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

BERKELEY LAB

Before we begin…

Simulation vs Optimization

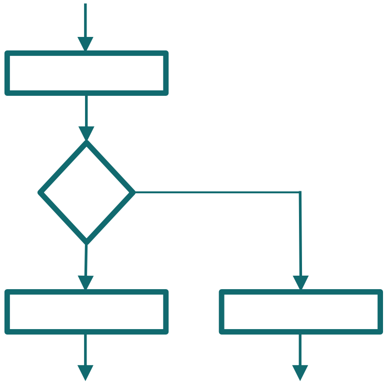
Simulation:

- 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):

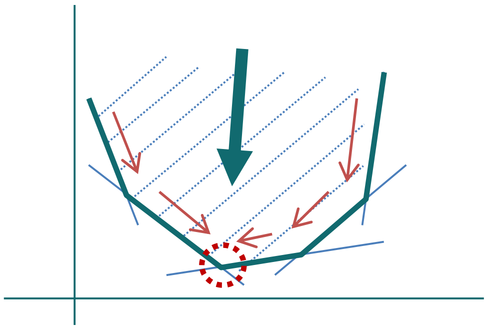
- Define boundaries for each variable

  Min <= *Battery SOC* <= *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

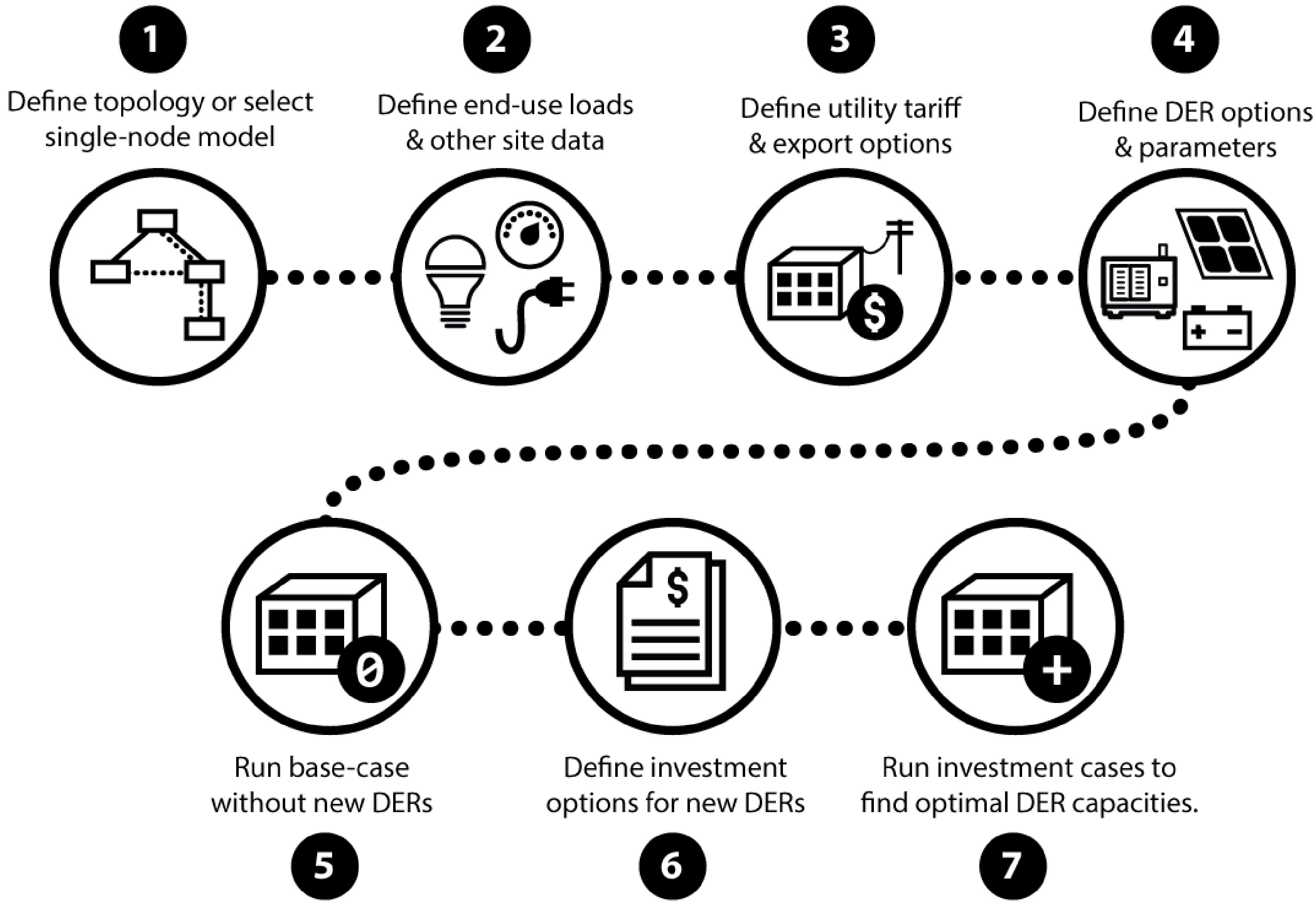
- Energy loads
- Electricity & fuel prices
- DER technologies
- Local weather
- Topology

Many variables!

DER-CAM

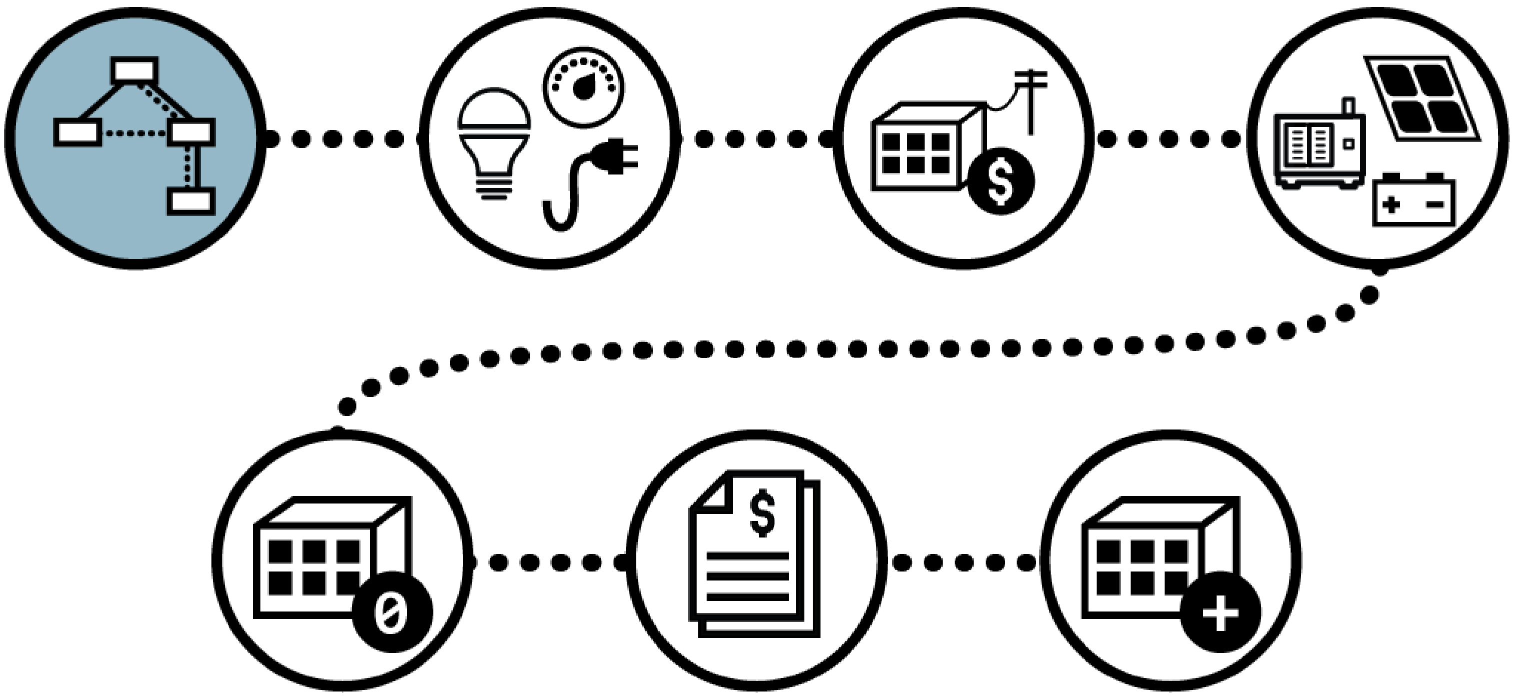
- Optimal DER Portfolio
- Optimal DER Sizing
- Optimal DER Placement
- Optimal DER dispatch

DER-CAM Project Workflow:

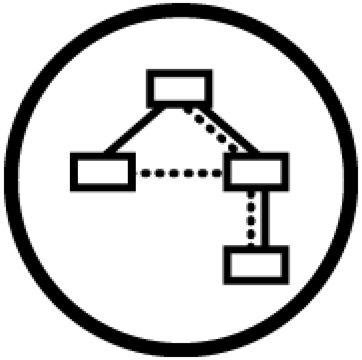


1

Define topology or select single-node model



1 – Define Topology

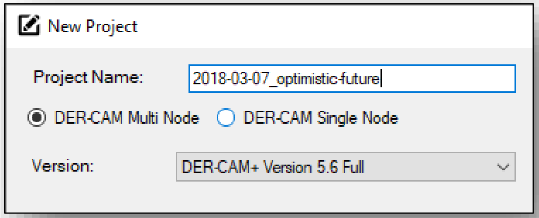


Start by deciding between single or multi-node

- 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

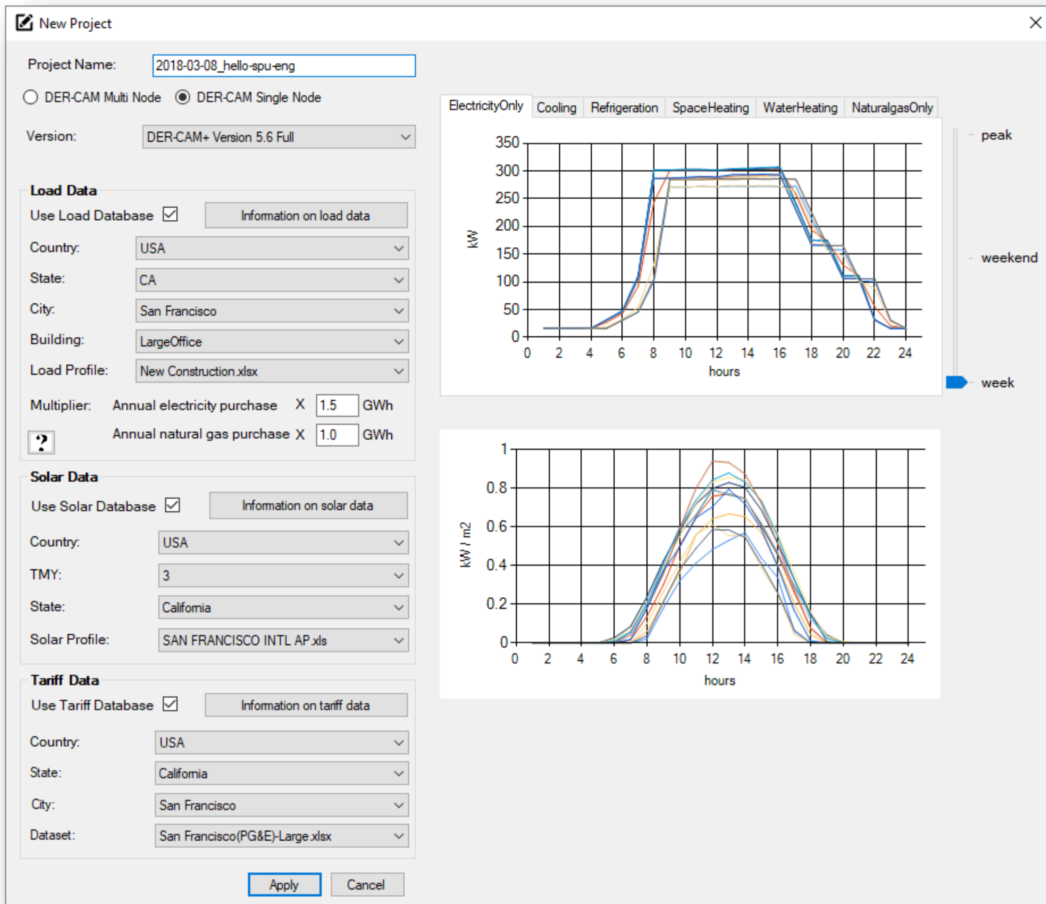
- Choosing between single or multi-node happens when creating a new project
- This decision cannot be changed later on

