**Examining issues related to PV generator components**

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1. **Original objectives**

* Define **shading surface** as **PV generator** object in **EnergyPlus** through **LB+HB**
* get the following **Building electricity usage and PV electricity production related output variables** for data analysis:

|  |
| --- |
| Output:Variable,\*,Generator Produced DC Electric Power, hourly;  Output:Variable,\*,Generator Produced DC Electric Energy, hourly;  Output:Variable,\*,Generator PV Array Efficiency, hourly;  Output:Variable,\*,Generator PV Cell Temperature, hourly;  Output:Variable,\*,Facility Total Surplus Electric Energy, hourly;  Output:Variable,\*,Facility Total Purchased Electric Energy, hourly;  Output:Variable,\*,Facility Total Produced Electric Energy, hourly;  Output:Variable,\*,Facility Net Purchased Electric Energy, hourly;  Output:Variable,\*,Facility Total Building Electric Demand Power, hourly;  Output:Variable,\*,Facility Total Building Electric Demand Energy, hourly;  Output:Variable,\*,Facility Total HVAC Electric Demand Power, hourly;  Output:Variable,\*,Facility Total HVAC Electric Demand Energy, hourly;  Output:Variable,\*,Facility Total Electric Demand Power, hourly;  Output:Variable,\*,Facility Total Electric Demand Energy, hourly;  Output:Meter, Electricity:Building, hourly;  Output:Meter, ElectricityNet:Facility, hourly;  Output:Meter, ElectricityPurchased:Facility, hourly; |

1. **Test model**

* A simple model was created for the test which includes a small building with three thermal zones in different shapes and volumes. Three shading surfaces detached from the roofs were defined as PV surfaces.
* Default settings on building program and constructions are used.
* Chicago’s epw file was used to get both cooling and heating loads.

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1. **Tests**

Different combinations of the old and new versions of the following components were tested using the same building model. In total seven scenarios were tested.

|  |  |  |
| --- | --- | --- |
| **Component** | **Old version** | **New version** |
| Ladybug | V0066, JUN-02-2018 | V0066 JUL-11-2018 |
| Honeybee | V0063, JAN-20-2018 | V0063 JUN-29-2018 |
| PVgen | V0063, JAN-20-2018 | V0063, MAR-08-2018 |
| generationSystem | V0062, JUL-28-2017 | V0063, JAN-20-2018 |
| runEnergySimulation | V0063, JAN-20-2018 | v0063, JUL-24-2018 |
| exportToOpenStudio |  | V0063, AUG-08-2018 |
| EnergyPlus | V8.8.0 | |

Compatibility between the components and main issues are summarized in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

1. **Results**

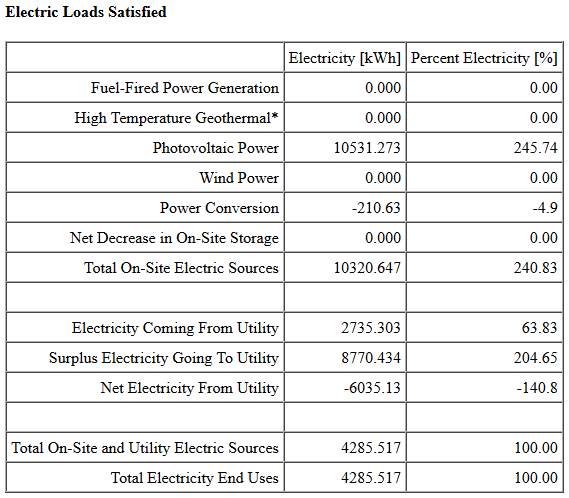
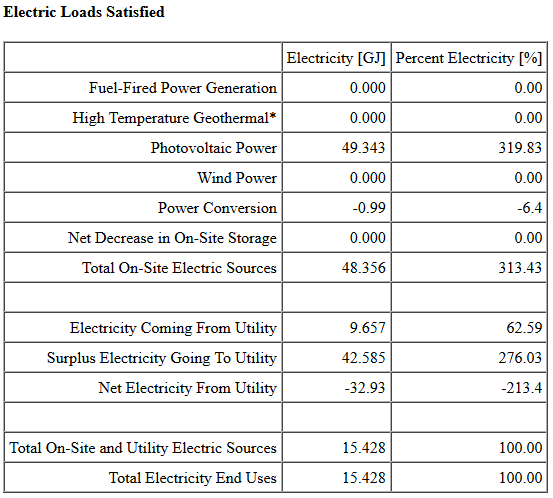
* **Combination A (Scenario 1)** using the older version of the components generates the requested output variables correctly. (see result of Scenario 1 on page 5)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

* **Combination B (Scenario 7)** using the latest version of the components works only when the code of PVgen is revised in two places to suppress the error output of “-1”.
* A few of the key output variables requested were missing. (see result of Scenario 7 on page 13)

