SimStadt crash course

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License

SimStadt in a nutshell

- SimStadt is a 3D urban energy system modelling platform developed by HFT Stuttgart
  - https://simstadt.hft-stuttgart.de

- It has a Graphical User Interface (GUI) and consists of different workflow steps that use information from
  - An (XML-encoded) CityGML-based 3D city model
  - Building physics and usage libraries
  - Weather data

- Typical urban applications:
  - Building energy demand (heating, cooling, DHW production)
  - Building refurbishment scenarios
  - Photovoltaic potential
  - Scenarios for adoption of renewables

SimStadt in a nutshell

- The building physics library is based on the work of the Institut für Wohnen und Umwelt (IWU) (Weiler et al., 2019). Buildings are classified according to:
  - Type (e.g. single-family house, terraced house, etc.)
  - Period of construction

- For each building type and period, there is a building *archetype* with its respective wall, roof and window physical parameters. SimStadt associates these parameters with the actual building geometry (i.e. thermal envelope)

- SimStadt requires INSEL. INSEL is a software for simulation, monitoring and visualization of energy systems. It is the underlying engine of multiple workflow steps
  - It has some predefined simulation models included, but it is also possible to design your own model extensions or entirely new models

Installation: software requirements

Currently, SimStadt runs best on a **Windows** platform, however it can be used on Linux (e.g. Ubuntu) and (still experimental) macOS, too

- Some of the underlying modules are not supported in other operating systems, e.g. the Simplified Radiosity Algorithm, which is required for shadow calculations

Software requirements

1) Java 8 64bit (JDK or JRE) with JavaFX libraries – or equivalent
2) INSEL (current version: 8)
3) SimStadt
4) Simplified Radiosity Algorithm

Additional (optional) resources

- KIT ModelViewer
- 3D City Database (with Energy ADE plugin) for data retrieval and storage
- FME for ETL operations

Short installation guide

Please note: This is a short version of the detailed guide available at
https://simstadt.hft-stuttgart.de/getting-started/install-software

