111.0116	300.9
24	electricity-only	December	peak	15.8272	15.8272	15.8272	15.8272	15.8272	31.6545	47.7027	111.0116	300.9
25	electricity-only	January	weekend	17.234	15.8272	17.4099	15.8272	17.4099	15.8272	31.658	29.9941	87.85
26	electricity-only	February	weekend	15.8272	15.8272	15.8272	15.8272	15.8272	15.8272	31.765	31.765	95.07

Load - Help

Here the hourly load for each of the design days (type (peak, week, week-end) and month) for each node. The load must be provided in kW and is assumed to be the average load (per day-type) in each hour that has to be satisfied by the available technologies.

The loads include: electric space-heating, water-heating, cooling, refrigeration, natural gas (e.g. for cooking)

Note: The default load values are taken from the database for a medium office in San Francisco.

DER-CAM+ Version 5.6 Full

2 – End-use loads and site data

End-use loads...

- Up to 3(+3) “design days” per month



The screenshot shows the DER-CAM+ software interface. The main window displays a table titled "Number of Days" with columns for months and various day types. The "Number of Days - Help" panel is open on the right, providing instructions on how to use the table.

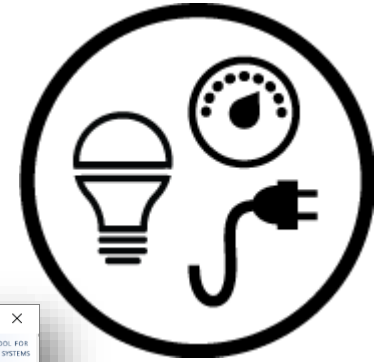
	F1	peak	week	weekend	emergency-week	emergency-peak	emergency-weekend
1	January	3	20	8	0	0	0
2	February	3	17	8	0	0	0
3	March	3	18	10	0	0	0
4	April	3	19	8	0	0	0
5	May	3	20	8	0	0	0
6	June	3	17	10	0	0	0
7	July	3	20	8	0	0	0
8	August	3	19	9	0	0	0
9	September	3	18	9	0	0	0
10	October	3	20	8	0	0	0
11	November	3	18	9	0	0	0
12	December	3	19	9	0	0	0

Number of Days - Help

This table is used to specify the number of peak, week and weekend days for each month. If the considered year is a leap year please note the relation between this table and the table GenConstraints (TechnologyGeneratorConstraints). If you are using 8760 hours for Maximum annual operation hours in the generation constraints and a leap year, the 8760 hours must be replaced by 8784 hours; otherwise the DER equipment is not allowed to run the whole year.

2 – End-use loads and site data

Other site data...



The screenshot displays the DER-CAM+ software interface with several overlapping windows. The main window shows the 'Solar Radiation' data table. Other windows show 'Wind Power Potential' and 'Ambient Hourly Temperature' data tables. The interface includes a menu bar, a toolbar, and a sidebar with project navigation options.

Solar Radiation - Help

The solar radiation is given as average fraction of maximum solar insolation.

F1	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0407	0.2931	0.4336	0.5875	0.6559	0.6423	0.6237
2 February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0896	0.2938	0.4643	0.5129	0.599	0.5812	0.5945
3 March	0.00	0.00	0.00	0.00	0.00	0.00	0.0012	0.2018	0.4227	0.6011	0.7108	0.8197	0.8177	0.7625

Wind Power Potential - Help

F1	1	2	3	4	5	6	7	8	9	10	11	12	13
1 January	28.9261	25.4619	23.5633	26.9506	27.5886	25.425	29.6506	32.2706	27.6983	25.1842	19.4589	19.075	22

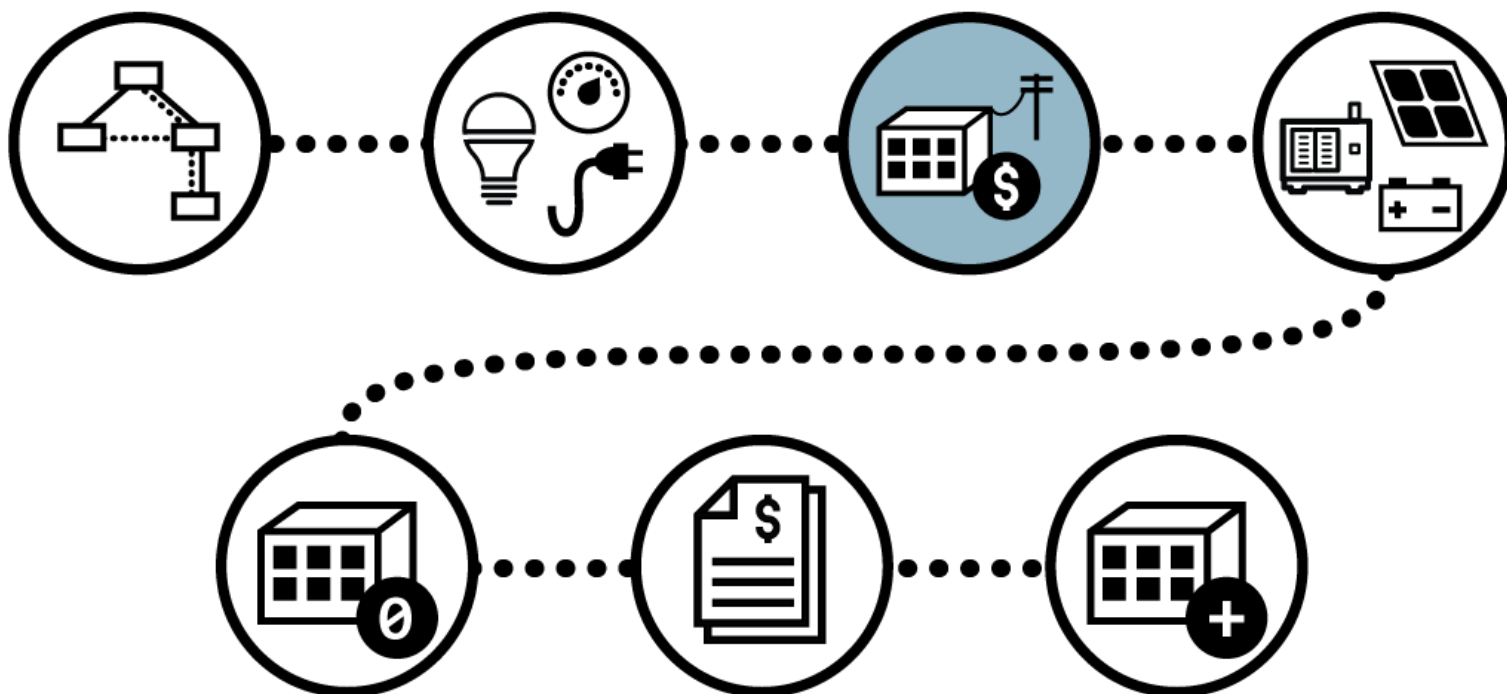
Ambient Hourly Temperature - Help

The ambient hourly temperature data must be inserted in degrees Celsius. This information is relevant to estimate changes in internal loads inside the building where passive retrofit options are being considered (such as improved windows), and it is also used to estimate the efficiency of panels.

F1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 January	8.10	7.90	7.80	7.70	7.80	7.90	8.00	8.90	9.70	10.60	11.50	12.40	13.30	13.40	13
2 February	9.70	9.50	9.30	9.10	8.80	8.60	8.20	9.50	10.70	12.00	13.20	14.40	15.50	15.60	15
3 March	11.10	10.60	10.10	9.60	9.30	9.00	8.70	9.90	11.10	12.30	13.40	14.50	15.60	15.90	16
4 April	10.30	9.80	9.40	9.00	9.40	9.70	10.10	11.50	13.00	14.50	15.60	16.80	18.00	18.10	18
5 May	11.20	11.10	10.80	10.40	10.90	11.30	11.70	13.20	14.60	16.10	17.50	18.90	20.40	20.20	20
6 June	13.00	12.90	12.70	12.30	12.90	13.60	14.20	15.50	16.70	18.00	19.40	20.70	22.00	21.60	21
7 July	13.40	13.30	13.10	13.00	13.70	14.10	15.50	16.90	18.30	19.80	21.30	22.80	22.40	22	
8 August	14.00	13.80	13.60	13.40	13.50	13.70	13.90	15.20	16.50	17.90	19.60	21.40	22.40	22.60	22
9 September	14.80	14.50	14.10	13.70	13.50	13.70	14.70	16.20	17.70	19.00	20.60	22.20	23.40	23.60	23
10 October	13.40	12.90	12.40	11.90	12.10	12.30	12.50	14.20	15.80	17.40	18.60	19.90	21.10	21.20	21
11 November	10.80	10.20	9.60	9.20	9.30	9.30	9.90	11.50	13.40	14.40	15.30	16.60	17.10	17.40	17
12 December	8.20	7.90	7.40	6.90	6.90	7.00	7.00	8.10	9.30	10.40	11.50	12.60	13.60	13.80	13

3

Define utility tariff & export options



3 – Utility tariffs and export options

Electricity and fuel prices...