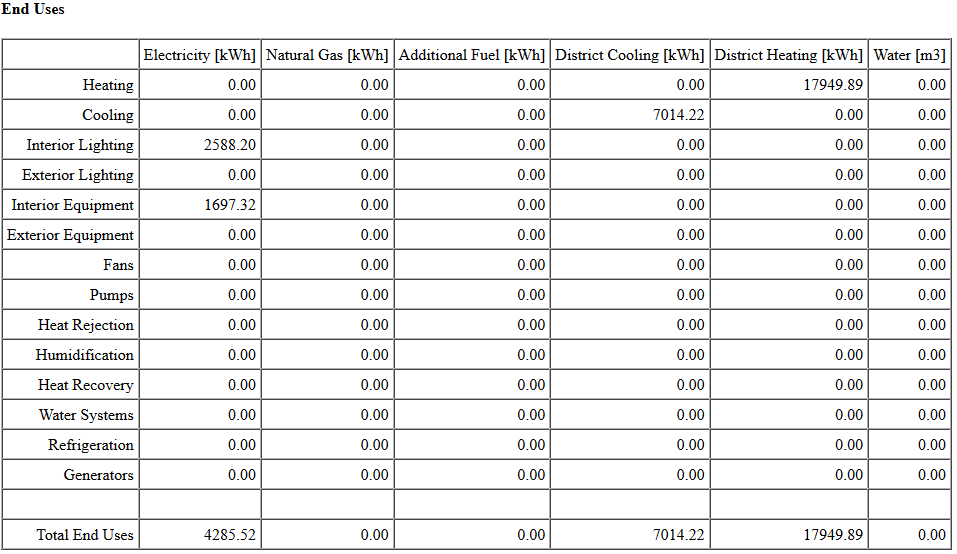
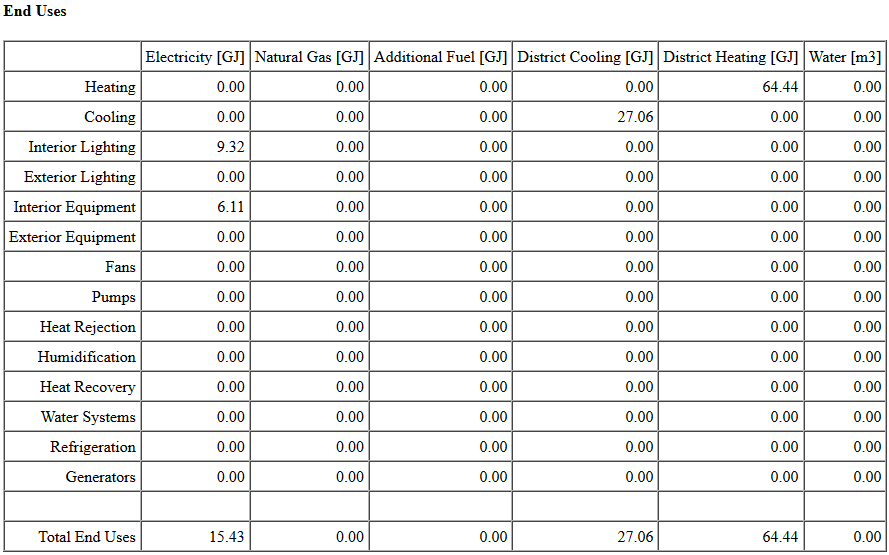
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

Assuming the result of combination A is correct, the result on PV electricity yield for combination B is overestimated by 30.1%. (note the difference in energy unit)

Result of combination A Result of combination B

For combination B, electricity usage is about the same. But cooling loads is overestimated by 7.2%, and heating loads is slightly underestimated by only -0.3%.

Result of combination A Result of combination B

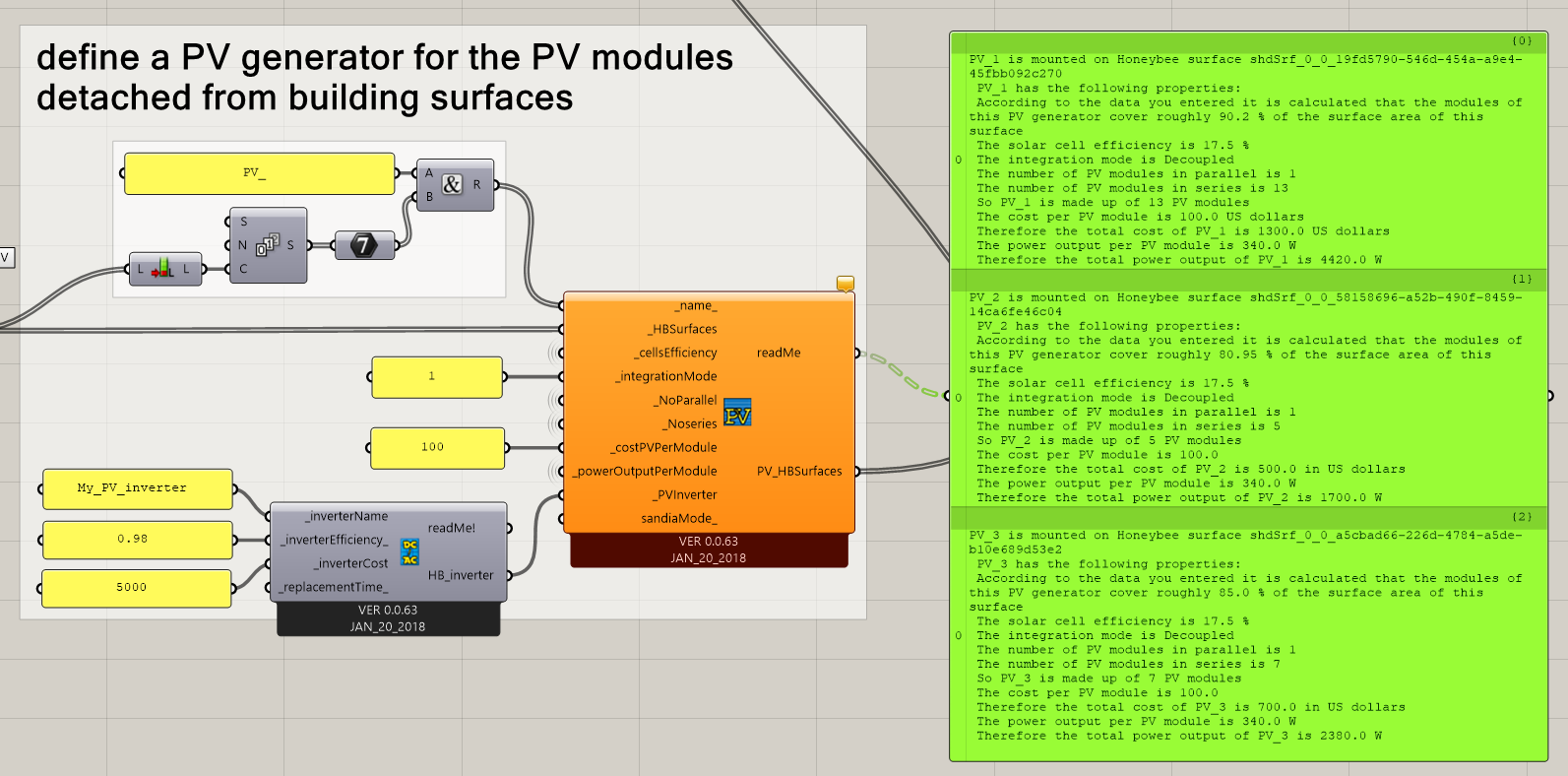
Without PV, the difference in electricity usage, cooling and heating loads between combination A and B is very small and could be regarded as zero.