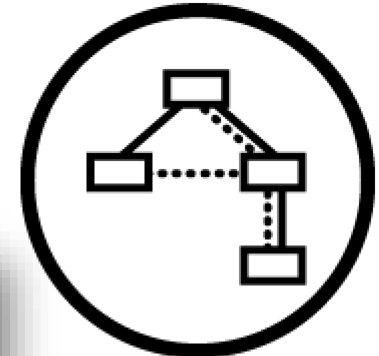


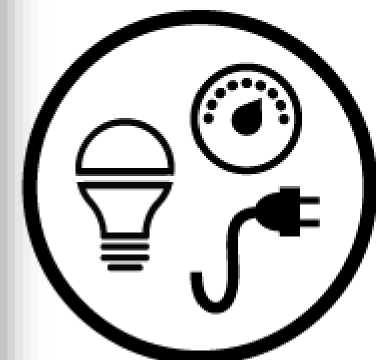
1+2+3 – Using the databases

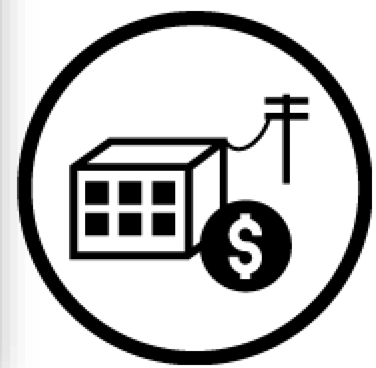
Single node example…

- Large Office Building in San Francisco



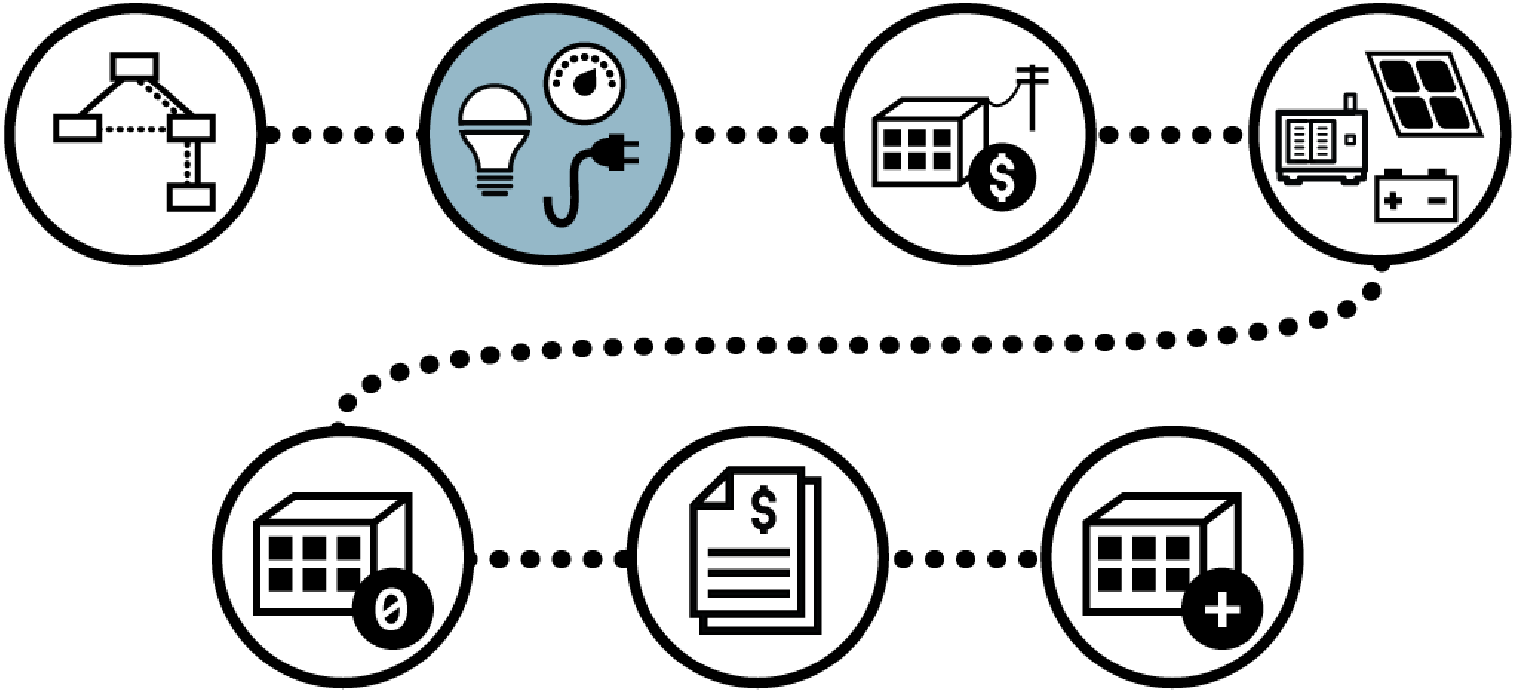




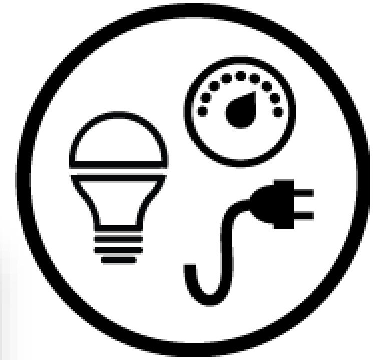


2

Define end-use loads & other site data

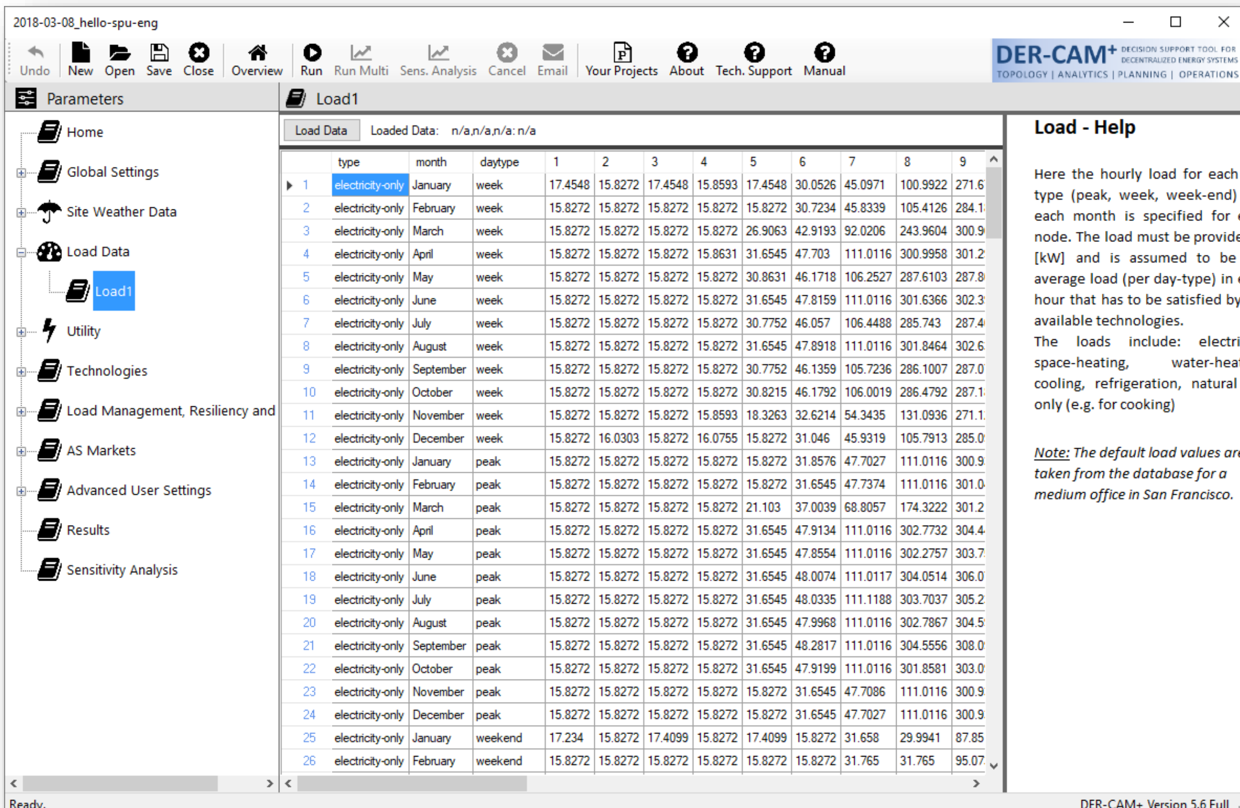


2 – End-use loads and site data



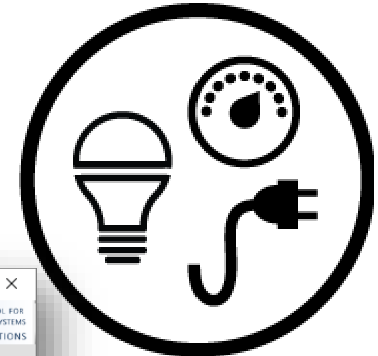
End-use loads…

- Up to 3(+3) “design days” per month



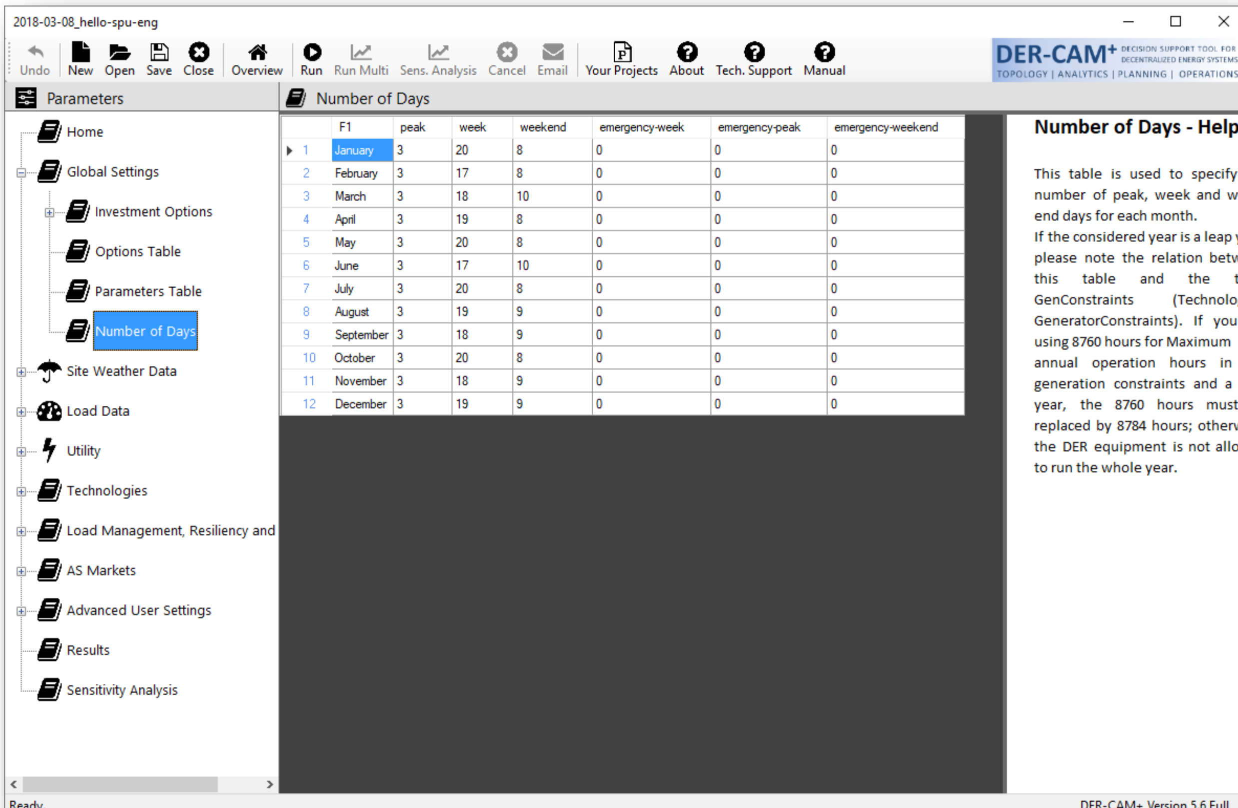
	type	month	daytype	1	2	3	4	5	6	7	8	9
1	electricity-only	January	week	17.4548	15.8272	17.4548	15.8593	17.4548	30.0526	45.0971	100.9922	271.6
2	electricity-only	February	week	15.8272	15.8272	15.8272	15.8272	15.8272	30.7234	45.8339	105.4126	284.1
3	electricity-only	March	week	15.8272	15.8272	15.8272	15.8272	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