E-19 TOU	\$3.94267 per meter per day		Secondary			Primary	Transmission	Secondary			Primary	Transmission
			Max. Peak	Part Peak	Maximum	Peak	Part Peak	Off Peak	Peak	Part Peak	Off Peak	
Summer			\$9.71	\$8.91	\$7.03	Peak	\$0.14026	\$0.13861	\$0.09129			
			\$3.33	\$3.06	\$2.78	Part Peak	\$0.09916	\$0.09219	\$0.08665			
Winter			\$16.04	\$12.08	\$7.87	Off Peak	\$0.07512	\$0.07456	\$0.07043			
			\$0.24	\$0.46	\$0.00	Part Peak	\$0.09451	\$0.09196	\$0.08500			
			\$9.71	\$8.63	\$7.87	Off Peak	\$0.07885	\$0.07787	\$0.07214			

	F1	coincident	noncoincident	onpeak	midpeak	offpeak
1	January	0	9.71	0	0.24	0
2	February	0	9.71	0	0.24	0
3	March	0	9.71	0	0.24	0
4	April	0	9.71	0	0.24	0
5	May	0	16.04	9.71	3.33	0
6	June	0	16.04	9.71	3.33	0
7	July	0	16.04	9.71	3.33	0
8	August	0	16.04	9.71	3.33	0
9	September	0	16.04	9.71	3.33	0
10	October	0	16.04	9.71	3.33	0
11	November	0	9.71	0	0.24	0
12	December	0	9.71	0	0.24	0

	F1	On	Mid	Off
1	January	0	0.09451	0.07885
2	February	0	0.09451	0.07885
3	March	0	0.09451	0.07885
4	April	0	0.09451	0.07885
5	May	0.14026	0.09916	0.07512
6	June	0.14026	0.09916	0.07512
7	July	0.14026	0.09916	0.07512
8	August	0.14026	0.09916	0.07512
9	September	0.14026	0.09916	0.07512
10	October	0.14026	0.09916	0.07512
11	November	0	0.09451	0.07885
12	December	0	0.09451	0.07885

3 – Utility tariffs and export options

Electricity and fuel prices...



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Parameters

Time-of-Use Rates

	month	on	mid	off
1	January	0.00	0.1019	0.078
2	February	0.00	0.1019	0.078
3	March	0.00	0.1019	0.078
4	April	0.00	0.1019	0.078
5	May	0.1623	0.1089	0.074
6	June	0.1623	0.1089	0.074
7	July	0.1623	0.1089	0.074
8	August	0.1623	0.1089	0.074
9	September	0.1623	0.1089	0.074
10	October	0.1623	0.1089	0.074
11	November	0.00	0.1019	0.078
12	December	0.00	0.1019	0.078

Electricity Rates - Help

The electricity rates reflect the volumetric cost of the regulated utility tariff, set on a time-of-use basis. The unit is [\$/kWh]. DER-CAM+ considers Peak (On), Mid-peak (Mid), and Off-peak (off) time-of-use periods to calculate volumetric electricity costs. The rate specified here for each control period will be multiplied with the electricity purchase from the grid of the corresponding hours.

Note: Default values are based on PG&E tariff for a medium building.

Ready. DER-CAM+ Version 5.6 Full

Hint: to create a microgrid model from the perspective of the utility or DSO tariffs can be replaced by costs they would incur to serve clients

3 – Utility tariffs and export options

Export Options...



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Undo New Open Save Close Overview Run Run Multi Sens. Analysis Cancel Email Your Projects Ab...

Parameters Options Table

	F1	F2
1 NonRenewableSales	0.00	
2 RenewableSales	0.00	
3 NetMetering	0.00	
4 ASMarkets	0.00	

Home Global Settings Investment Options Options Table Parameters Table Number of Days

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Undo New Open Save Close Overview Run Run Multi Sens. Analysis Cancel Email Your Projects About Tech. Support Manual

Parameters Hourly Feed-in Tariff

	F1	F2	1	2	3	4	5	6	7	8	9	10	11
1 January Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 January Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 January Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 February Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 February Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6 February Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 March Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8 March Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9 March Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 April Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11 April Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12 April Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13 May Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 May Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15 May Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16 June Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17 June Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 June Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 July Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20 July Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21 July Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22 August Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23 August Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24 August Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 September Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26 September Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27 September Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28 October Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29 October Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30 October Weekend	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31 November Week	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32 November Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Home Global Settings Site Weather Data Load Data Utility Technologies Load Management, Resiliency and Reliability AS Markets Advanced User Settings Financial Incentives Feed in Options Hourly Feed-in Tariff Tiered Feed-in Tariff SGIP Results Sensitivity Analysis

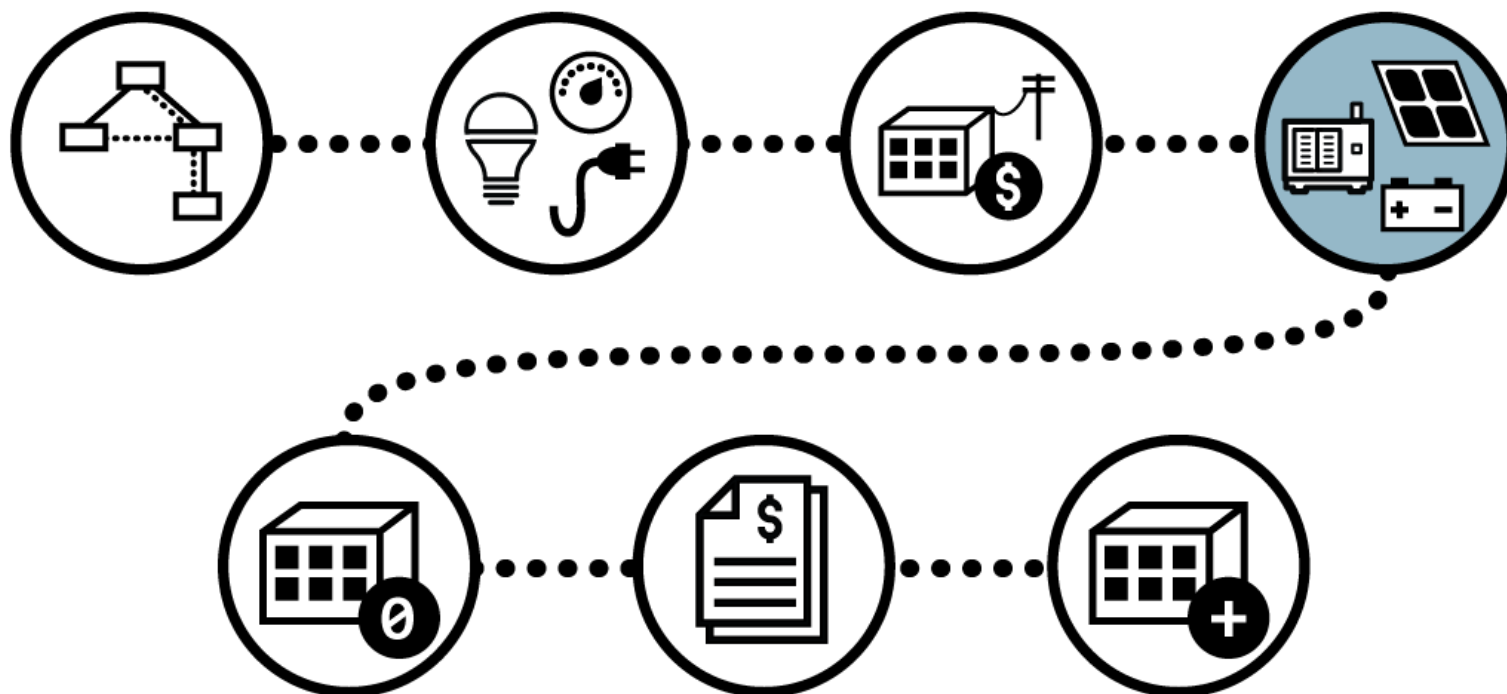
PX - Help

This input contains the hourly price profiles for energy exported from the local system to the grid each day type (peak, week, weekend) and each month. The units PX are \$ per kWh and should represent average hourly prices.

Ready. DER-CAM+ Version 5.6 Full

4

Define DER options & parameters



4 – DER Options and Parameters

Continuous vs Discrete!?