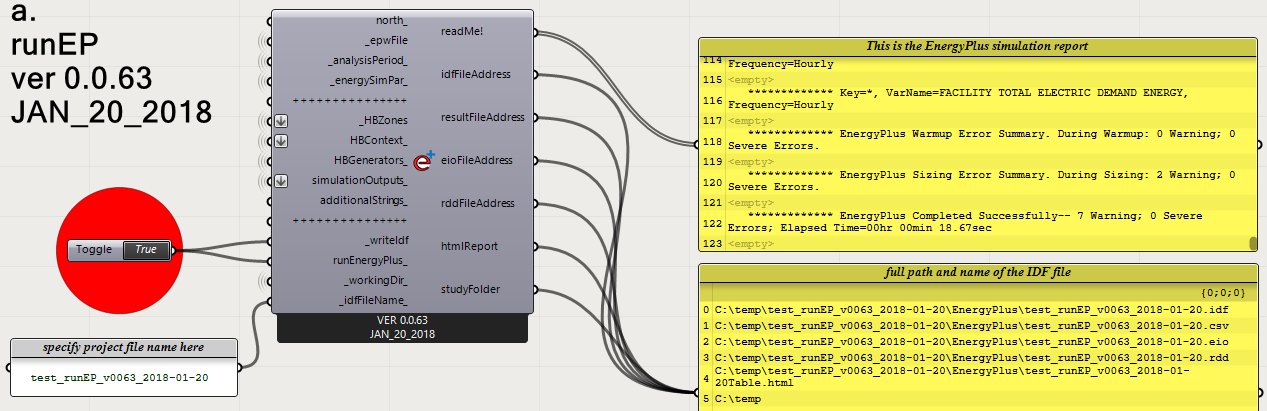
The outcome of the seven scenarios tested are shown below.

**Scenario 1 (S1) :** test\_PVgen\_s1.gh

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error  The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

**Results (correct):**





**End Uses** (as reported in the html file generated)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
| Heating | 0.00 | 0.00 | 0.00 | 0.00 | 17949.89 | 0.00 |
| Cooling | 0.00 | 0.00 | 0.00 | 7014.22 | 0.00 | 0.00 |
| Interior Lighting | 2588.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 1697.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| … | … | … | … | … | … | … |
| Total End Uses | 4285.52 | 0.00 | 0.00 | 7014.22 | 17949.89 | 0.00 |

**Electric Loads Satisfied** (as reported in the html file generated)

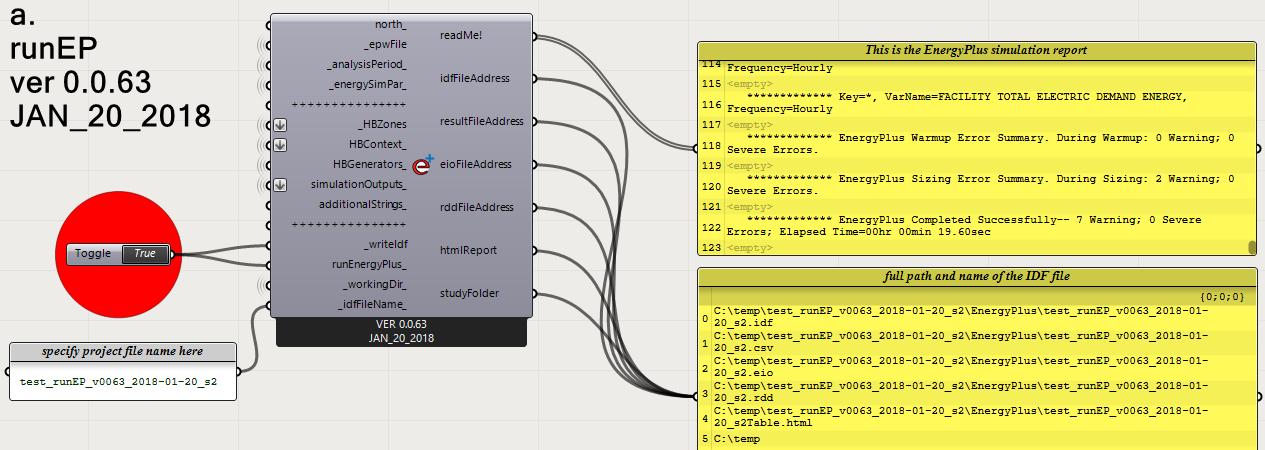
|  |  |  |
| --- | --- | --- |
|  | Electricity [kWh] | Percent Electricity [%] |
| Fuel-Fired Power Generation | 0.000 | 0.00 |
| High Temperature Geothermal\* | 0.000 | 0.00 |
| Photovoltaic Power | 10531.273 | 245.74 |
| Wind Power | 0.000 | 0.00 |
| Power Conversion | -210.63 | -4.9 |
| Net Decrease in On-Site Storage | 0.000 | 0.00 |
| Total On-Site Electric Sources | 10320.647 | 240.83 |
|  |  |  |
| Electricity Coming From Utility | 2735.303 | 63.83 |
| Surplus Electricity Going To Utility | 8770.434 | 204.65 |
| Net Electricity From Utility | -6035.13 | -140.8 |
|  |  |  |
| Total On-Site and Utility Electric Sources | 4285.517 | 100.00 |
| Total Electricity End Uses | 4285.517 | 100.00 |