2 – End-use loads and site data



End-use loads…

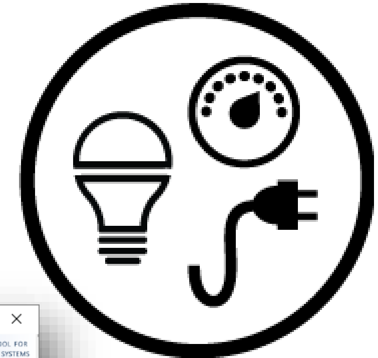
- Up to 3(+3) “design days” per month

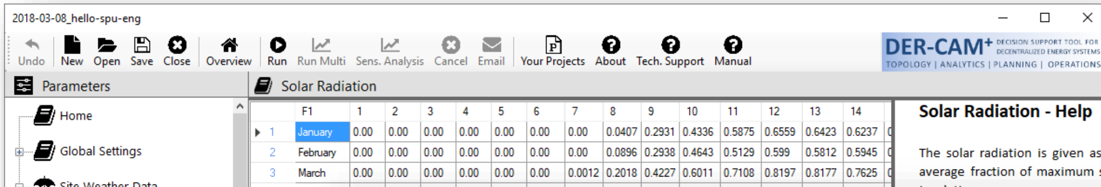
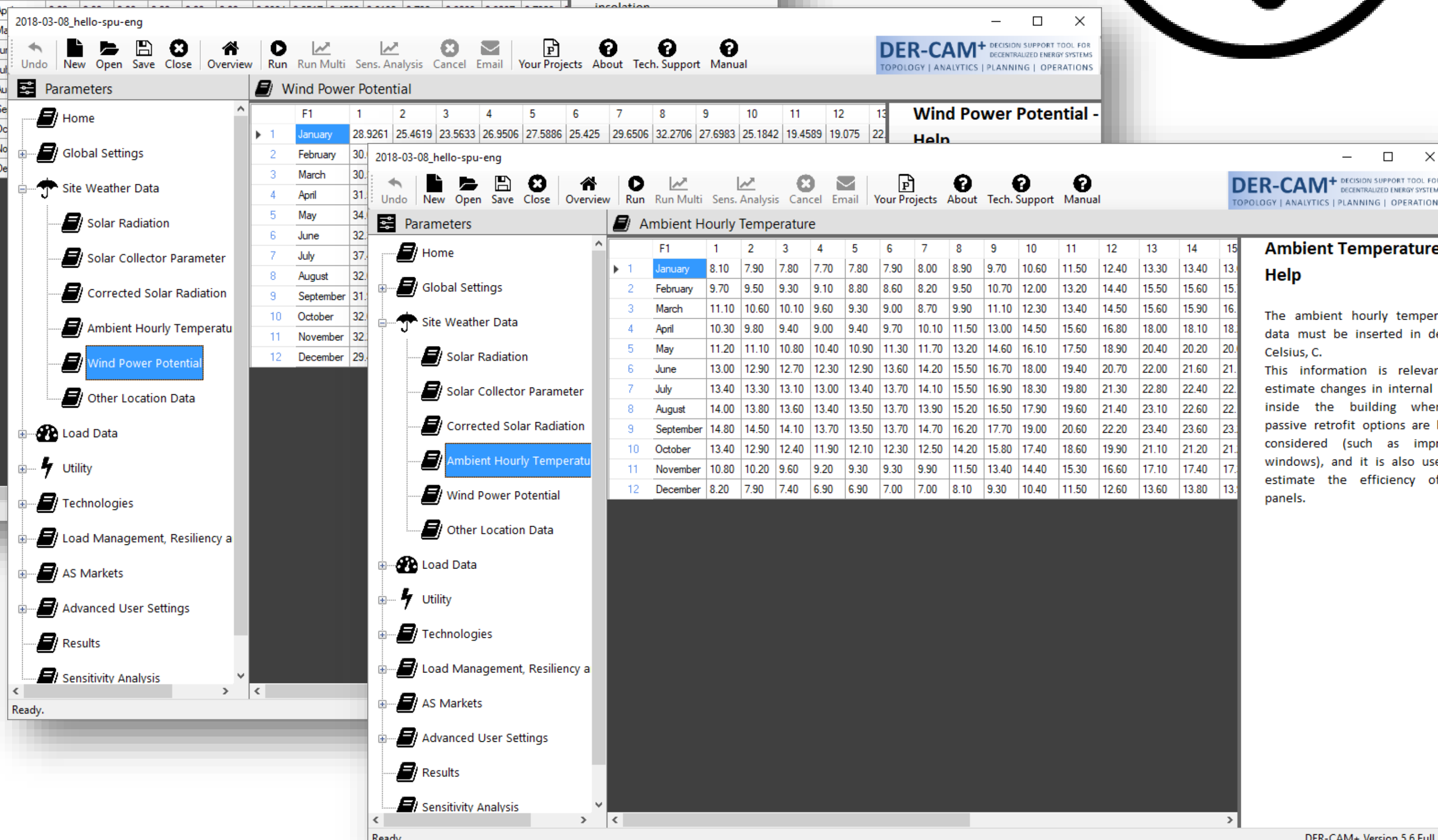
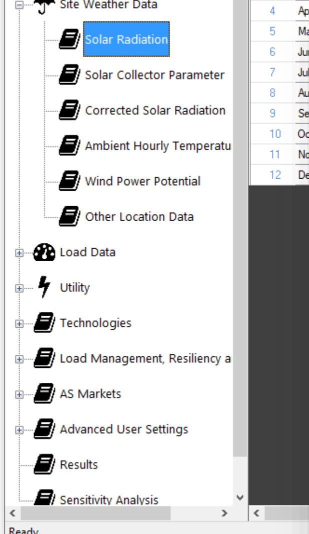


	F1	peak	week	weekend	emergency-week	emergency-peak	emergency-weekend
1	January	3	20	8	0	0	0
2	February	3	17	8	0	0	0
3	March	3	18	10	0	0	0
4	April	3	19	8	0	0	0
5	May	3	20	8	0	0	0
6	June	3	17	10	0	0	0
7	July	3	20	8	0	0	0
8	August	3	19	9	0	0	0
9	September	3	18	9	0	0	0
10	October	3	20	8	0	0	0
11	November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

2 – End-use loads and site data

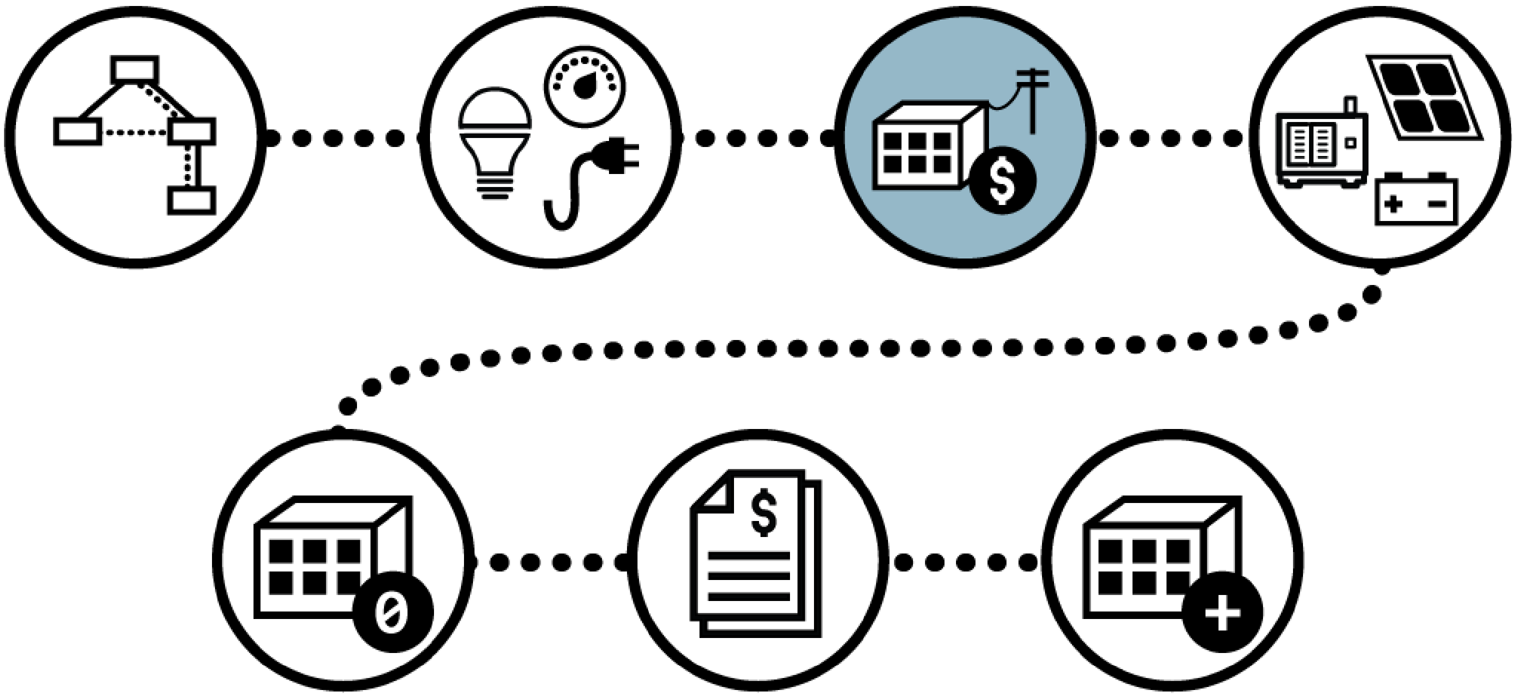
Other site data…



3

Define utility tariff & export options



3 – Utility tariffs and export options

Electricity and fuel prices…

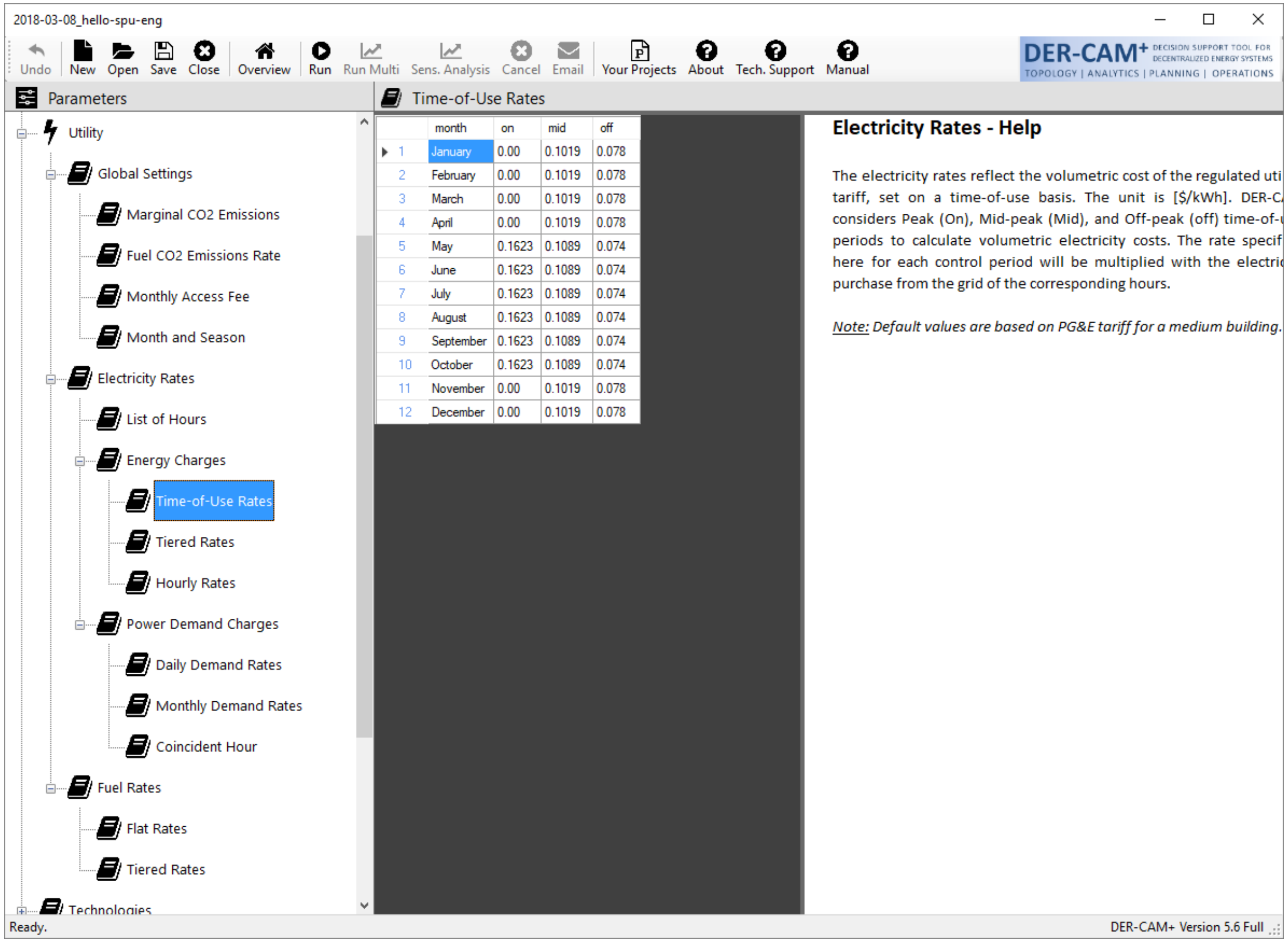
				Secondary	Primary	Transmission		Secondary	Primary	Transmission
E-19 TOU	$3.94267 per meter per day	Summer	Max. Peak	$9.71	$8.91	$7.03	Peak	$0.14026	$0.13861	$0.09129
			Part Peak	$3.33	$3.06	$2.78	Part Peak	$0.09916	$0.09219	$0.08665
			Maximum	$16.04	$12.08	$7.87	Off Peak	$0.07512	$0.07456	$0.07043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