2018-03-08_hello-spu-eng

DER-CAM+ DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
TOPOLOGY | ANALYTICS | PLANNING | OPERATIONS

Parameters DER Technologies Info

TechNo	Description	maxp	maxs	lifetime	capcost	OMFix	OMVar
1	DGTech01 MT_CHP-HW_65	65.00	65.00	15.00	6440.00	0.00	0.0073
2	DGTech02 ICE_RB_CHP-HW_75	75.00	75.00	15.00	5761.4074	0.00	0.0128
3	DGTech03 MT_CHP-HW_200	200.00	200.00	15.00	6300.00	0.00	0.0085
4	DGTech04 ICE_RB_CHP-HW_250	250.00	250.00	15.00	5227.7333	0.00	0.0125
5	DGTech05 MT_CHP-HW_250	250.00	250.00	15.00	5438.00	0.00	0.006
6	DGTech06 MCFC_CHP-HW_300	300.00	300.00	20.00	20600.00	0.00	0.023
7	DGTech07 PAFC_HP-HW_400	400.00	400.00	20.00	14600.00	0.00	0.0185
8	DGTech08 ICE_LB_CHP-HW_500	500.00	500.00	15.00	4617.60	0.00	0.0108
9	DGTech09 ICE_LB_CHP-HW_750	750.00	750.00	20.00	4400.597	0.00	0.0108
10	DGTech10 ICE_LB_CHP-HW_1000	1000.00	1000.00	20.00	4968.60	0.00	0.0098
11	DGTech11 MT_CHP-HW_1000	1000.00	1000.00	15.00	5000.00	0.00	0.0063
12	DGTech12 MCFC_CHP-HW_1000	1000.00	1000.00	20.00	12820.00	0.00	0.0178
13	DGTech13 MCFC_CHP-HW_1400	1400.00	1400.00	20.00	9200.00	0.00	0.0178
14	DGTech14 ICE_LB_CHP-HW_2500	2500.00	2500.00	20.00	4223.0868	0.00	0.0081
15	DGTech15 MCFC_CHP-HW_2800	2800.00	2800.00	20.00	8300.00	0.00	0.0178
16	DGTech16 CT_CHP-HW_3500	3500.00	3500.00	20.00	6144.7337	0.00	0.006
17	DGTech17 CT_CHP-HW_DB_3500	3500.00	3500.00	20.00	6309.1789	0.00	0.0063
18	DGTech18 ICE_LB_CHP-HW_5000	5000.00	5000.00	20.00	3074.0211	0.00	0.0044
19	DGTech19 CT_CHP-HW_5000	5000.00	5000.00	20.00	3890.9918	0.00	0.0053
20	DGTech20 CT_CHP-HW_DB_5000	5000.00	5000.00	20.00	3984.1806	0.00	0.0055
21	DGTech21 CT_CHP-HW_7500	7500.00	7500.00	20.00	3754.9146	0.00	0.0051
22	DGTech22 CT_CHP-HW_DB_7500	7500.00	7500.00	20.00	3841.241	0.00	0.0053
23	DGTech23 CT_CHP-HW_15000	15000.00	15000.00	20.00	2887.7754	0.00	0.0037
24	DGTech24 CT_CHP-HW_DB_15000	15000.00	15000.00	20.00	2952.9811	0.00	0.0038
25	DGTech25 CT_CHP-HW_25000	25000.00	25000.00	20.00	2377.3427	0.00	0.0036
26	DGTech26 CT_CHP-HW_DB_25000	25000.00	25000.00	20.00	2428.5374	0.00	0.0037
27	DGTech27 MT_65	65.00	65.00	15.00	5474.00	0.00	0.0065
28	DGTech28 ICE_RB_75	75.00	75.00	15.00	4460.4444	0.00	0.012
29	DGTech29 MT_200	200.00	200.00	15.00	5355.00	0.00	0.008
30	DGTech30 ICE_RB_250	250.00	250.00	15.00	4146.1333	0.00	0.012
31	DGTech31 MT_250	250.00	250.00	15.00	4622.30	0.00	0.0055
32	DGTech32 MCFC_300	300.00	300.00	20.00	20000.00	0.00	0.0225
33	DGTech33 PAFC_400	400.00	400.00	20.00	14000.00	0.00	0.018
34	DGTech34 ICE_LB_500	500.00	500.00	15.00	3628.1143	0.00	0.0105
35	DGTech35 ICE_LB_750	750.00	750.00	20.00	3504.1791	0.00	0.0105

DER Technologies Parameters - Help

This table shows the characteristics of potential DER technologies that are internally modeled using discrete variables.

Maxp
Nameplate capacity of technology [kW]

Maxs
Nameplate kVA capacity of technology [kVA]

Lifetime
Lifetime of technology in years [year]

Capcost
Investment costs of technology [\$/kW]

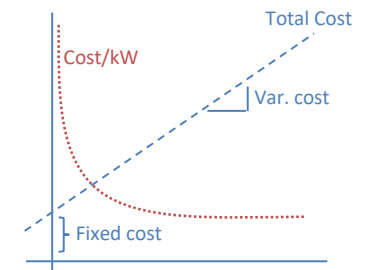
OMFix
Annual operation costs independent of output [\$/kW-year]

OMVar
Variable operation costs [\$/kWh]

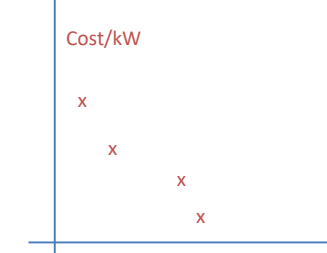
SprintCap
Sprint capacity of technology [kW]. Some technologies can exceed their nameplate capacity for a certain time to provide peak load if necessary.

SprintHours
Maximum number of hours in which sprint

“continuous”



“discrete”



4 – DER Options and Parameters

Technologies included...

Discrete:

- Conventional generators and CHP units
 - Continuous duty, load following
- Wind generators

Continuous:

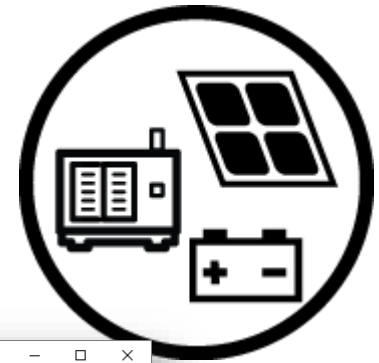
- PV, Solar Thermal
- Storage
 - Conventional, Flow Batteries, EVs, Heat storage
- Heat pumps
- Absorption chillers
- Central cooling / heating



4 – DER Options and Parameters

Existing DER...

- Do you want to fix the exact DER size?
- If so, what size you are forcing?
- Is this an existing DER?
- If so, how old is it?



The screenshot shows the DER-CAM+ software interface. The main window displays a table of 'Forced Investment Parameters' with columns for F1, F2, FixedInvest, ForcedInvestCapacity, ExistingYN, and Age. The table lists 14 rows of parameters for 'node 1'. To the right of the table is a help section for 'Continuous Forced Investment Parameter - Help'.

	F1	F2	FixedInvest	ForcedInvestCapacity	ExistingYN	Age
1	node 1	ElectricStorage	1	0	0	0
2	node 1	H2Storage	1	0	0	0
3	node 1	Electrolyzer	1	0	0	0
4	node 1	HeatStorage	1	0	0	0
5	node 1	ColdStorage	1	0	0	0
6	node 1	FlowBatteryEnergy	1	0	0	0
7	node 1	FlowBatteryPower	1	0	0	0
8	node 1	AbsChiller	1	0	0	0
9	node 1	AbsRefrigeration	1	0	0	0
10	node 1	PV	1	0	0	0
11	node 1	SolarThermal	1	0	0	0
12	node 1	EVs1	1	0	0	0
13	node 1	AirSourceHeatPump	1	0	0	0
14	node 1	GroundSourceHeatPump	1	0	0	0

Continuous Forced Investment Parameter - Help

This table allows forcing the technologies present into the solution found by DER-CAM. This can either represent technologies that already installed at the site, or technologies that desired by the user:

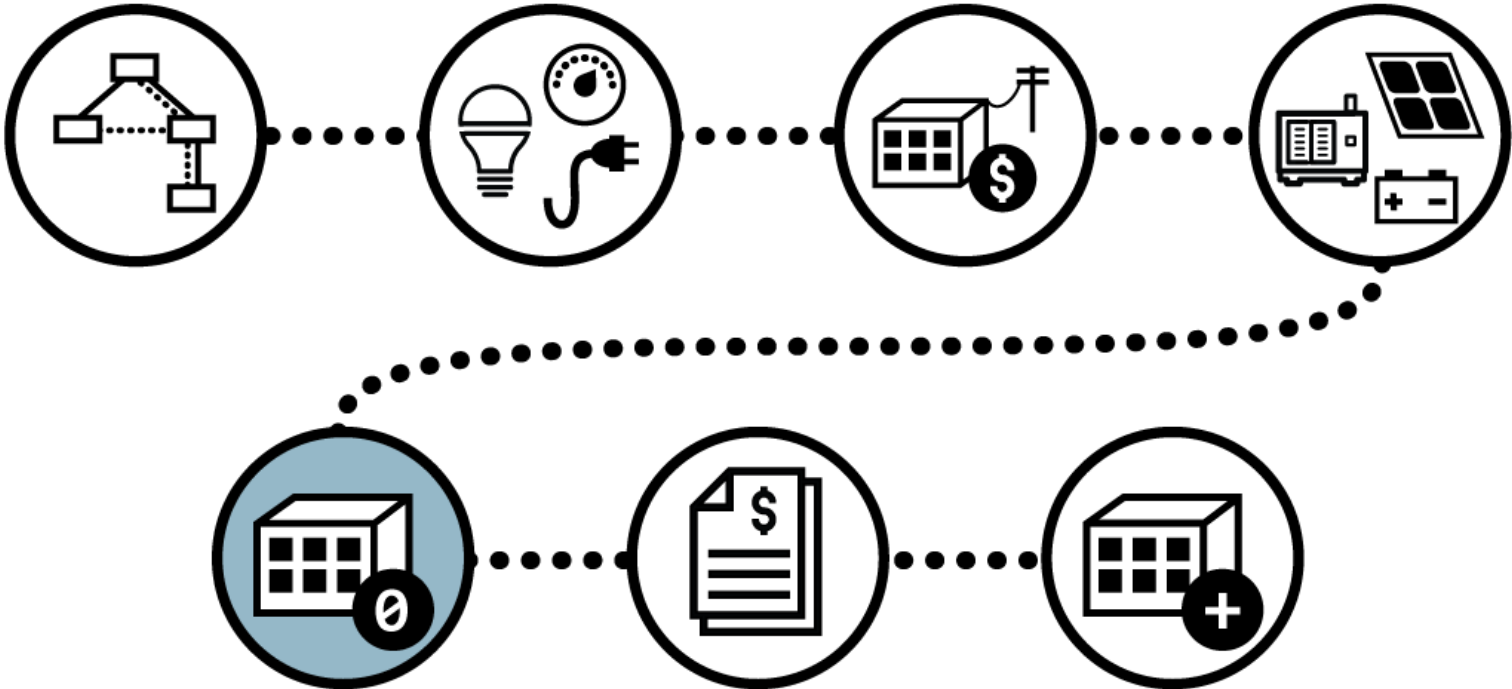
FixedInvest
A binary parameter to enable/disable forced investments.
0: Technology is not forced into the solution, it may still be installed if investments have been enabled in EnableInvest table.
1: Technology will be installed with exactly the value entered in ForcedInvestCapacity.

ForcedInvestCapacity
Minimum capacity that is forced into the solution even if ContinuousInvest is disabled in the EnableInvest table. If FixedInvest is set to 1, ForcedInvestCapacity will be the exact capacity included in the solution. Units are [kW] or [kWh].

ExistingYN
Binary parameter to determine if the forced number is existing at the site

5

Run base-case
without new DERs



5 – Running the Base Case

Base Case...

Understanding DER-CAM

Objective function:

Minimize total energy costs (or CO₂) such that:

- energy balance is preserved
 - energy supply (t) = energy demand (t)
- technologies operate within physical boundaries
 - power output (t) ≤ max output
- **financial constrains are verified**
 - **max payback**: savings obtained by the use of new DER must generate savings that repay investments within the max payback period

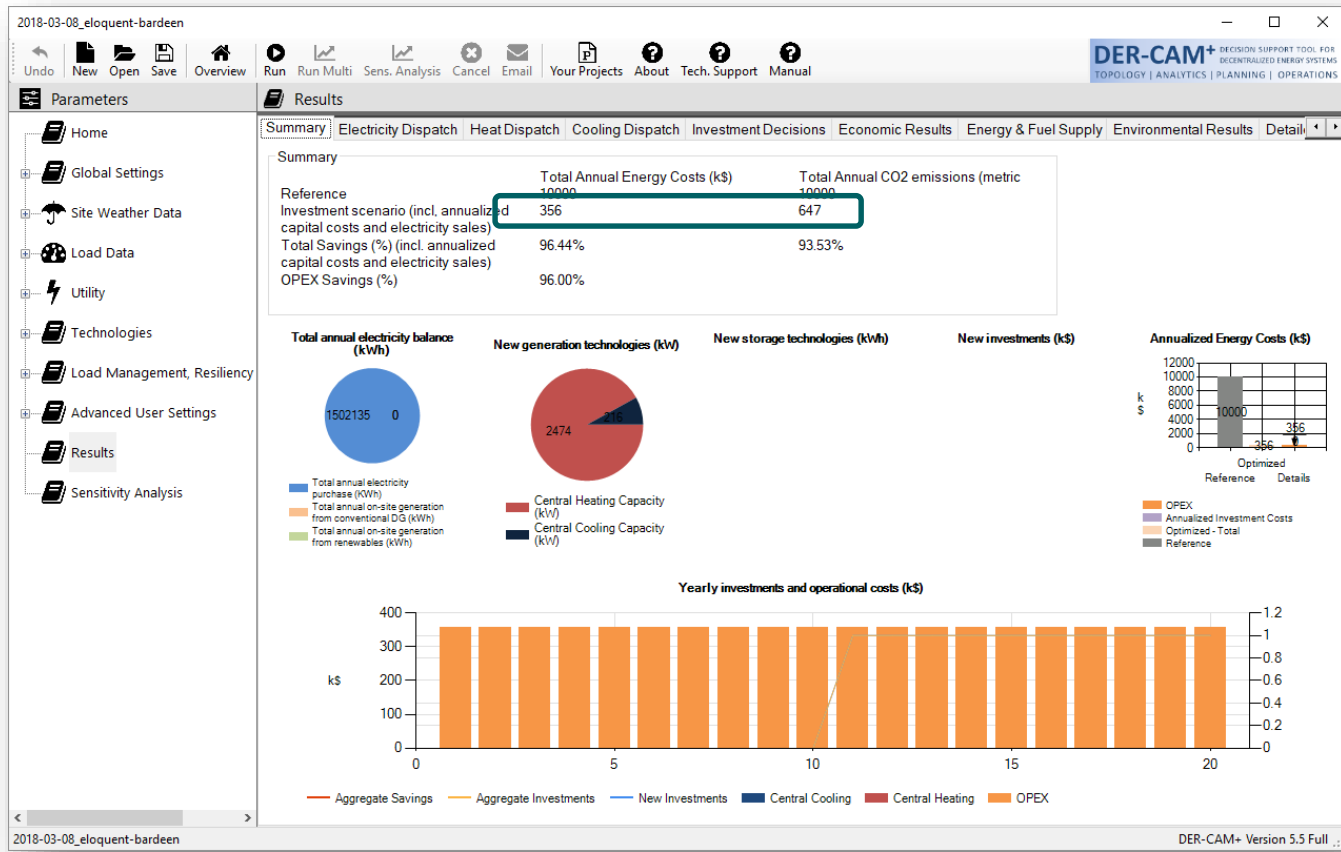


To use DER-CAM, **at least** two runs are needed: 1) Base Case; 2) Investment

5 – Running the Base Case

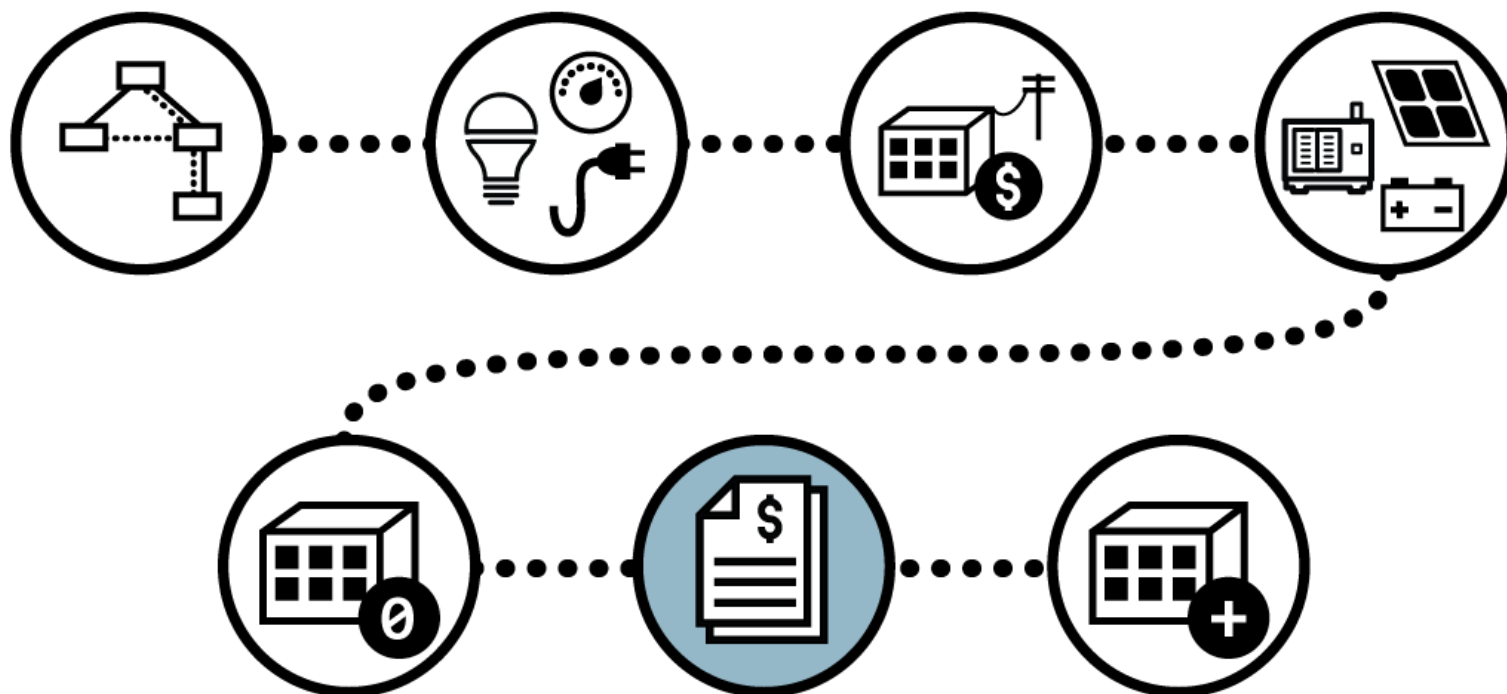
Base Case...