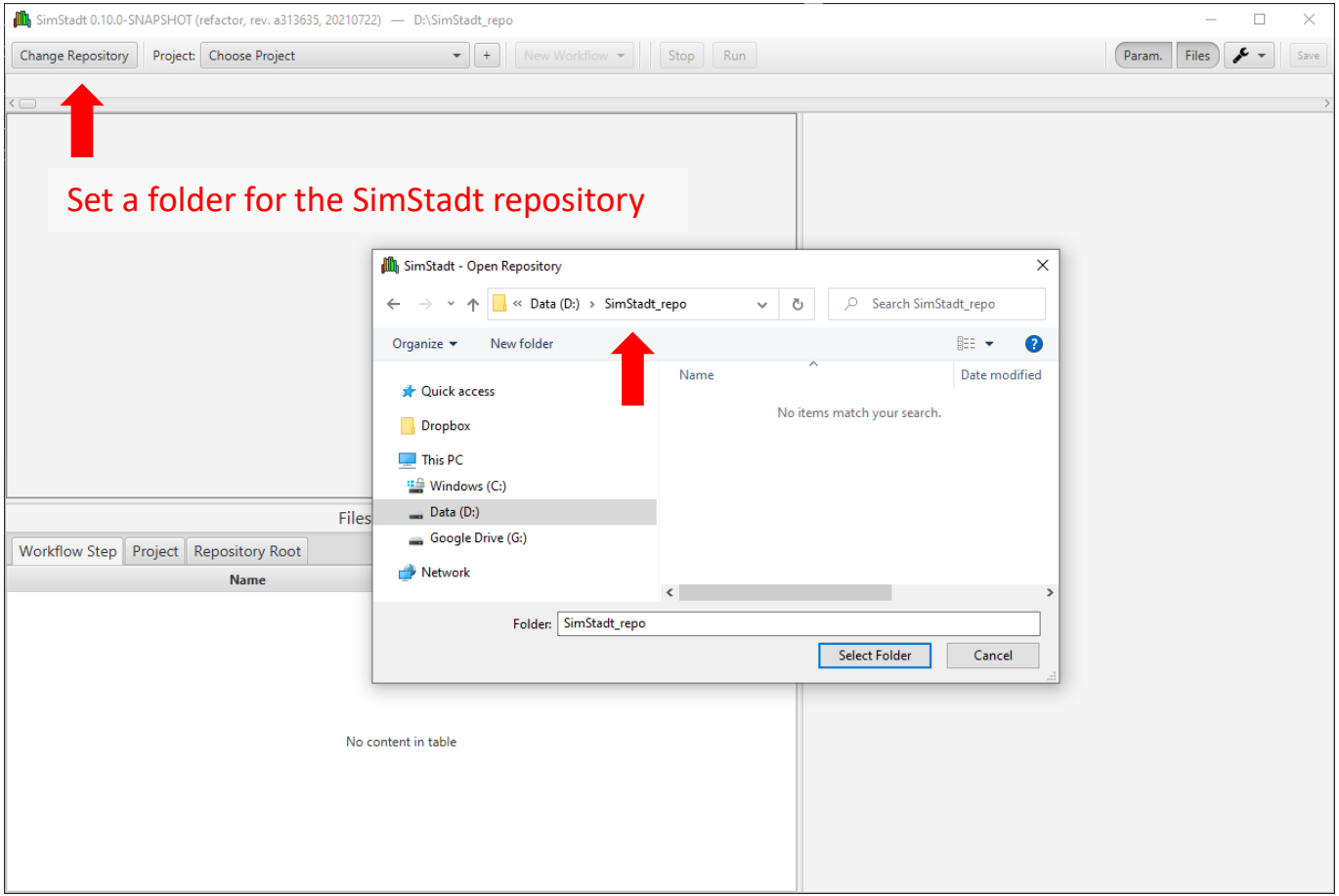
Installation steps

1) Download and install **Java**
2) Download and install **INSEL**
   - It will be installed by default in C:\Program Files (x86)\Insel 8.3
3) Download and replace INSEL file **inselBS.dll**
   - The file to replace is in folder C:\Program Files (x86)\Insel 8.3\resources
4) Download and unzip **SimStadt**
   - E.g. into C:\Program Files\SimStadt
5) Download and unzip the **Simplified Radiosity Algorithm** (SRA)
   - Extract to C:\Program Files\ so that C:\Program Files\SimplifiedRadiosity\shortwave_integer.exe is an executable
   - SRA executable should then be found by the IrradianceProcessor in SimStadt when SRA_Perez is selected
6) Optional, but recommended: download and install Gnuplot
   - Needed for the Visualisation step in SimStadt