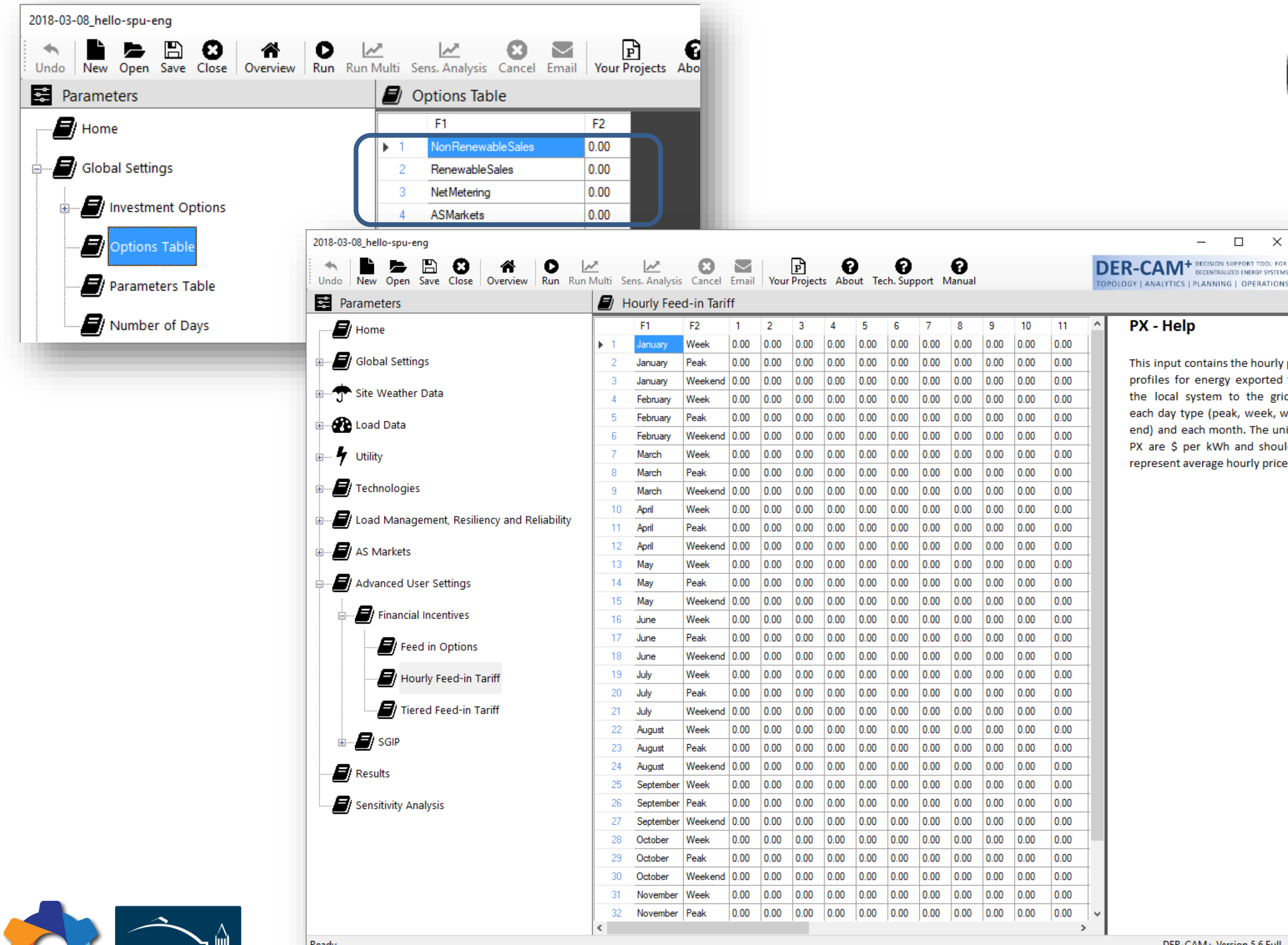
Electricity and fuel prices…

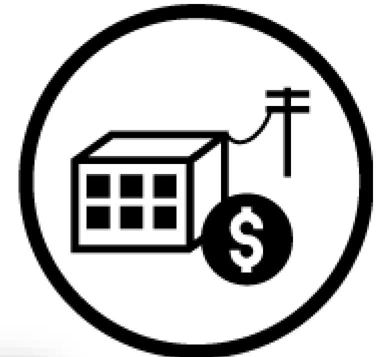


Hint: to create a microgrid model from the perspective of the utility or DSO tariffs can be replaced by costs they would incur to serve clients

3 – Utility tariffs and export options

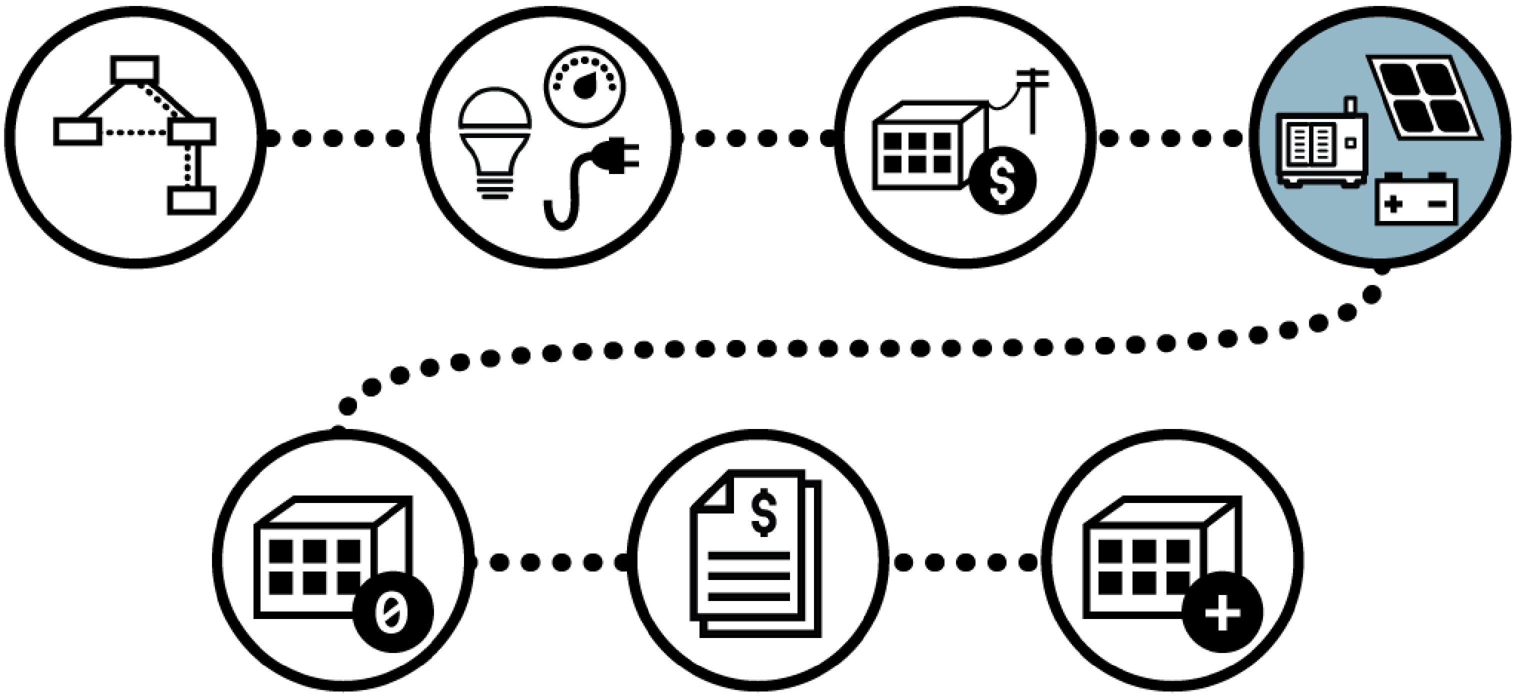
Export Options…





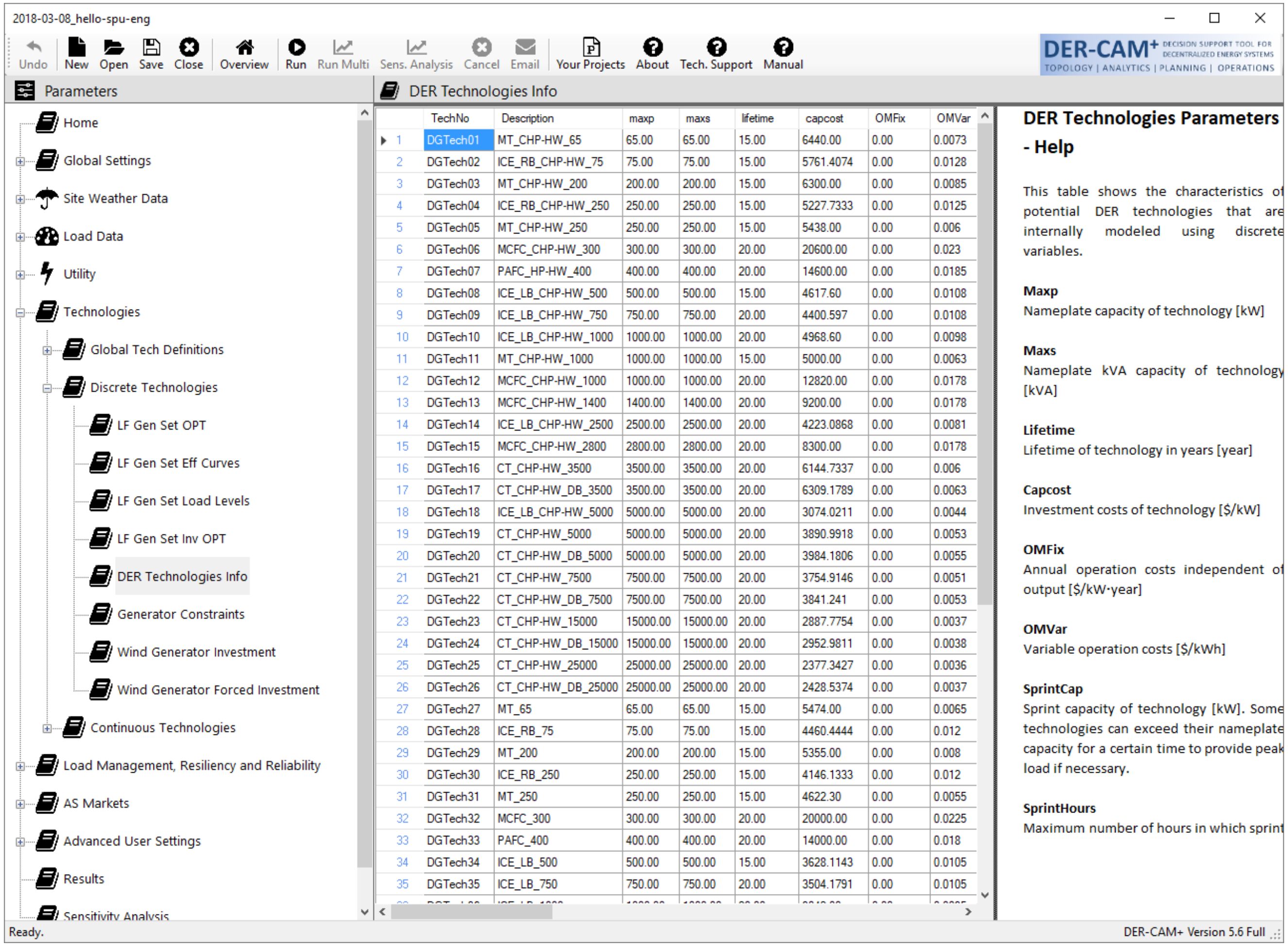
4

Define DER options & parameters

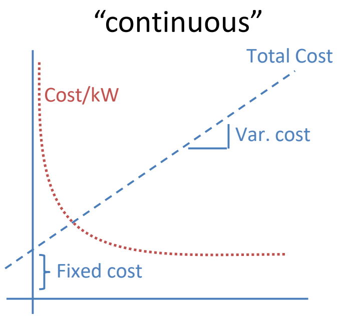


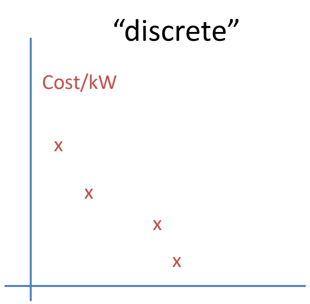
4 – DER Options and Parameters

Continuous vs Discrete!?