By default, investment is disabled on “New” models



6

Define investment options for new DERs



6 – Defining Investment Options

Investment Case...



This is where the optimization starts!

- Enable / disable technology groups
- Enable / disable specific technologies
- Define reference values (from Base Case)
- Define financial values (Payback time, discount rate)
- Run the model!

E.g. PV + Storage mode, 5% discount rate, 12 year payback

6 – Defining Investment Options

Investment Case...

Max Payback

- DER-CAM uses technologies with different lifetimes
- “Max Payback” is a global payback
- Acts as a constrain

Min (total energy costs) such that annual savings / investment \leq Max Payback

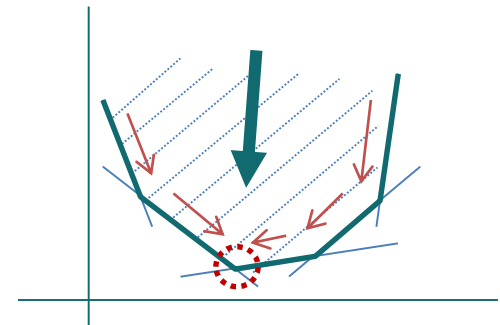


Annualized Capital Costs

- Different technology lifetimes require a method to compare them fairly
- Annualized Capital Cost is the cost per year of owning the equipment
- Total Energy Costs will include Annualized Capital Costs

Optimization algorithm

- “Greedy” approach
 - More of what is most efficient
- Solver precision & problem size
 - Flat solution space
- Indifferent preference
 - Cost vs Benefit



6 – Defining Investment Options

Investment Case...

E.g. PV + Storage mode, 5% discount rate, 12 year payback



2018-03-08_eloquent-bardeen

Parameters

Enable Investment

	F1	DiscreteInvest	ContinuousInvest	DFChillInvest
1 node1	0		1	0

Enable technology group

2018-03-08_eloquent-bardeen

Parameters

Forced Investment Parameters

	F1	F2	FixedInvest	ForcedInvestCapacity	ExistingYN	Age
1 node1	ElectricStorage		0	0	0	0
2 node1	H2Storage		1	0	0	0
3 node1	Electrolyzer		1	0	0	0
4 node1	HeatStorage		1	0	0	0
5 node1	ColdStorage		1	0	0	0
6 node1	FlowBatteryEnergy		1	0	0	0
7 node1	FlowBatteryPower		1	0	0	0
8 node1	AbsChiller		1	0	0	0
9 node1	AbsRefrigeration		1	0	0	0
10 node1	PV		0	0	0	0
11 node1	SolarThermal		1			
12 node1	EVs1		1			
13 node1	AirSourceHeatPump		1			
14 node1	GroundSourceHeatPump		1			

Enable technologies

Define reference values

2018-03-08_eloquent-bardeen

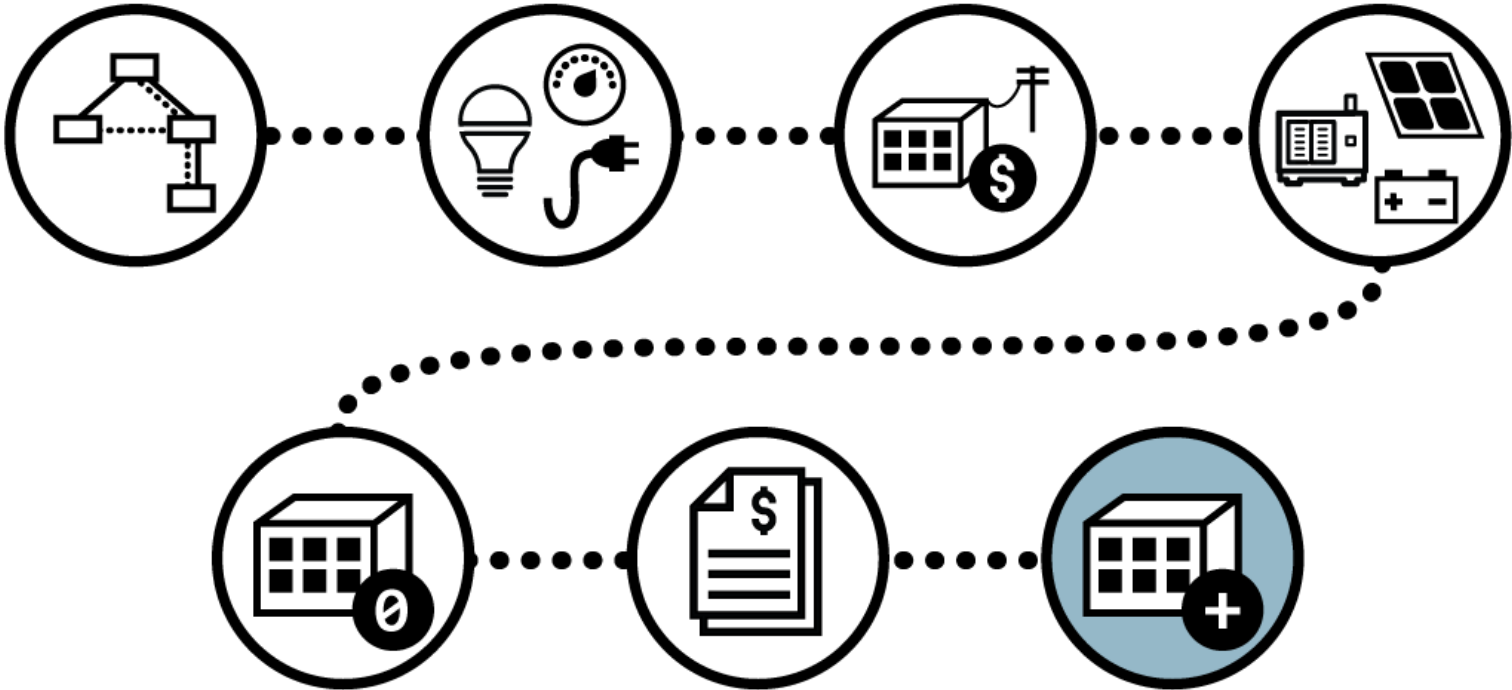
Parameters

Parameters Table

	F1	F2
1	IntRate	0.05
2	Standby	0.00
3	Contrct	0.00
4	tumvar	0.00
5	CO2Tax	0.00
6	macroeff	0.34
7	cooleff	0.00
8	BaseCaseCost	360000.00
9	BaseCaseCO2	647000.00
10	MaxPaybackPeriod	12.00
11	FractionBaseLoad	0.50
12	FractionPeakLoad	0.10

7

Run investment cases to find optimal DER capacities.



7 – Run investment case

Investment Case...

E.g. PV + Storage mode, 5% discount rate, 12 year payback



Running Optimization... [X]

1. Saving Temporary Data...
2. Authenticating with Server
3. Uploading optimization file
4. Running Optimization
5. Downloading Results

[Progress bar]

2018-03-08_eloquent-bardeen

DER-CAM+ DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
TOPOLOGY | ANALYTICS | PLANNING | OPERATIONS

Parameters Results

Summary Electricity Dispatch Heat Dispatch Cooling Dispatch Investment Decisions Economic Results Energy & Fuel Supply Environmental Re...