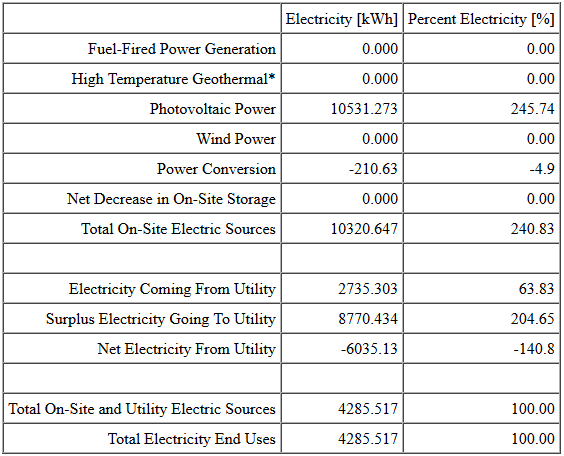
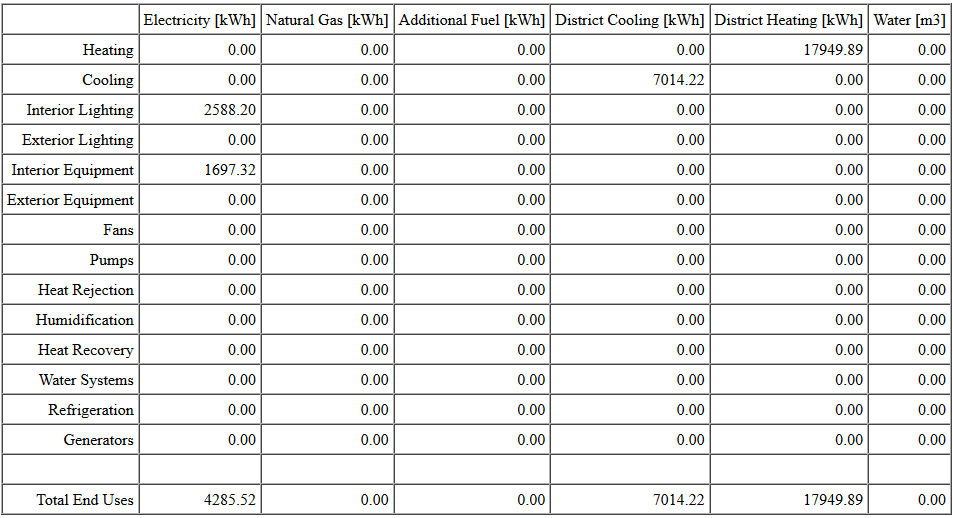
**Scenario 2 (S2) :** test\_PVgen\_s2.gh

**generationSystem** component is replaced with the latest version.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error  The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

**Results (correct):**





**Scenario 3 (S3) :** test\_PVgen\_s3.gh

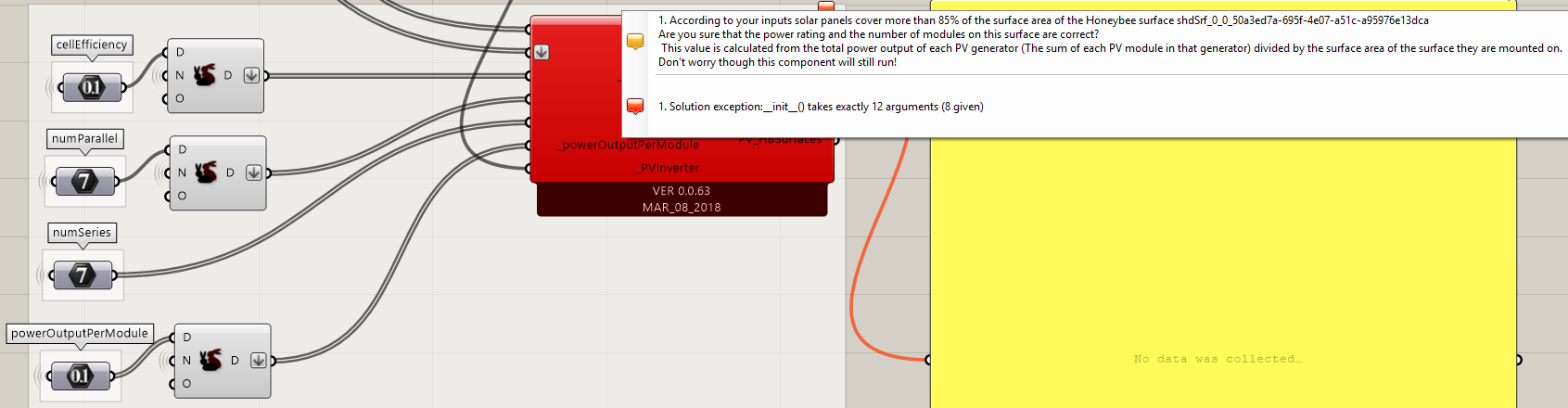
PVgen component is replaced with the latest version.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error  The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

**Error:**

Got the following error even if the input data for each of the input nodes has been changed to a list of values:

***1. Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given)***



Unable to proceed to run the simulation.