	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





4 – DER Options and Parameters

Technologies included…

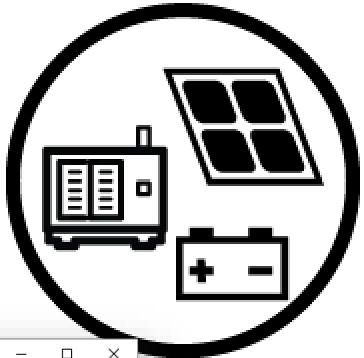
Discrete:

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

Continuous:

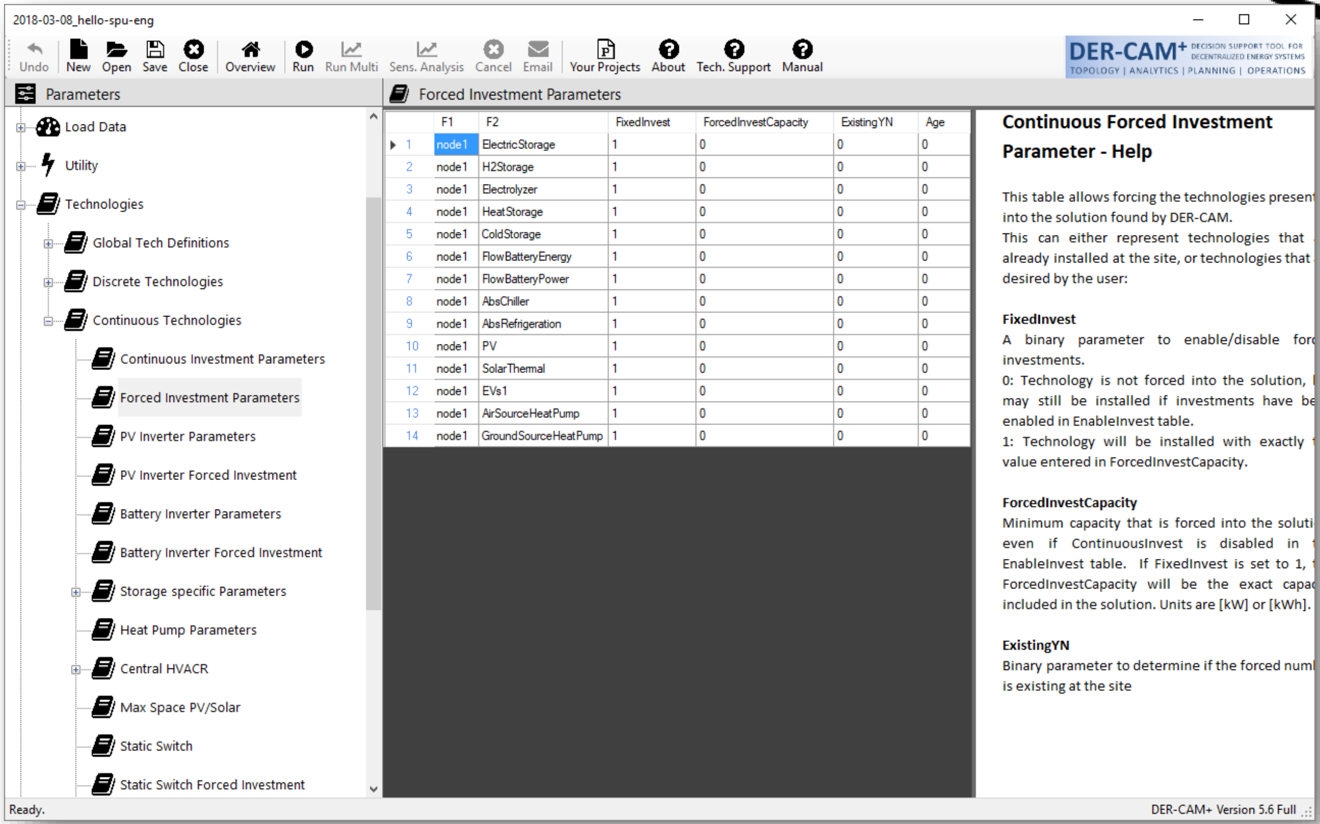
- PV, Solar Thermal
- Storage
  - Conventional, Flow Batteries, EVs, Heat storage
- Heat pumps
- Absorption chillers
- Central cooling / heating

4 – DER Options and Parameters



Existing DER…

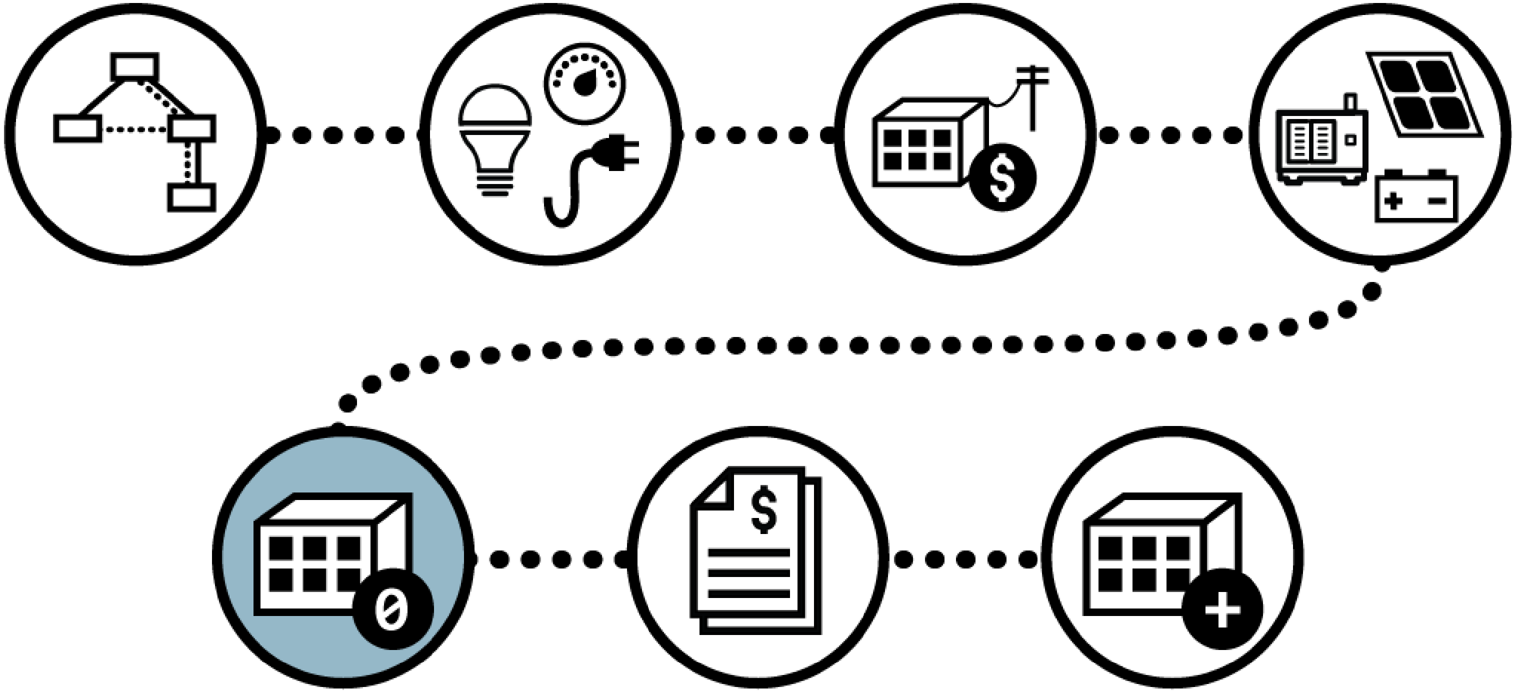
- Do you want to fix the exact DER size?
- If so, what size you are forcing?
- Is this an existing DER?
- If so, how old is it?



	F1	F2	FixedInvest	ForcedInvestCapacity	ExistingYN	Age
1	node1	ElectricStorage	1	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	1	0	0	0
11	node1	SolarThermal	1	0	0	0
12	node1	EVs1	1	0	0	0
13	node1	AirSourceHeatPump	1	0	0	0
14	node1	GroundSourceHeatPump	1	0	0	0

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:

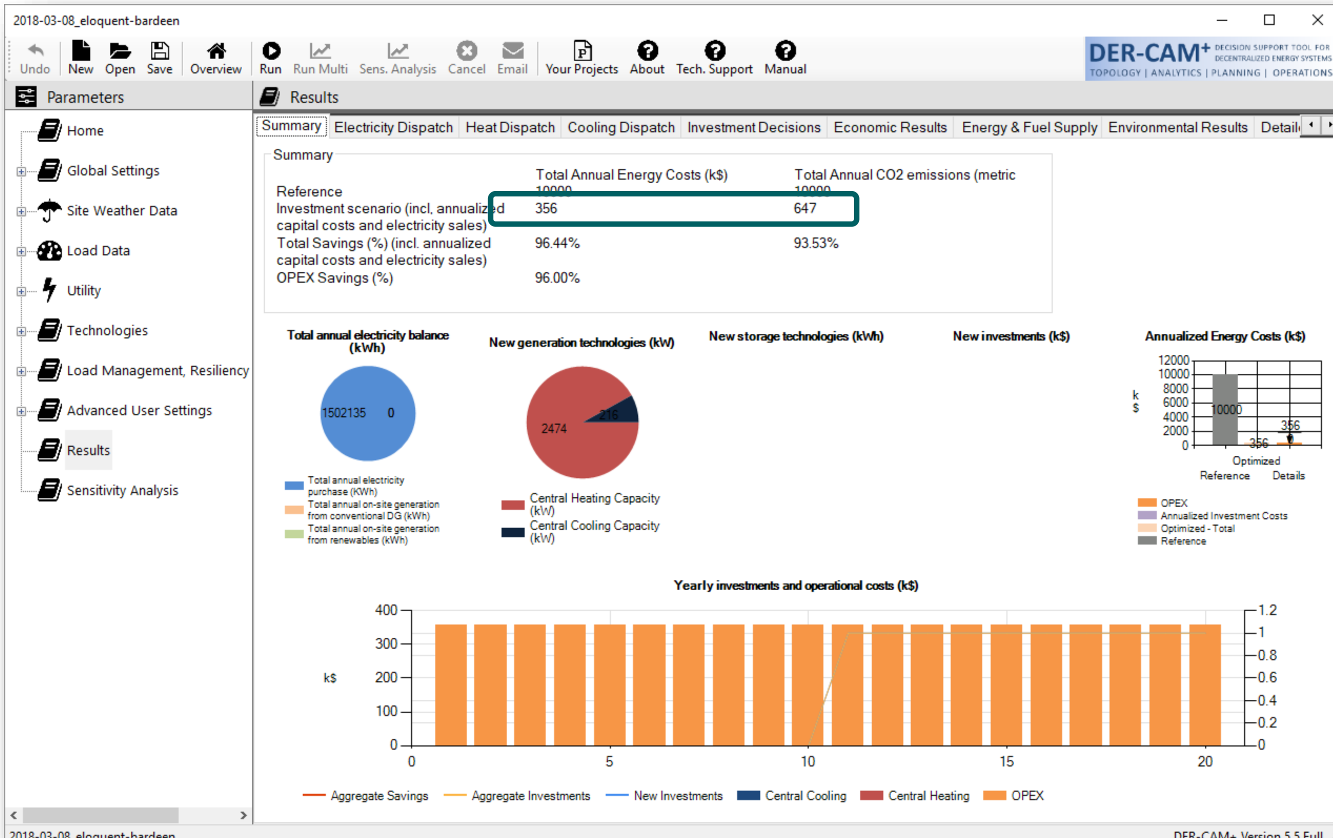
- energy balance is preserved
  - energy supply (t) = energy demand (t)
- technologies operate within physical boundaries
  - power output (t) <= max output
- ***financial constrains are verified***
  - **max payback**: savings obtained by the use of new DER must generate savings that repay investments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