Summary	Total Annual Energy Costs (k\$)	Total Annual CO2 emissions (metric tons)
Reference	360	647
Investment scenario (incl. annualized capital costs and electricity sales)	321	513
Total Savings (%) (incl. annualized capital costs and electricity sales)	10.75%	20.73%
OPEX Savings (%)	27.00%	

Total annual electricity balance (kWh)

Total annual electricity purchase (kWh)	1067270
Total annual on-site generation from conventional DG (kWh)	441735
Total annual on-site generation from renewables (kWh)	

New generation technologies (kW)

Photovoltaic (kW, peak power under test conditions)	212
Central Heating Capacity (kW)	2474
Central Cooling Capacity (kW)	

New storage technologies (kWh)

Stationary Battery Capacity (kWh)	207
-----------------------------------	-----

New investments (k\$)

Photovoltaic	104
Stationary Battery	532

Annualized Energy Costs (k\$)

Reference	360
Optimized	321
Details	263

Yearly investments and operational costs (k\$)

Aggregate Savings (red line), Aggregate Investments (orange line), New Investments (blue bars), Central Cooling (dark blue bars), Central Heating (red bars), Photovoltaic (yellow bars), Stationary Battery (teal bars), OPEX (orange bars).

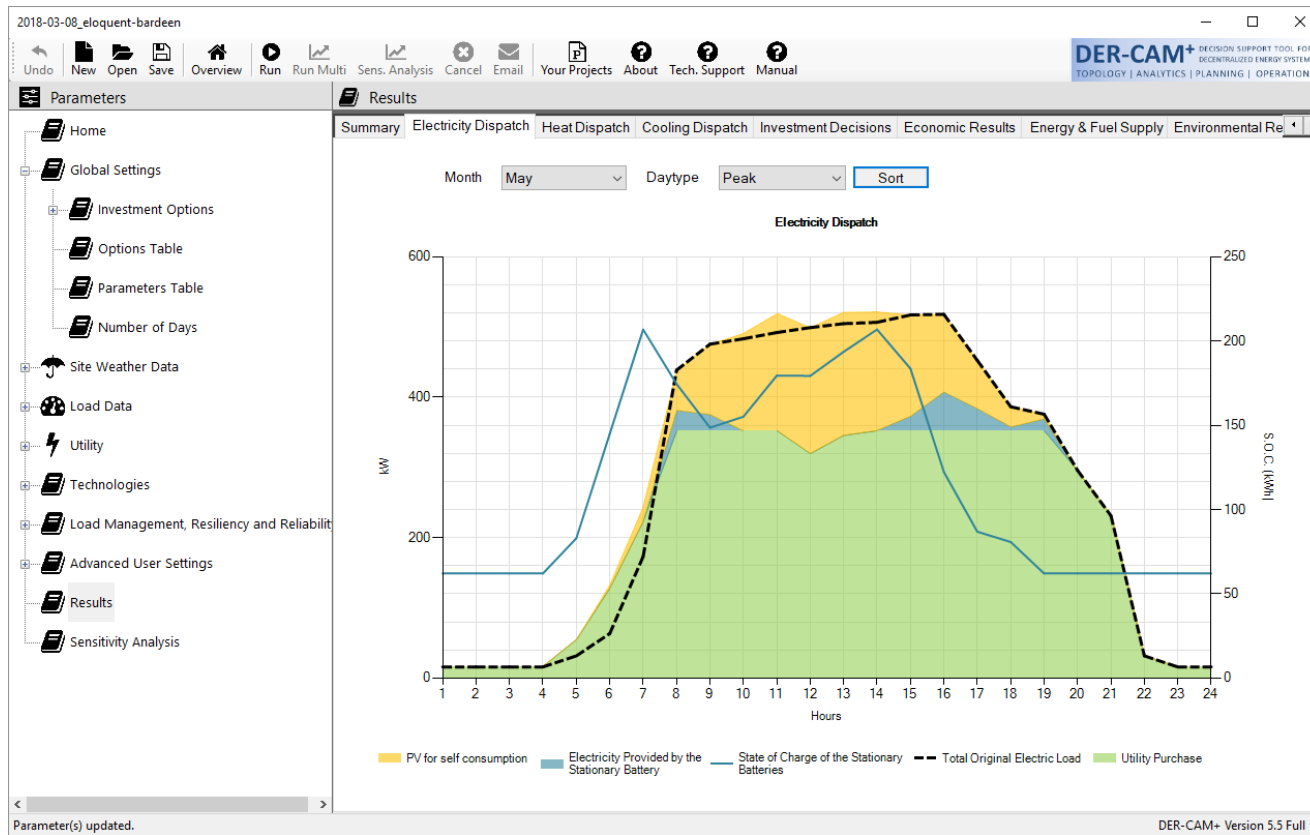
Parameter(s) updated.

DER-CAM+ Version 5.5 Full ...

7 – Run investment case

Investment Case...

E.g. PV + Storage mode, 5% discount rate, 12 year payback



THE END

Contact Information:

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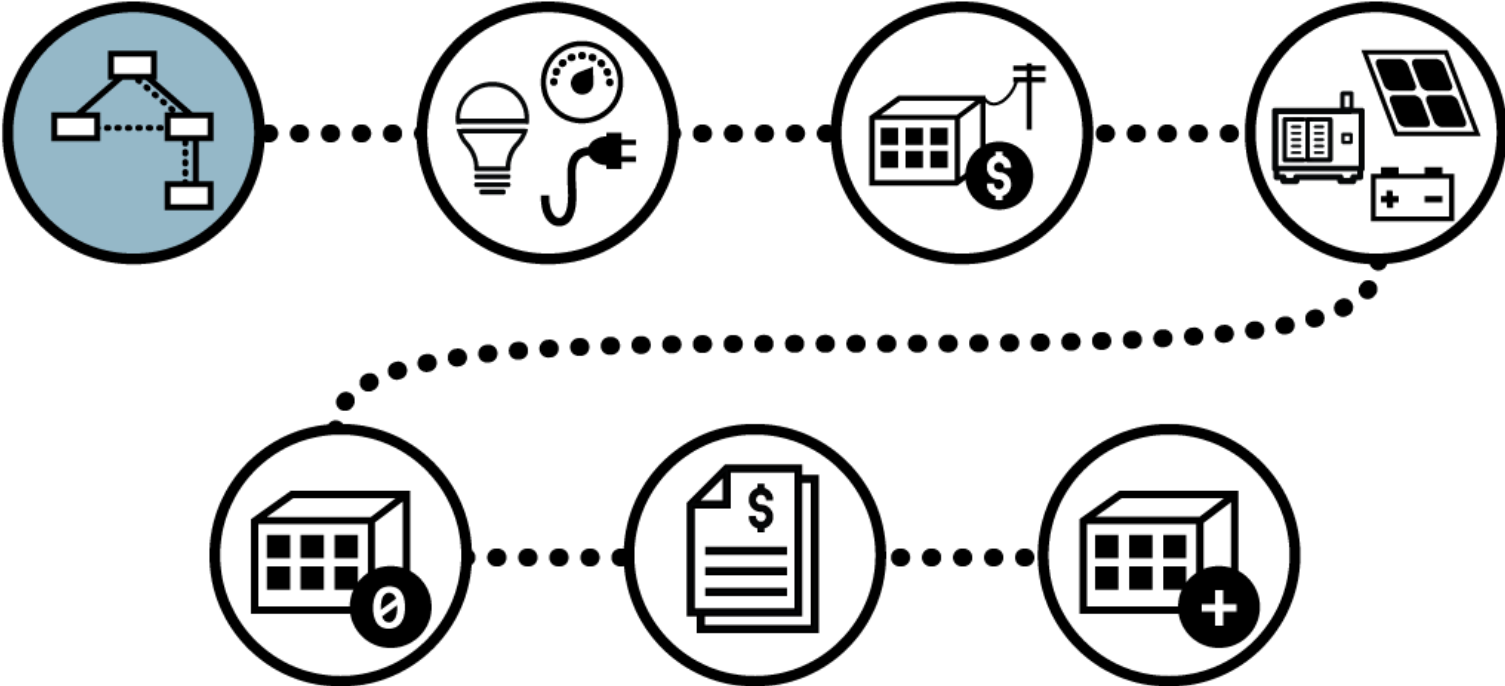
Nicholas DeForest
ndeforest@lbl.gov

Miguel Heleno
mheleno@lbl.gov

<http://building-microgrid.lbl.gov/>

1

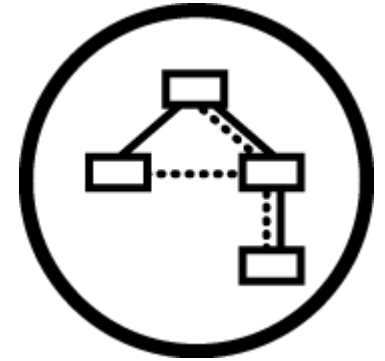
Define topology or select single-node model



1 – Define Topology

Start by deciding between single or multi-node

- Single node models can be a good first approach
- Faster to solve, less data required
- Ideal if loads can be aggregated:
 - Strong network, no loss or voltage concerns
 - Optimal DER placement not required
- Multi-node models provide additional depth
- (Optimal) power flow and heat flow is integrated in the analysis
- Optimal DER placement is provided
- Choosing between single or multi-node happens when creating a new project
- This decision cannot be changed later on

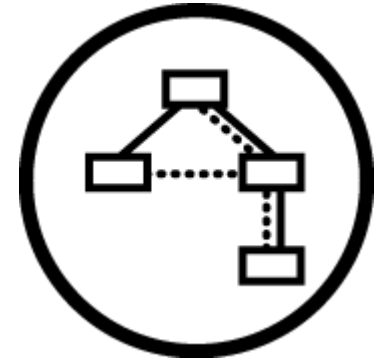
A screenshot of a software dialog box titled "New Project". It contains the following fields and options:

- Project Name: 2018-03-07_optimistic-future|
- Radio buttons: DER-CAM Multi Node and DER-CAM Single Node
- Version: DER-CAM+ Version 5.6 Full (with a dropdown arrow)

1 – Define Topology

If you selected multi-node...