**Scenario 4 (S4) :** test\_PVgen\_s4.gh

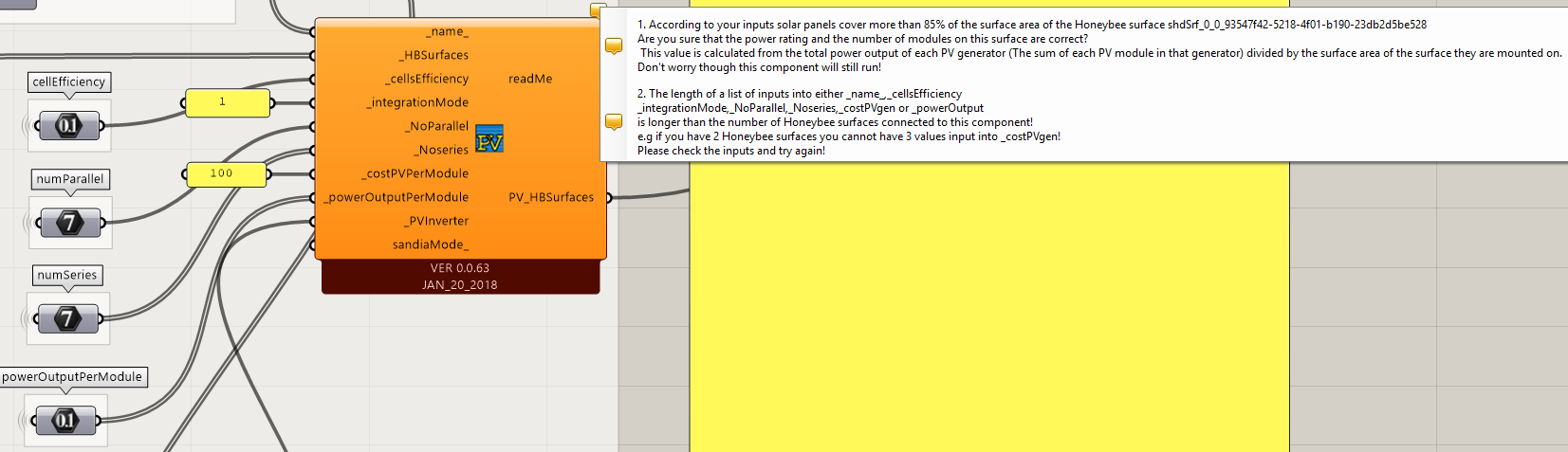
Old PVgen and generationSystem components were tested in new LB+HB

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error  The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

**Error:**

Got the following error on mismatching input lists, although all the inputs remain the same.

* ***The length of a list of inputs into either \_name\_, \_cellsEfficiency, \_integrationMode, \_NoParallel,\_Noseries, \_costPVgen or \_powerOutput is longer than the number of Honeybee surfaces connected to this component! e.g if you have 2 Honeybee surfaces you cannot have 3 values input into \_costPVgen! Please check the inputs and try again!***



Unable to proceed to run the simulation.

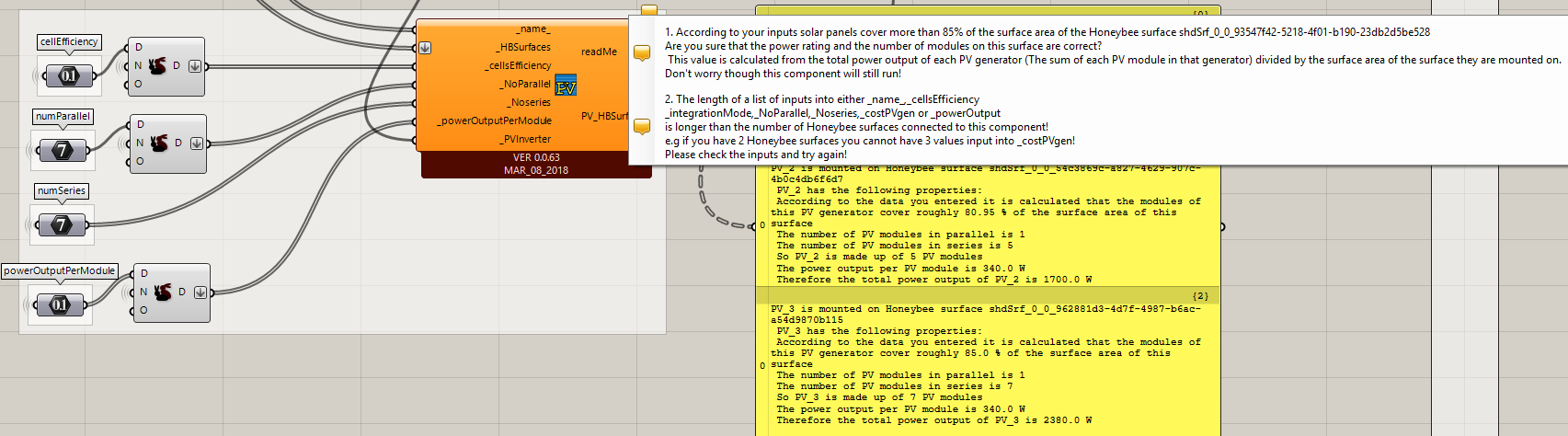
**Scenario 5 (S5) :** test\_PVgen\_s5.gh

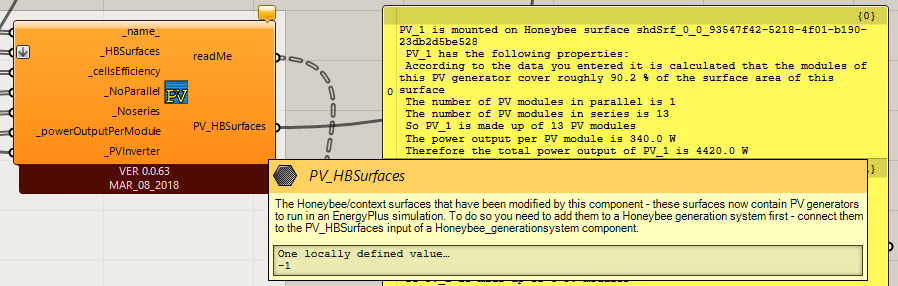
New PVgen and generationSystem components were used.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | |  | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! * PV\_HBSurfaces output is “-1” | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | |  | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | |  | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 |  | |

**Error:**

* Still have the input list length mismatching issue
* PV\_HBSurfaces output is “-1”, although the PV generator definition seems to be OK.