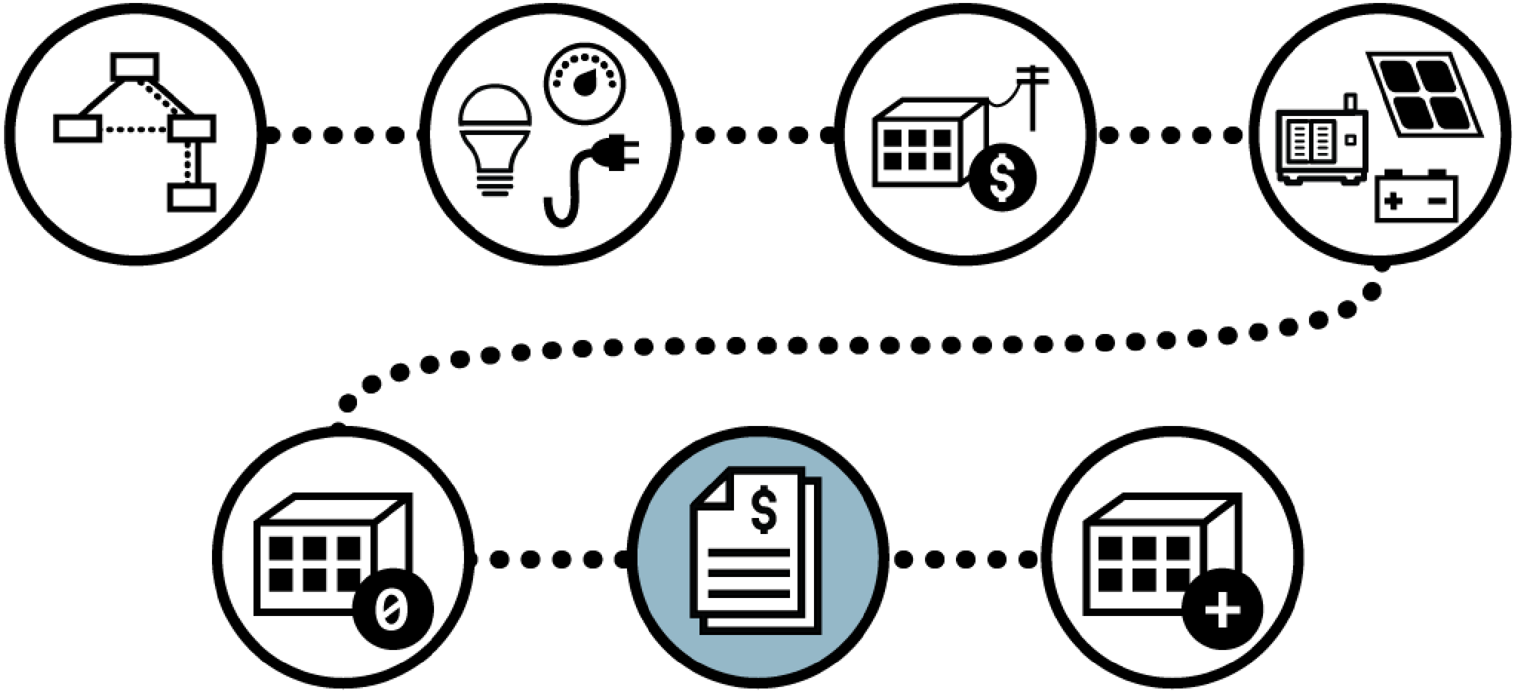
Base Case…

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…

<u>Max Payback</u>

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

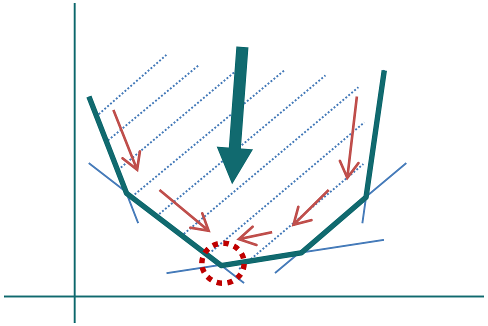
Min (total energy costs) such that annual savings / investment <= Max Payback

<u>Annualized Capital Costs</u>

- 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

<u>Optimization algorithm</u>

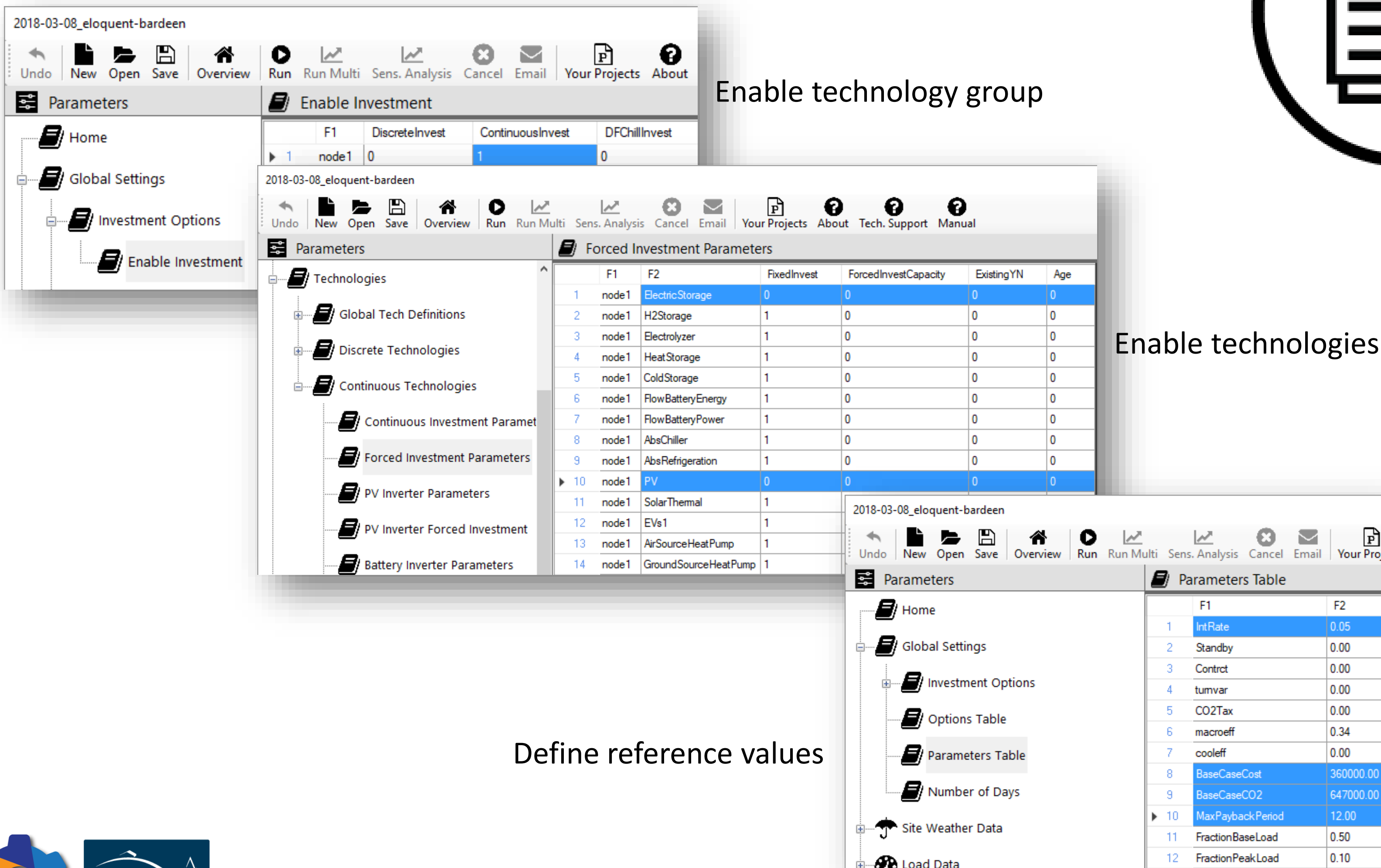
- “Greedy” approach
  - More of what is most efficient
- Solver precision & problem size
  - Flat solution space
- Indifferent preference
  - Cost vs Benefit



6 – Defining Investment Options

Investment Case…

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



	F1	DiscreteInvest	ContinuousInvest	DFChillInvest
1	node1	0	1	0

Enable technology group

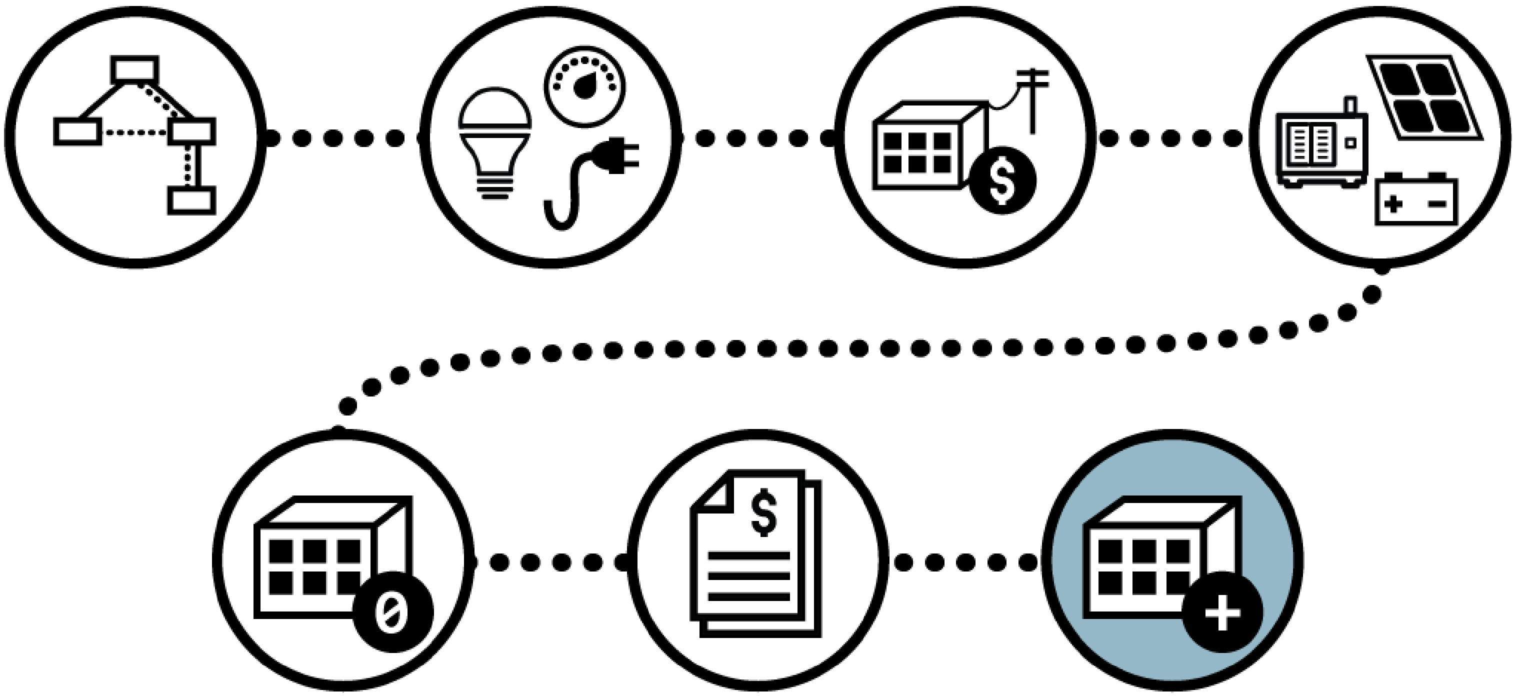
	F1	F2	FixedInvest	ForcedInvestCapacity	ExistingYN	Age
1	node1	ElectricStorage	0	0	0	0
2	node1	H2Storage	1	0	0	0
3	node1	Electrolyzer	1	0	0	0
4	node1	HeatStorage	1	0	0	0
5	node1	ColdStorage	1	0	0	0
6	node1	FlowBatteryEnergy	1	0	0	0
7	node1	FlowBatteryPower	1	0	0	0
8	node1	AbsChiller	1	0	0	0
9	node1	AbsRefrigeration	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

	F1	F2
1	IntRate	0.05
2	Standby	0.00
3	Contrct	0.00
4	turnvar	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

Define reference values

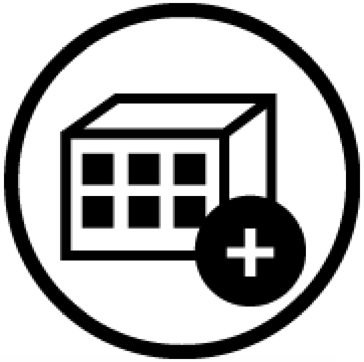
Run investment cases to
find optimal DER capacities.