- Single node models do not require further topology definition
- For multi-node models, the next steps consist of:
 - Creating nodes (up to 20)
 - Establishing connectivity
 - Defining the characteristics of the topology elements



To create a new node..

- Pick “Topology” from the menu
- Right-click grey area to “Add Node”
- You can have up to 20 nodes

2018-03-07_infallible-gates

DER-CAM+ DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
TOPOLOGY | ANALYTICS | PLANNING | OPERATIONS

Parameters Topology

Options Database Drag nodes with left click. Use right click to access properties of node/edge.

Node 1 Bus 1

Node 3 Bus 3

Node 2 Bus 2

Add Node

X: 0073 Y: 0324

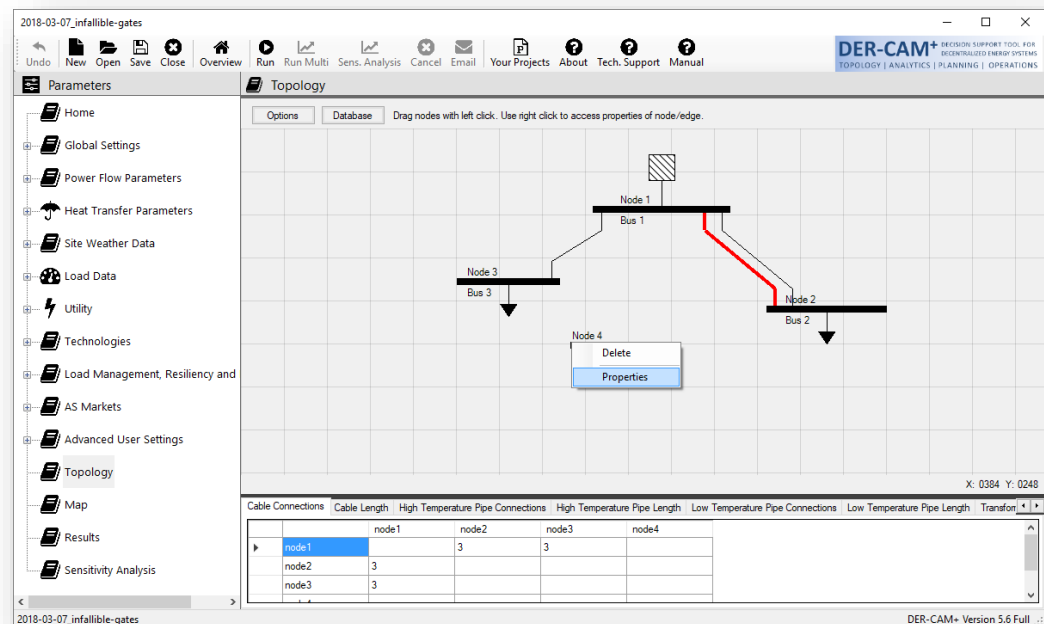
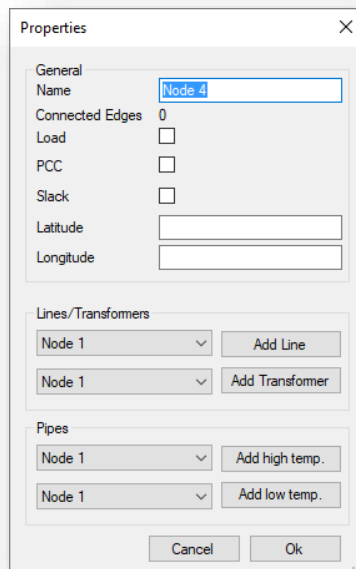
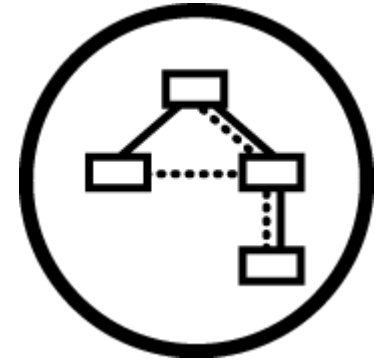
Cable Connections	Cable Length	High Temperature Pipe Connections	High Temperature Pipe Length	Low Temperature Pipe Connector
node1	3	3	3	
node2	3			
node3	3			

2018-03-07_infallible-gates DER-CAM+ Version 5.6 Full ..

1 – Define Topology

To establish connectivity...

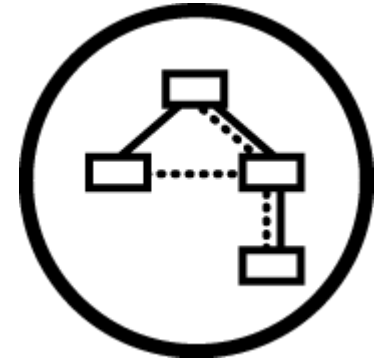
- Right-click any node and select “Properties”
- Define key properties of that node:
 - Does it have a load?
 - Is this where the microgrid connects to the utility (Point of common coupling)?
 - Should this be the “slack” / reference node for load flow calculations?
 - Where is this node located? (lat. / long.)
- Establish connectivity to other nodes:
 - Add line, transformer, high temperature, or low temperature pipe between this and any other node



1 – Define Topology

To define the characteristics of topology elements...

- Define the properties of relevant elements under “Power Flow Parameters” or “Heat Transfer Parameters” or use predefined
- In “Topology” view, right-click an element and select “Properties”
- Choose one of the options from the “Type” dropdown box



2018-03-07_infallible-gates

DER-CAM+ DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
TOPOLOGY | ANALYTICS | PLANNING | OPERATIONS

Parameters Cable Parameters

CableNo	Description	Cost	LifeTime	Res	Ind
1	CableType1 CU_XLPE_PVC_12kV_3CORE_25mm2	0.00	30.00	0.00000064375	0.000000868055E
2	CableType2 CU_XLPE_PVC_12kV_3CORE_35mm2	0.00	30.00	0.00000464583333333333	0.000000833333
3	CableType3 CU_XLPE_PVC_12kV_3CORE_50mm2	0.00	30.00	0.00000343055555555556	0.0000007986111
4	CableType4 CU_XLPE_PVC_12kV_3CORE_70mm2	0.00	30.00	0.00000238888888888889	0.000000763888E
5	CableType5 CU_XLPE_PVC_12kV_3CORE_95mm2	0.00	30.00	0.0000017152777777778	0.000000743055E
6	CableType6 CU_XLPE_PVC_12kV_3CORE_120mm2	0.00	30.00	0.000001361111111111111	0.000000722222E
7	CableType7 CU_XLPE_PVC_12kV_3CORE_150mm2	0.00	30.00	0.00000118055555555556	0.000000708333E
8	CableType8 CU_XLPE_PVC_12kV_3CORE_185mm2	0.00	30.00	0.000000895833333333333	0.0000006875
9	CableType9 CU_XLPE_PVC_12kV_3CORE_240mm2	0.00	30.00	0.0000006875	0.0000006736111
10	CableType10 CU_XLPE_PVC_12kV_3CORE_300mm2	0.00	30.00	0.000000565972222222222	0.000000645833E
11	CableType11 CU_XLPE_PVC_12kV_3CORE_400mm2	0.00	30.00	0.000000458333333333333	0.000000625
12	CableType12 AL_XLPE_PVC_12kV_3CORE_25mm2	0.00	30.00	0.000010694444444444444	0.000000868055E
13	CableType13 AL_XLPE_PVC_12kV_3CORE_35mm2	0.00	30.00	0.000007729166666666667	0.000000833333E
14	CableType14 AL_XLPE_PVC_12kV_3CORE_50mm2	0.00	30.00	0.000005708333333333333	0.0000007986111
15	CableType15 AL_XLPE_PVC_12kV_3CORE_70mm2	0.00	30.00	0.000003951388888888889	0.000000763888E
16	CableType16 AL_XLPE_PVC_12kV_3CORE_95mm2	0.00	30.00	0.000002854166666666667	0.000000743055E
17	CableType17 AL_XLPE_PVC_12kV_3CORE_120mm2	0.00	30.00	0.000002256944444444444	0.000000722222E
18	CableType18 AL_XLPE_PVC_12kV_3CORE_150mm2	0.00	30.00	0.000001840277777777778	0.000000708333E
19	CableType19 AL_XLPE_PVC_12kV_3CORE_185mm2	0.00	30.00	0.000001472222222222222	0.0000006875
20	CableType20 AL_XLPE_PVC_12kV_3CORE_240mm2	0.00	30.00	0.000001131944444444444	0.0000006736111
21	CableType21 AL_XLPE_PVC_12kV_3CORE_300mm2	0.00	30.00	0.000000909722222222222	0.000000645833E
22	CableType22 AL_XLPE_PVC_12kV_3CORE_400mm2	0.00	30.00	0.000000718055555555556	0.000000625
23	CableType23 AL_XLPE_PVC_12kV_3CORE_400mm2	0.00	30.00	0.000000718055555555556	0.000000625
24	CableType24 AL_XLPE_PVC_12kV_3CORE_400mm2	0.00	30.00	0.000000718055555555556	0.000000625
25	CableType25 AL_XLPE_PVC_12kV_3CORE_400mm2	0.00	30.00	0.000000718055555555556	0.000000625