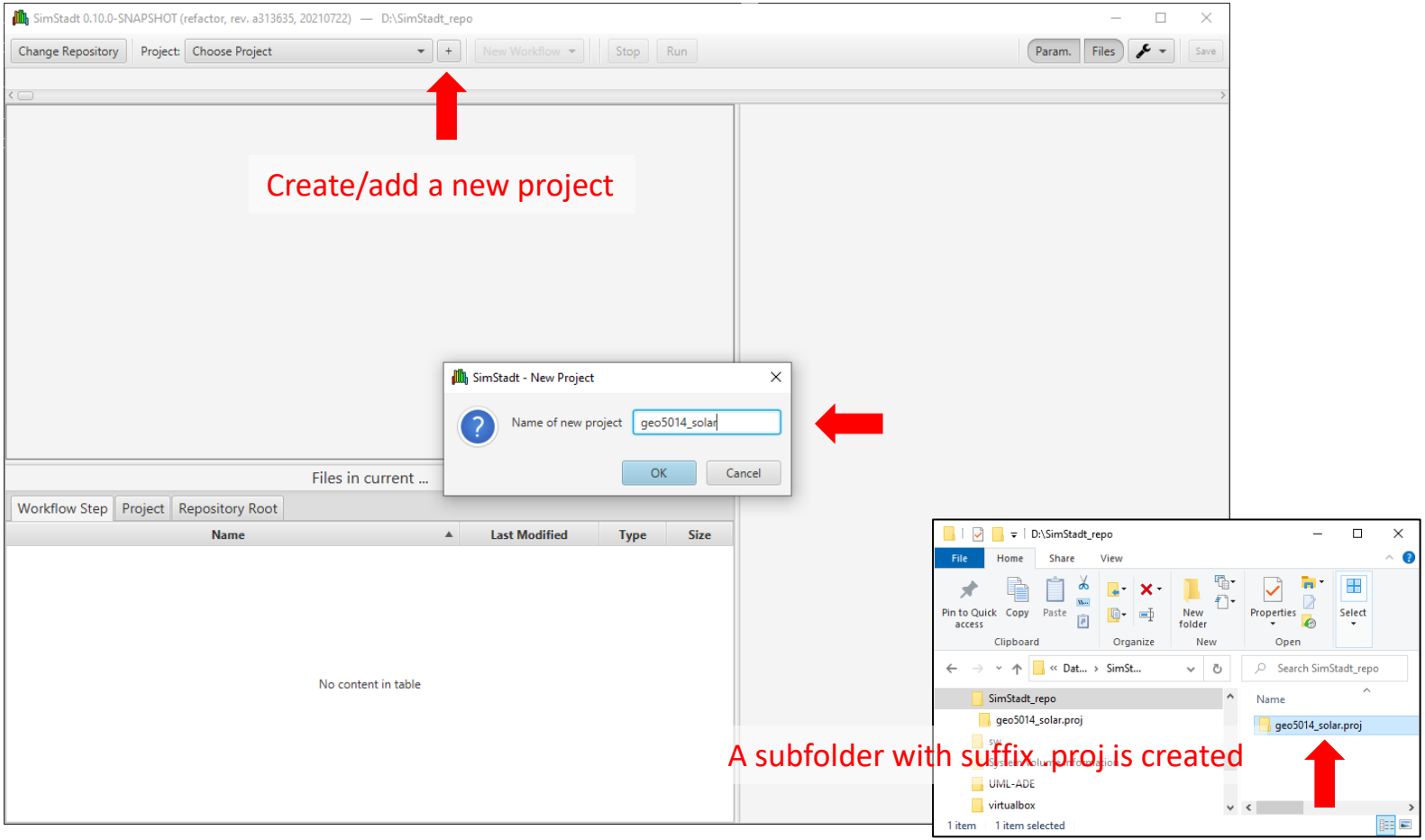
First run

- Once you are done installing the software, start SimStadt by double-clicking on **SimStadt.bat** in the SimStadt installation folder
  - You better create a shortcut to the Desktop or to the Start menu! ☺
- Upon first run, you are requested to define a folder for the *repository*
  - A repository in SimStadt is the root folder in which you collect and save all your projects and CityGML files
    - Check that you have writing permission in that folder!
  - You can immediately create a new project, e.g. *test_solar*
    - A subfolder with suffix .proj is created in the repository folder for each project
- Follow the instructions given in https://simstadt.hft-stuttgart.de/getting-started/first-run/
- The next slides contain an excerpt of the information available online in the SimStadt documentation webpage