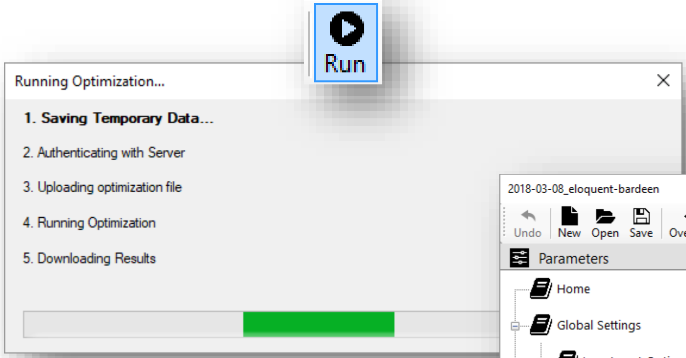


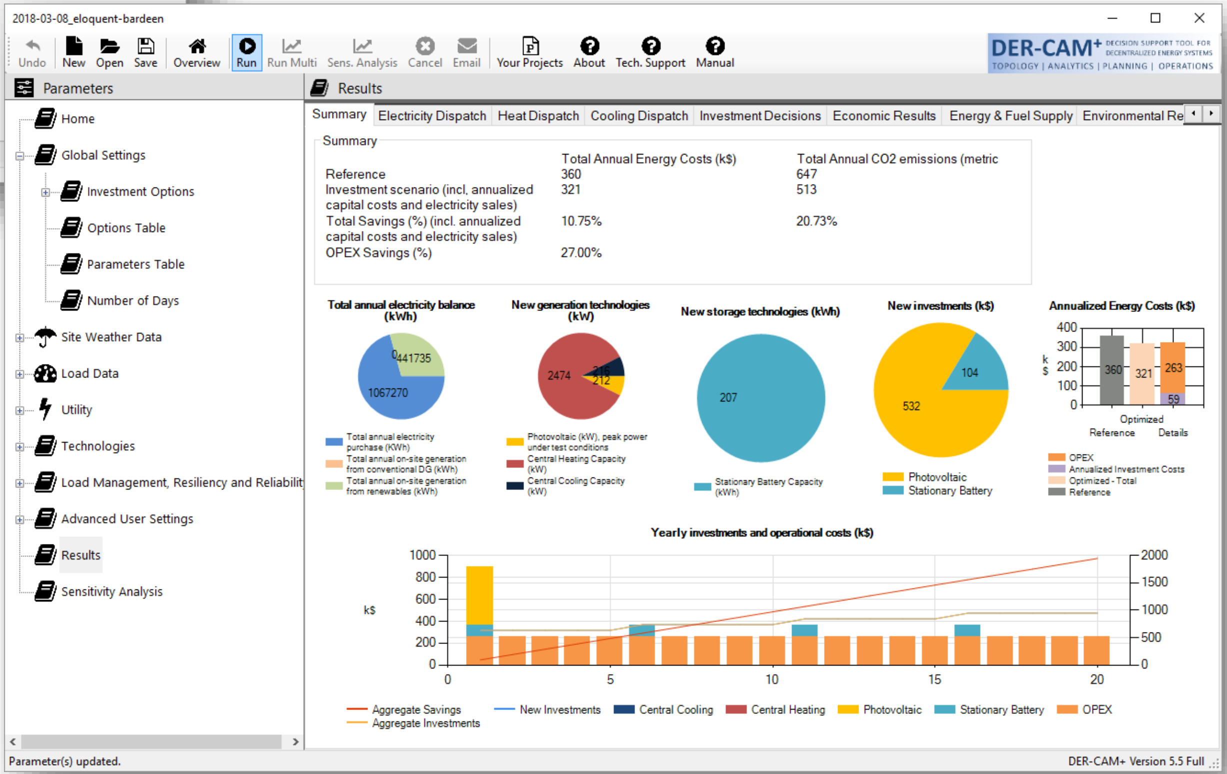
7 – Run investment case

Investment Case…

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



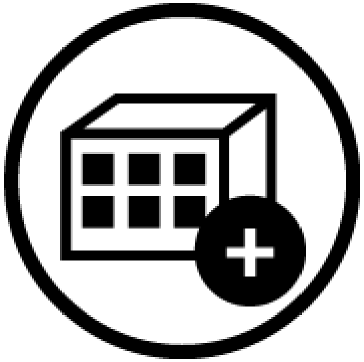


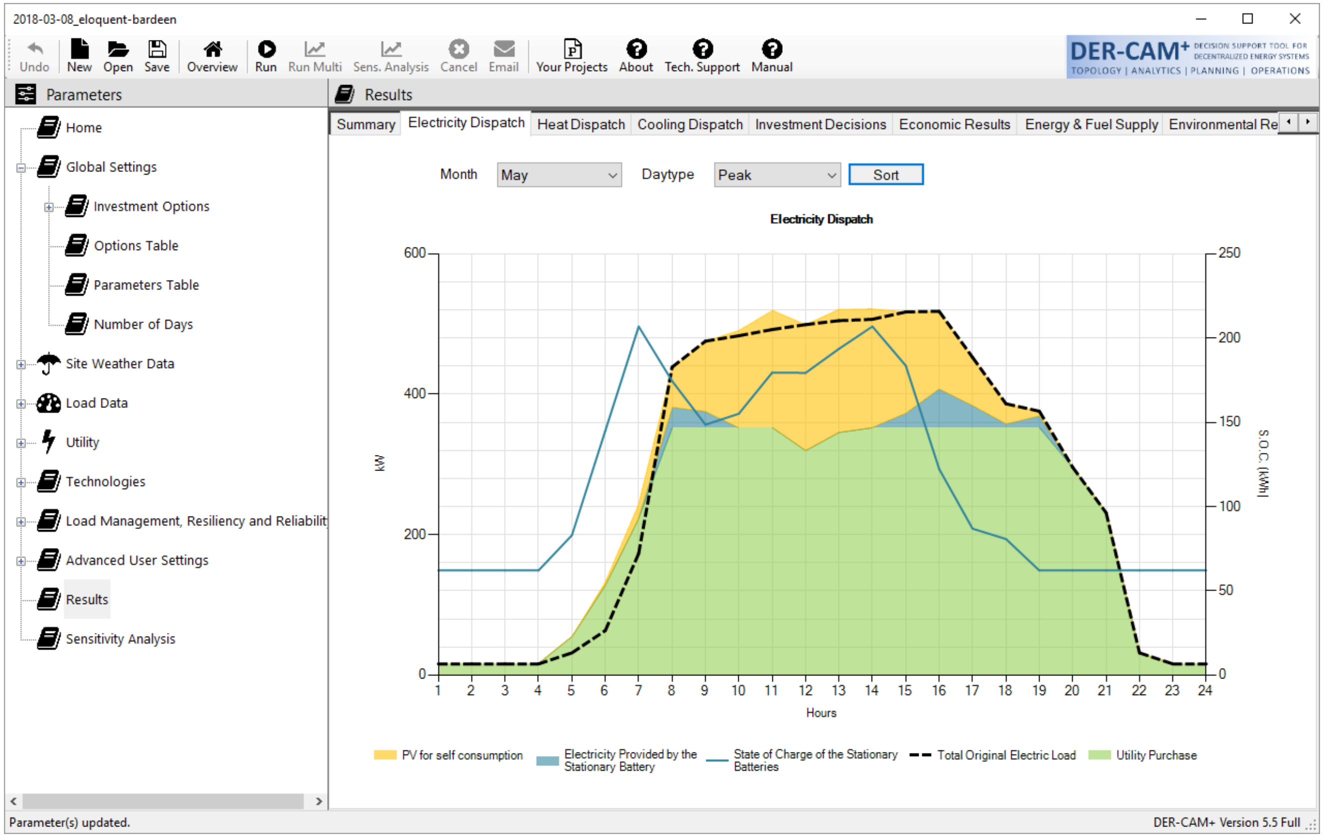


7 – Run investment case

Investment Case…

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





THE END

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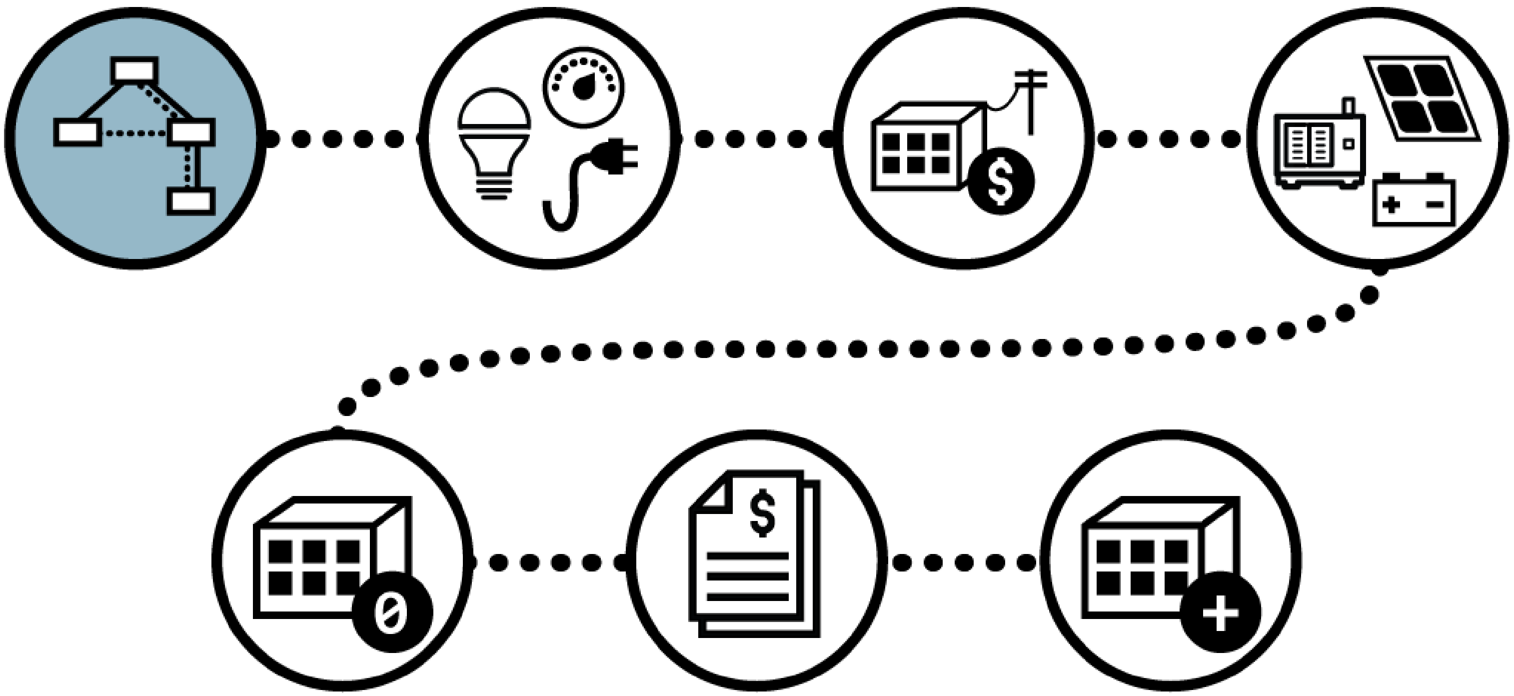
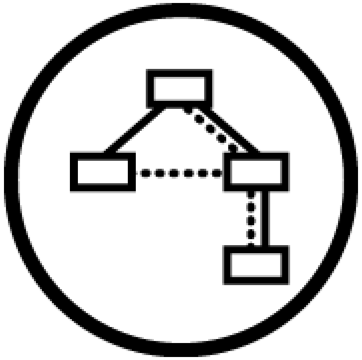
1

Define topology or select single-node model



1 – Define Topology

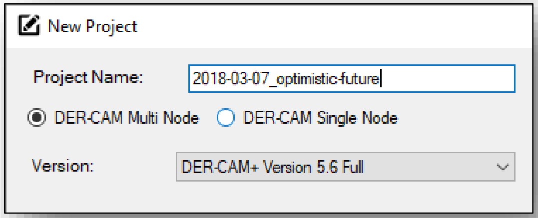


Start by deciding between single or multi-node

- 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

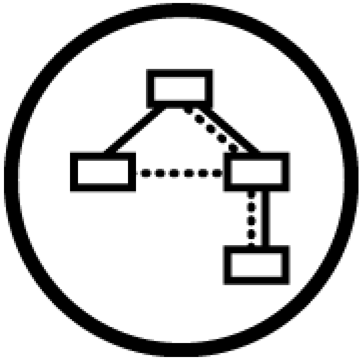
- Multi-node models provide additional depth
- (Optimal) power flow and heat flow is integrated in the analysis
- Optimal DER placement is provided

- Choosing between single or multi-node happens when creating a new project
- This decision cannot be changed later on