Cable Parameters - Help

This table allows setting cable parameters.

Cost
Cable cost (\$/m)

LifeTime
Cable lifetime used for annuity rate calculation [years]

Res
Cable resistance calculated based on Sbase given in the Power Flow Parameters table [pu/m]

Ind
Cable inductance calculated based on Sbase given in the Power Flow Parameters table [pu/m]

Ampacity
Cable ampere capacity (ampacity)

DER-CAM+ Version 5.6 Full ...

Topology

Options Database Drag nodes w

Properties

General

Name new Edge

Start Node Node 3

End Node Node 4

Electricity

Cable-Type CU_XLPE_PVC_12kV_3CORE

Cost CU_XLPE_PVC_12kV_3CORE

Lifetime CU_XLPE_PVC_12kV_3CORE

Resistance CU_XLPE_PVC_12kV_3CORE

Inductance CU_XLPE_PVC_12kV_3CORE

Ampacity CU_XLPE_PVC_12kV_3CORE

Cable Length (m) AL_XLPE_PVC_12kV_3CORE

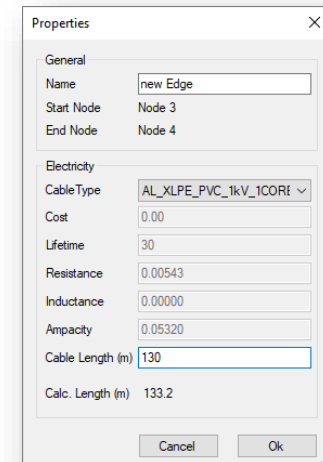
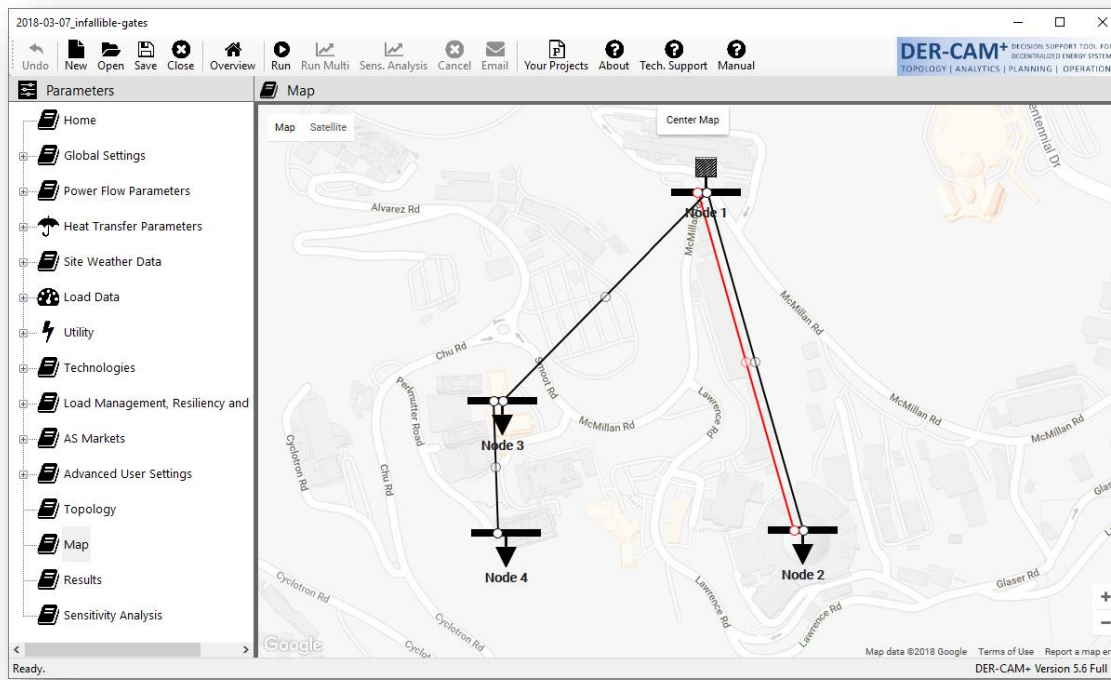
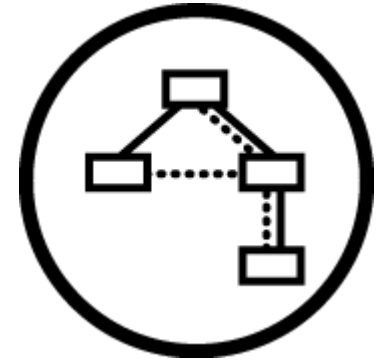
Calc. Length (m) AL_XLPE_PVC_12kV_3CORE

High Temper

1 – Define Topology

One extra step...

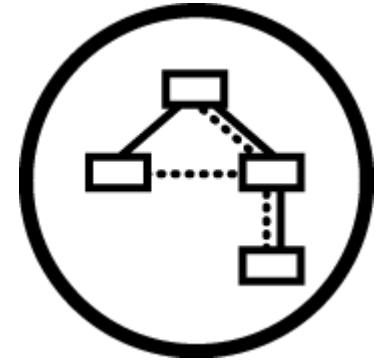
- “Map” view is also available
- Requires at least one node to have lat./long. values
- Moving nodes in the Map view updates estimated lengths
- Length used for calculation is always user-defined



1 – Define Topology

Not quite over yet...

- Two power flow models are available (radial / meshed)
- Some overall options are available, including:
 - Is this a DC network?
 - Are loads purely resistive, or include active / reactive power consumption?
- Each model can be further specified, including:
 - Min / Max acceptable voltage levels
 - Enabling / disabling the current or voltage magnitude constraints



Each option and parameter is documented in the right side, including references and additional recommendations

The screenshot shows the DER-CAM software interface. The 'Options' window is open, displaying a table with two columns, F1 and F2, and six rows of options. The 'Enable' option is selected in the F1 column.

	F1	F2
1	Enable	1
2	ModelNo	1
3	EnableLoadVAR	0
4	EnablePreOptPQLimit	0
5	EnableGenPQLimit	0
6	#DCSystem	0

The right side of the interface shows a help document titled 'Power Flow Optimizations - Help'. The text explains that the table allows setting key power flow options and provides detailed descriptions for 'Enable', 'ModelNo', and 'EnableLoadVAR'.

Power Flow Optimizations - Help

This table allows setting some of the key power flow options.

Enable
This binary parameter is used to enable/disable power flow in the model. If disabled, power flow equations and constraints won't be included, and hence, technology placement in the network will be arbitrary.
0: Disable power flow equations; 1: Enable power flow equations

ModelNo
This integer parameter determines the power flow model to be used for the study and is only relevant if Enable=1. Currently, there are two power flow models in DER-CAM. Model 1 is based on the linear model proposed in [\[http://dx.doi.org/10.1109/TPWRS.2015.2395452\]](http://dx.doi.org/10.1109/TPWRS.2015.2395452) and is applicable to some medium-voltage meshed/radial microgrids. Model 2 is based on the LinDistFlow model proposed in [\[http://dx.doi.org/10.1109/PSCC.2014.7038399\]](http://dx.doi.org/10.1109/PSCC.2014.7038399) and is applicable to medium-voltage radial microgrids. Model 2 is also used for DC radial networks (when #DCSystem set to 1).
1: Power flow model 1 is used; 2: Power flow model 2 is used

EnableLoadVAR
.....