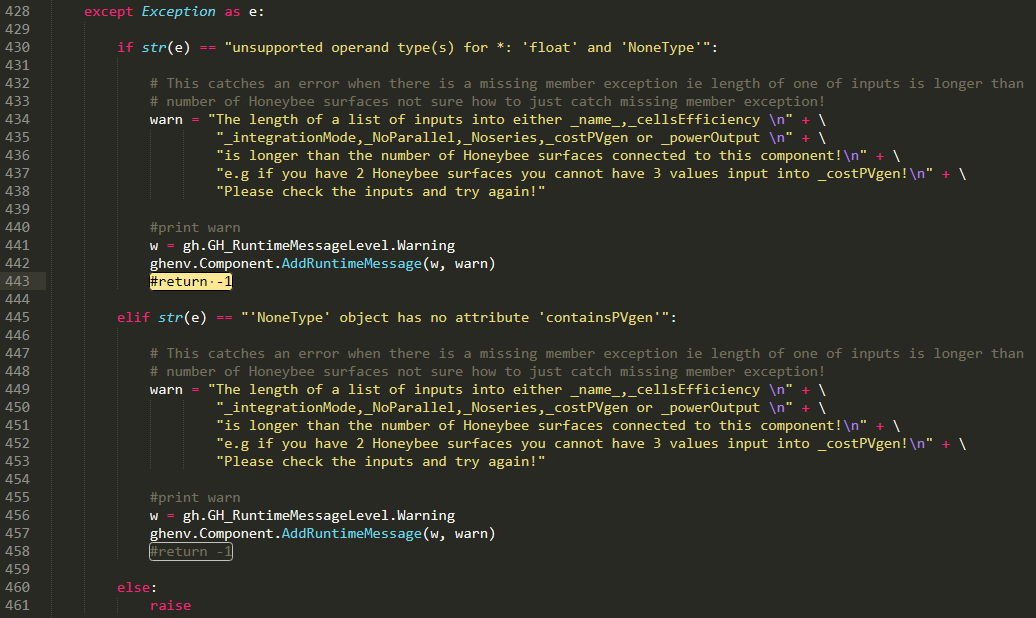


**Scenario 6 (S6) :** test\_PVgen\_s6.gh

The components used and the versions are the same as Scenario 5.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | |  | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! * PV\_HBSurfaces output is “-1” | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | |  | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | |  | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 |  | |

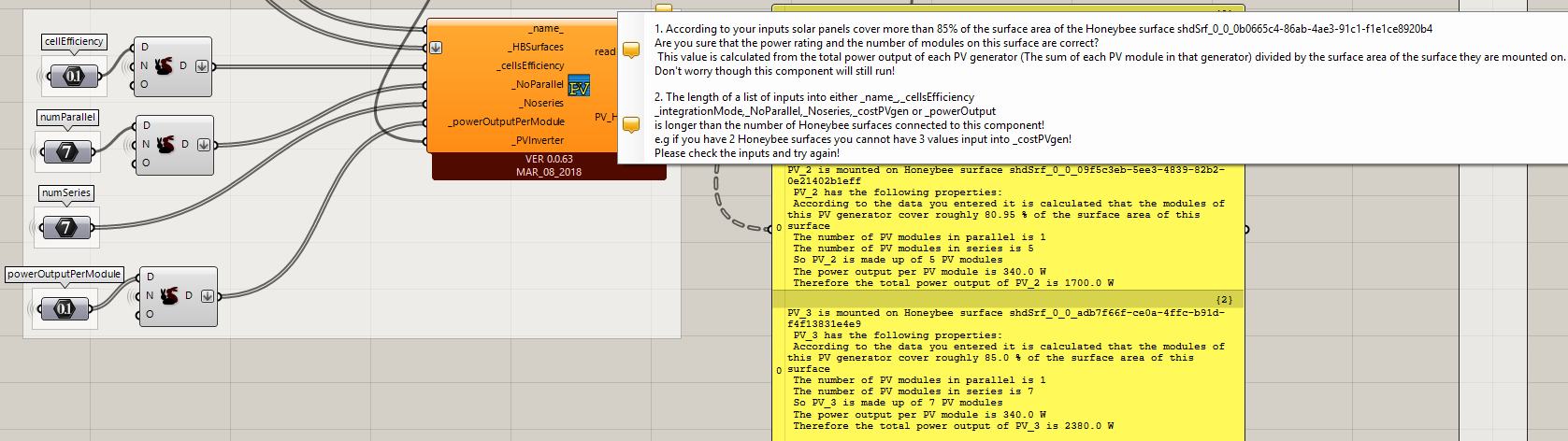
But line 443 and 458 of the code in PVgen component for the error return of “-1” were suppressed so that PV\_HBSurfaces can output surfaces.