1 – Define Topology

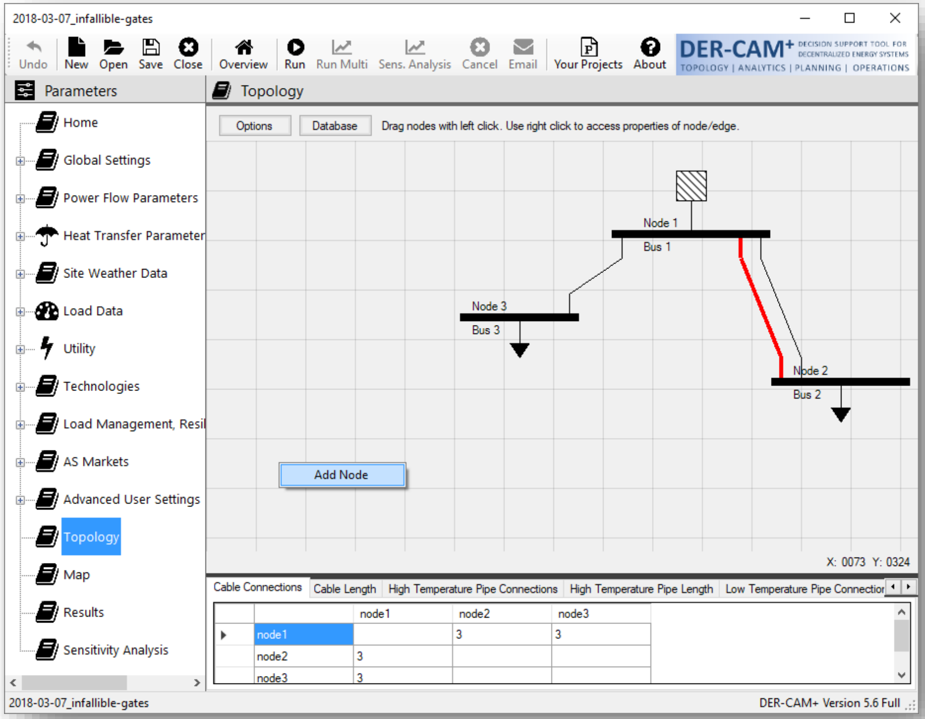
If you selected multi-node…



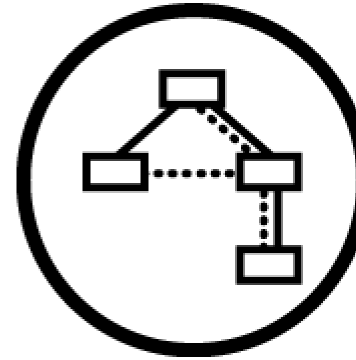
- Single node models do not require further topology definition
- For multi-node models, the next steps consist of:
  - Creating nodes (up to 20)
  - Establishing connectivity
  - Defining the characteristics of the topology elements

To create a new node..

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

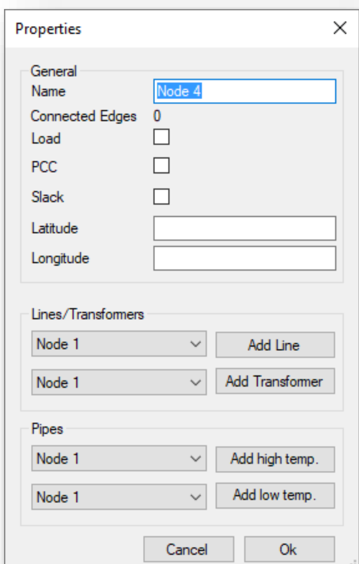


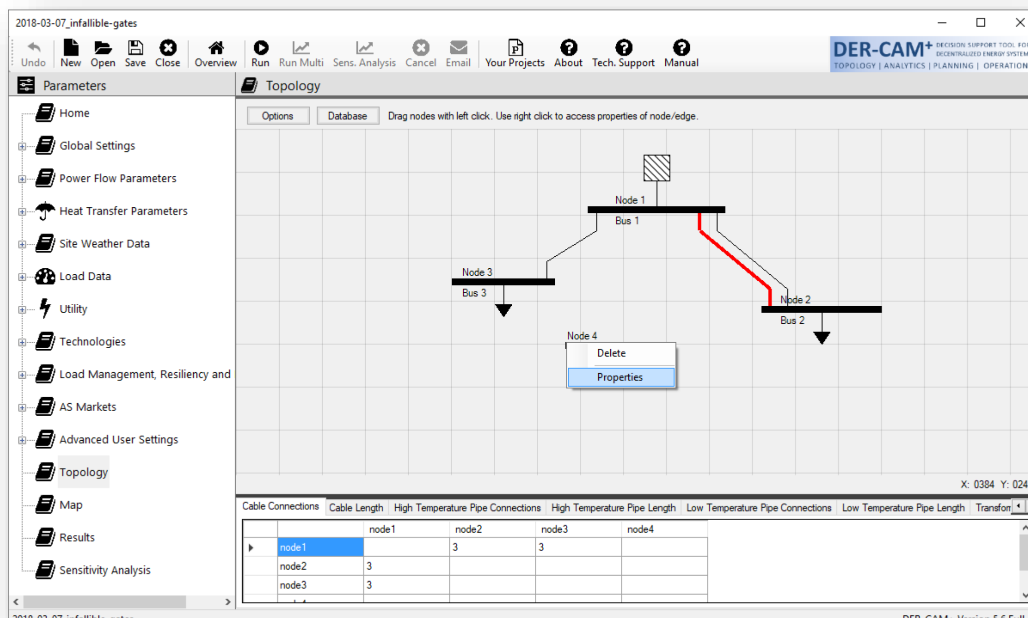
1 – Define Topology



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

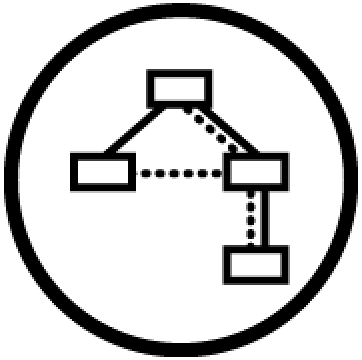


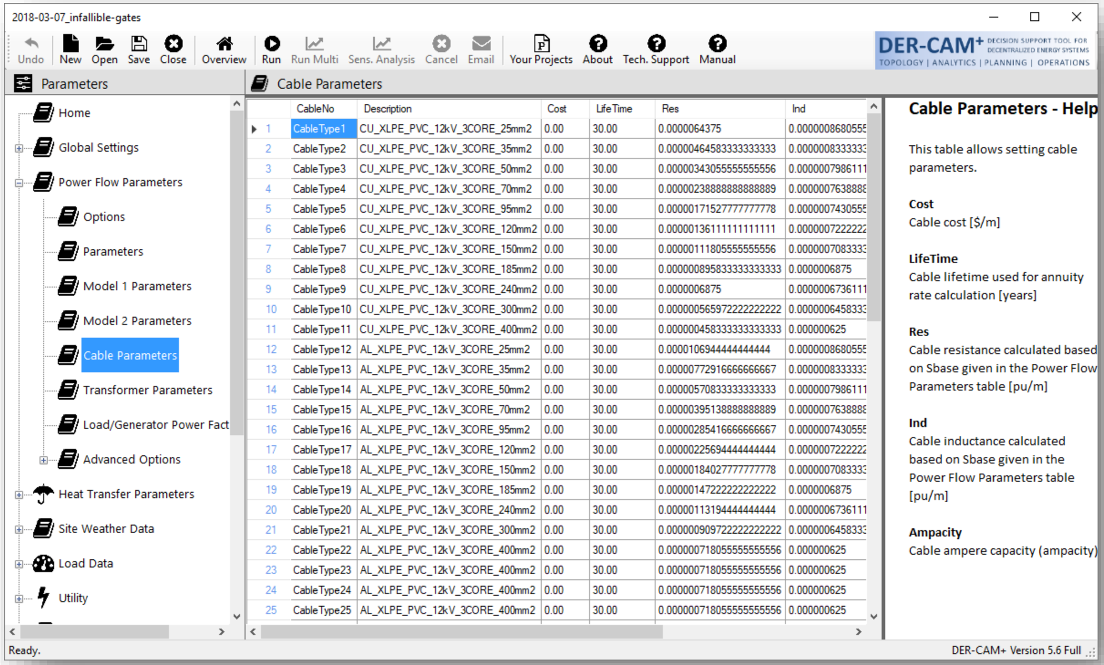


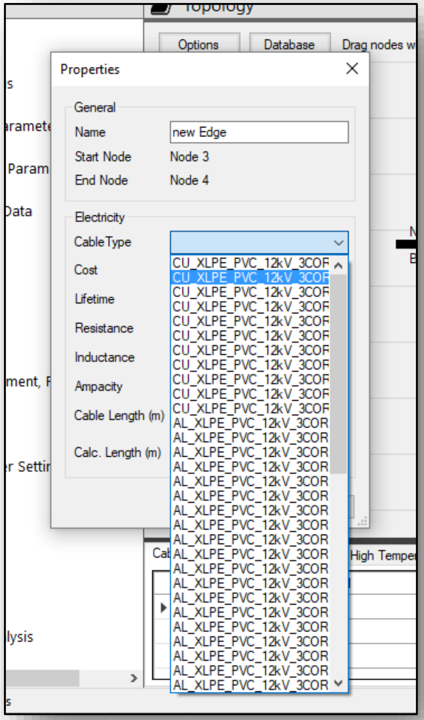
1 – Define Topology

To define the characteristics of topology elements…

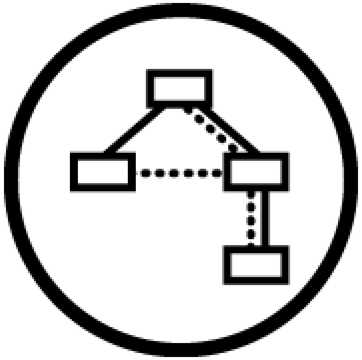
- Define the properties of relevant elements under "Power Flow Parameters" or "Heat Transfer Parameters" or use predefined
- In "Topology" view, right-click an element and select "Properties"
- Choose one of the options from the "Type" dropdown box





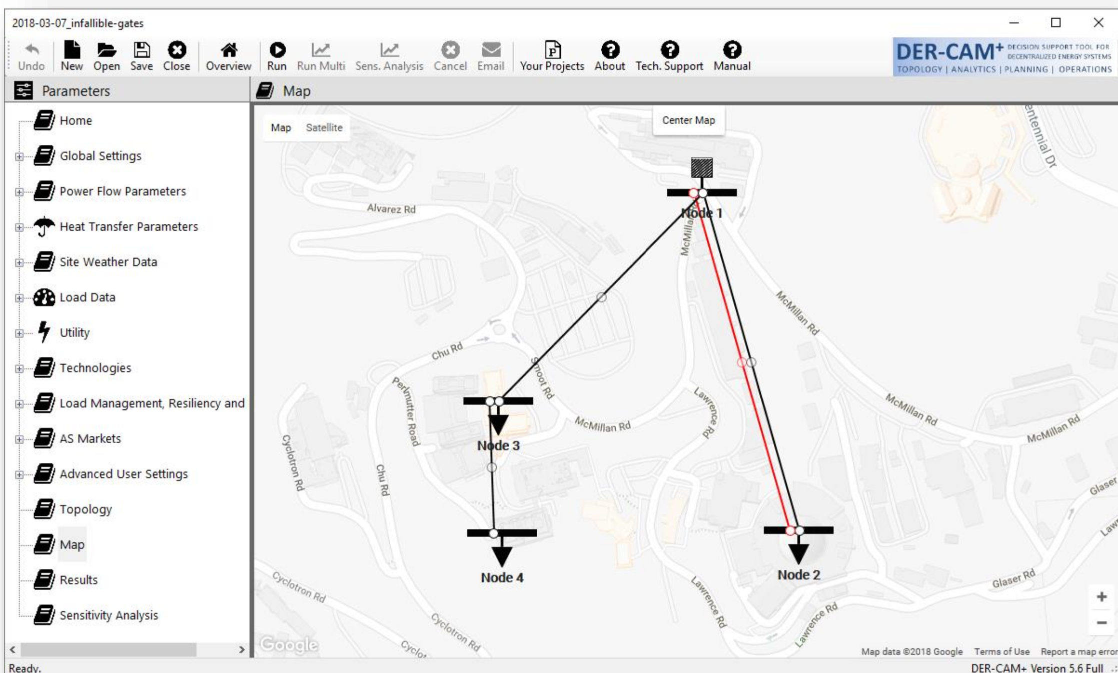


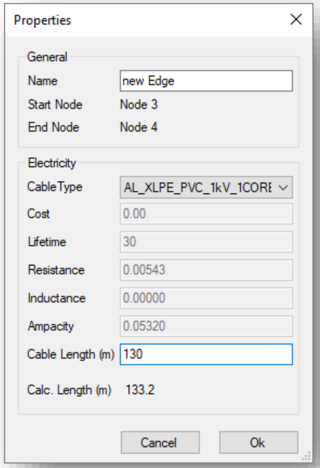
1 – Define Topology



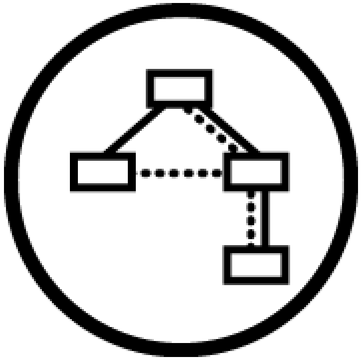
One extra step…

- “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