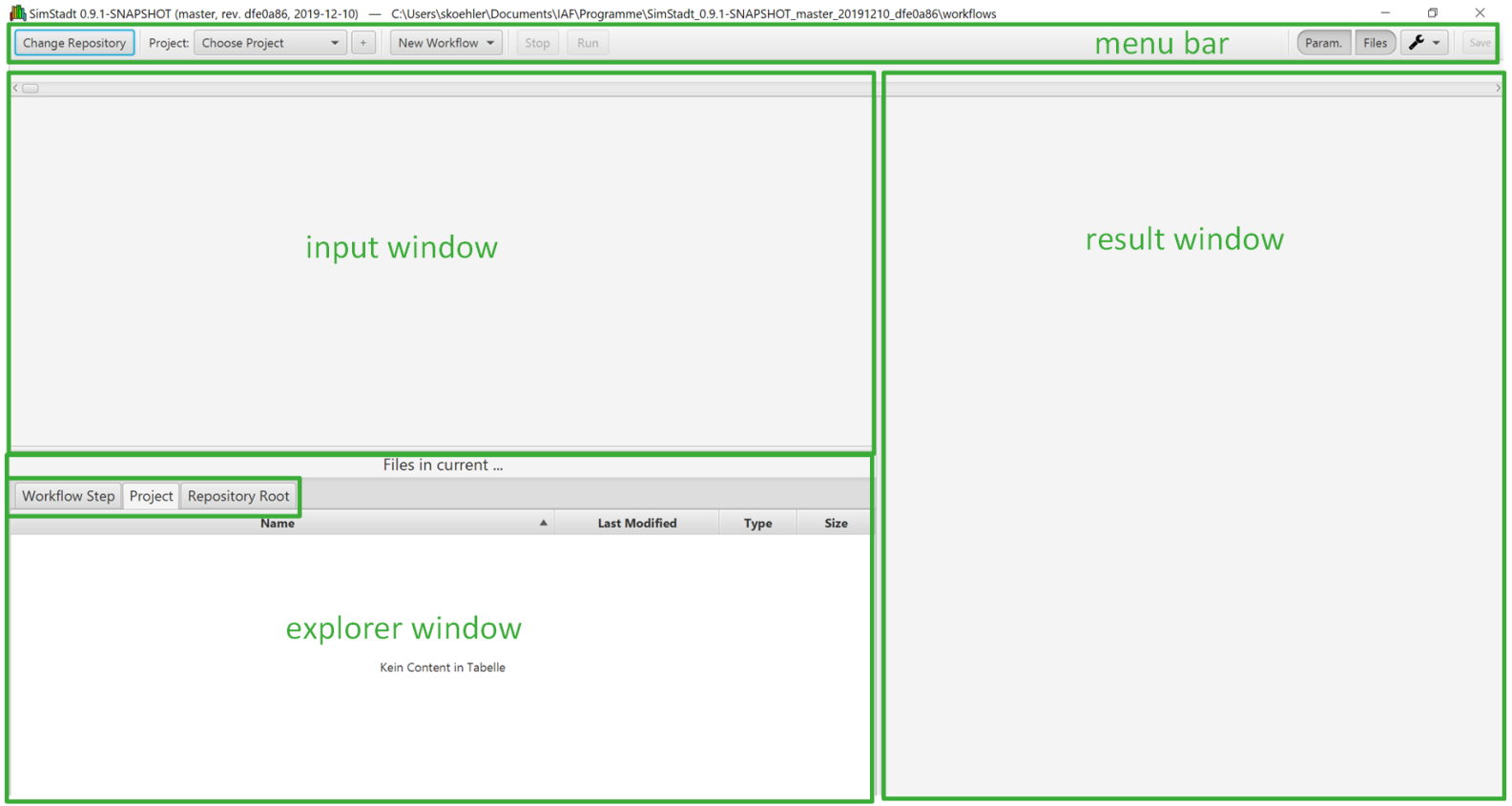
First run



First run

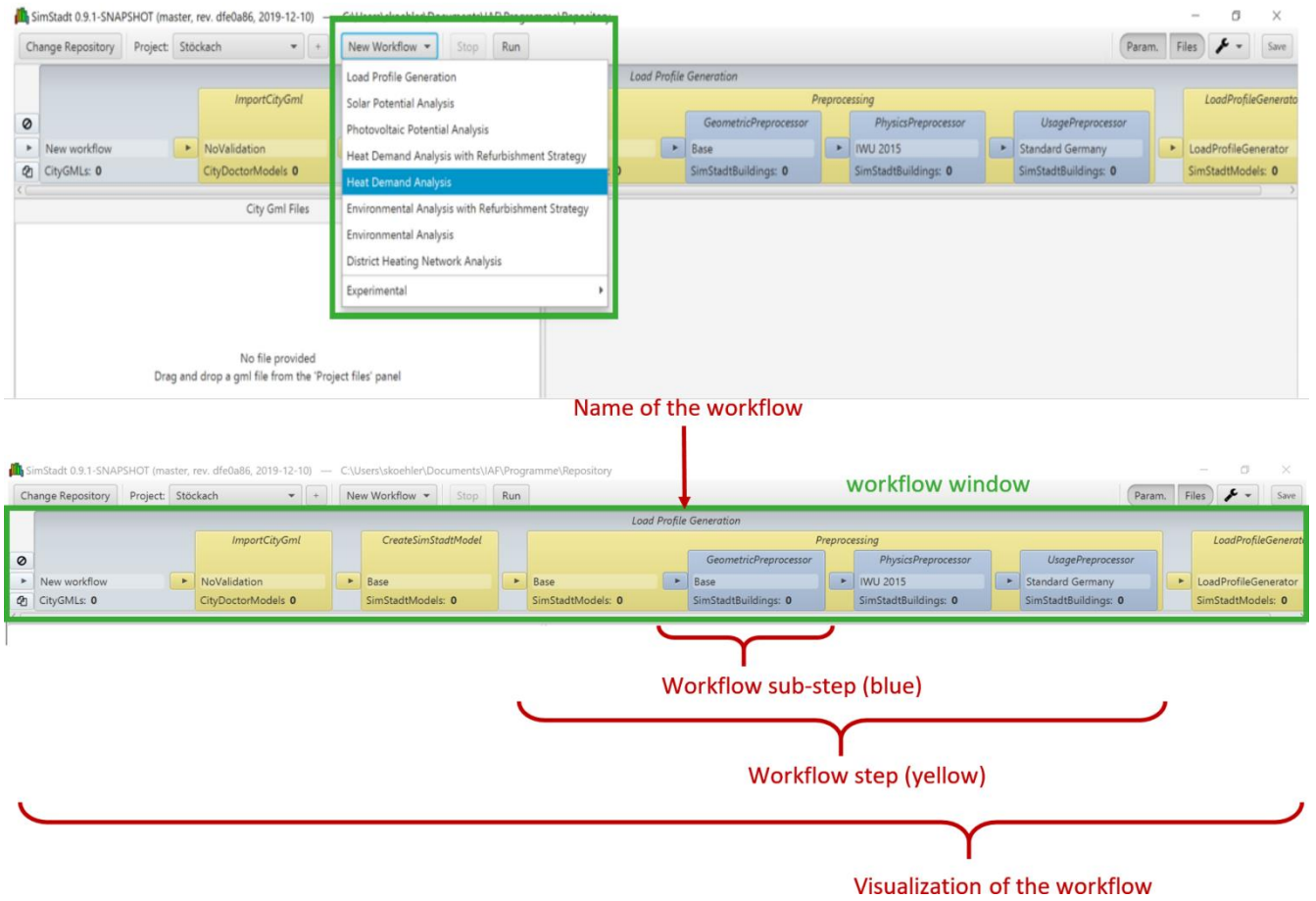