**Error:**

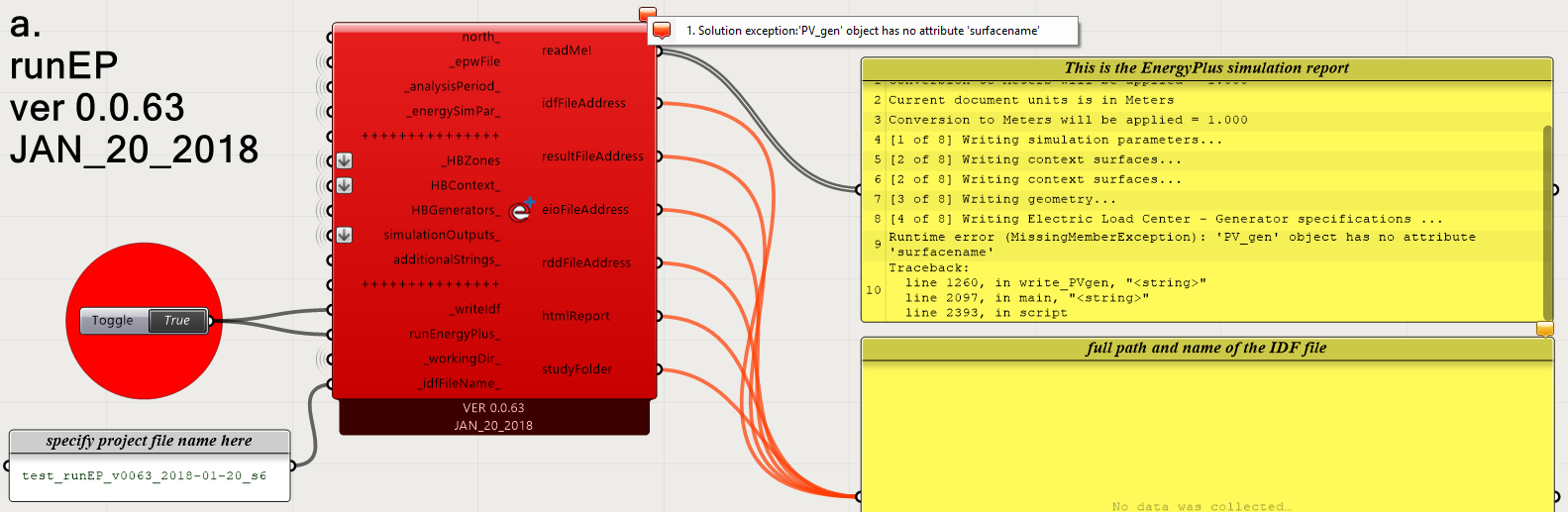
Although the three PV surfaces can be output from “PV\_HBSurfaces” now, the following warning remains:

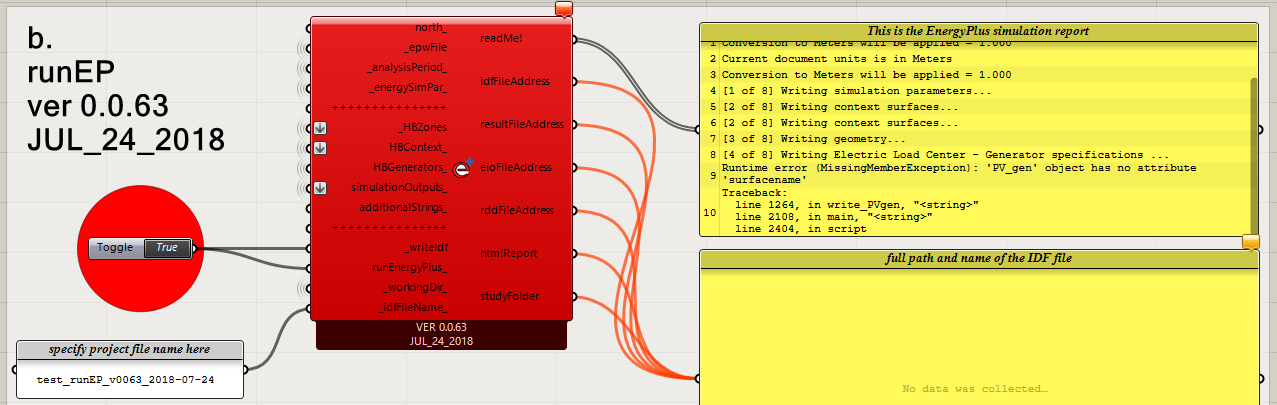
* ***The length of a list of inputs into either \_name\_, \_cellsEfficiency, \_integrationMode, \_NoParallel,\_Noseries, \_costPVgen or \_powerOutput is longer than the number of Honeybee surfaces connected to this component! e.g if you have 2 Honeybee surfaces you cannot have 3 values input into \_costPVgen! Please check the inputs and try again!***



The code revision above doesn’t work with the old and new versions of **runEnergySimulation** components, and the following error is reported:

***Solution exception:'PV\_gen' object has no attribute 'surfacename'***



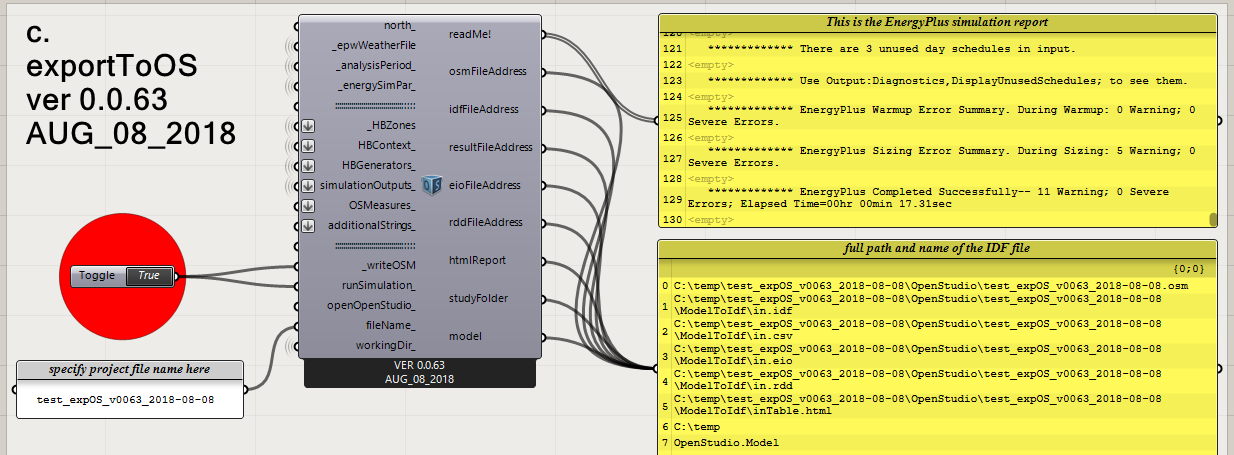


**Scenario 7 (S7)** : test\_PVgen\_s7.gh

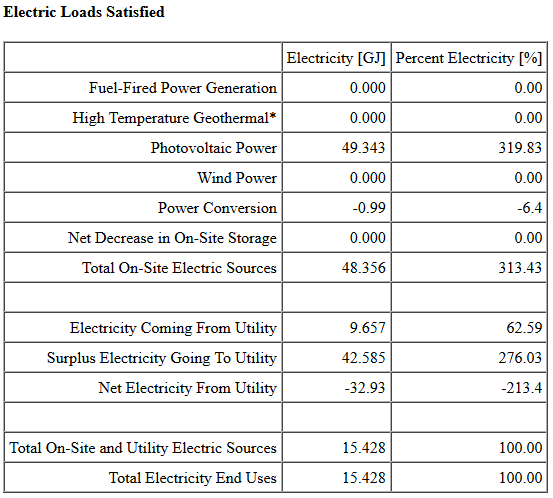
Simulation was run by the **exportToOpenStudio** component

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compatibility** | | **Old** | | **New** | |
| **Ladybug**  V0066  JUN-02-2018 | **Honeybee**  V0063  JAN-20-2018 | **Ladybug**  V0066  JUL-11-2018 | **Honeybee**  V0063  JUN-29-2018 |
| **Old** | **PVgen**  V0063  JAN-20-2018 | Yes | | Error  The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0062  JUL-28-2017 | Yes | |
| **runEnergySimulation**  V0063  JAN-20-2018 | Yes | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
| **New** | **PVgen**  V0063  MAR-08-2018 | Error   * Solution exception:\_\_init\_\_() takes exactly 12 arguments (8 given) | | Error   * The length of a list of inputs is longer than the number of Honeybee surfaces connected to this component! | |
| **generationSystem**  V0063  JAN-20-2018 | Yes | | Yes | |
| **runEnergySimulation**  v0063  JUL-24-2018 | No  (got reminder to update HB) | | Error   * Solution exception:'PV\_gen' object has no attribute 'surfacename' | |
|  | **exportToOpenStudio**  V0063  AUG-08-2018 | Yes | |

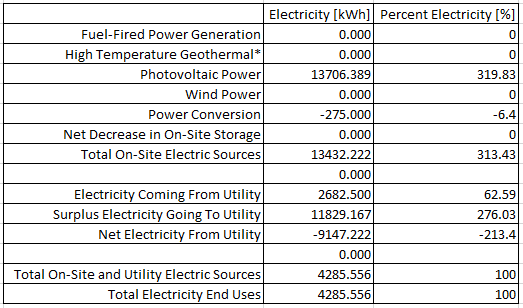
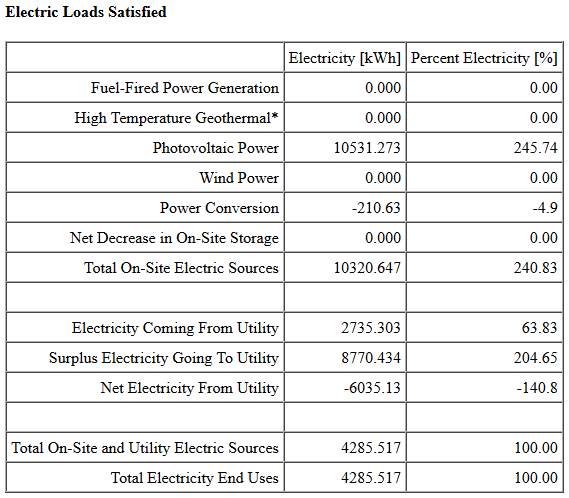
**Simulation works**



However, the PV electricity generation related output is not the same as the one generated using old versions of LB, HB, PVgen, generationSystem and runEnergySimulation components.



Result of Scenario 7 (in GJ)

Result of Scenario 7 (in kWh) Result of S1 (in kWh)

Four output variables were also missing which were generated correctly in Scenario 1.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Electricity load and generation related output variables requested** | | | **Scenario** | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 1 | **Electric Load Center Produced Electric Energy** | | |  |  |  |  |  |  | X |
| 2 | **Electricity:Building** | | |  |  |  |  |  |  | X |
| 3 | **ElectricityNet:Facility** | | |  |  |  |  |  |  | X |
| 4 | **ElectricityPurchased:Facility** | | |  |  |  |  |  |  | X |
| 5 | Facility Net Purchased Electric Energy | | |  |  |  |  |  |  |  |
| 6 | Facility Total Building Electric Demand Power | | |  |  |  |  |  |  |  |
| 7 | Facility Total Electric Demand Power | | |  |  |  |  |  |  |  |
| 8 | Facility Total HVAC Electric Demand Power | | |  |  |  |  |  |  |  |
| 9 | Facility Total Produced Electric Energy | | |  |  |  |  |  |  |  |
| 10 | Facility Total Purchased Electric Energy | | |  |  |  |  |  |  |  |
| 11 | Facility Total Surplus Electric Energy | | |  |  |  |  |  |  |  |
| 12 | Generator PV Array Efficiency | | |  |  |  |  |  |  |  |
| 13 | Generator PV Cell Temperature | | | X | X |  |  |  |  | X |
| 14 | Generator Produced DC Electric Energy | | |  |  |  |  |  |  |  |
| 15 | Generator Produced DC Electric Power | | |  |  |  |  |  |  |  |
|  | Generated | Not generated | X : missing |  | | | | | | |