GUI and functionalities

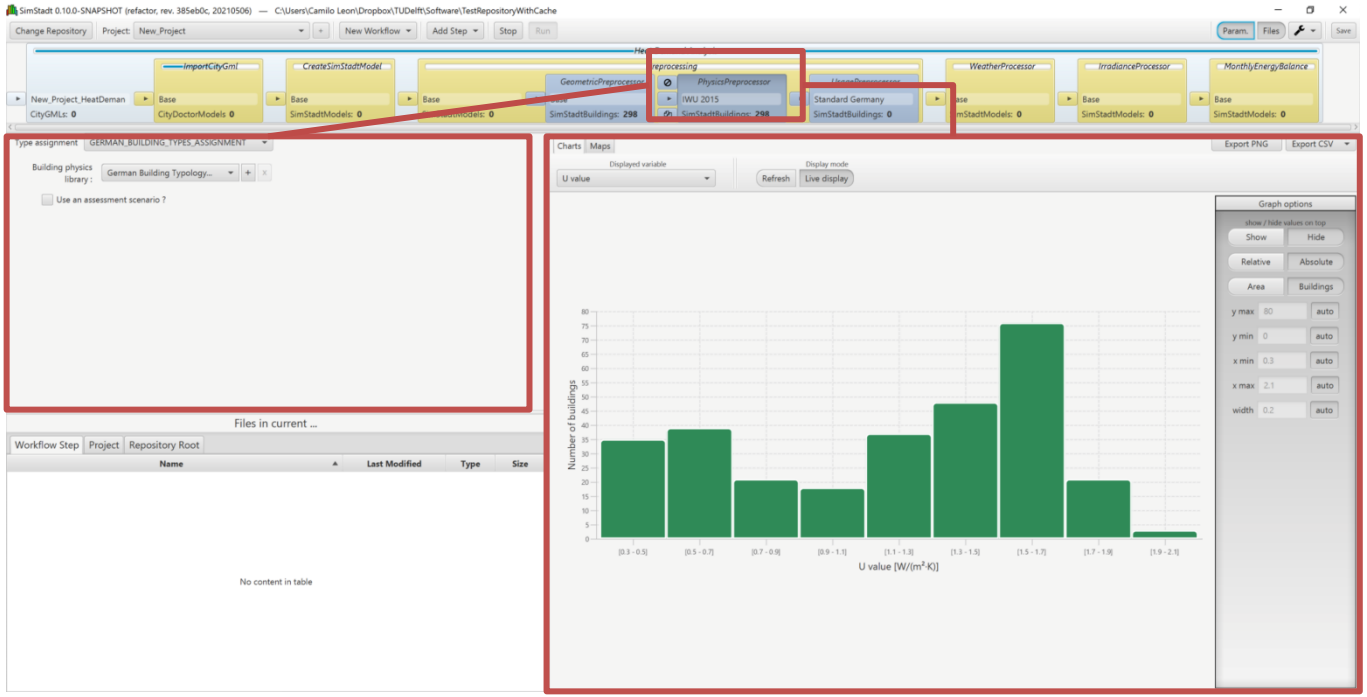


SimStadt

SimStadt GUI

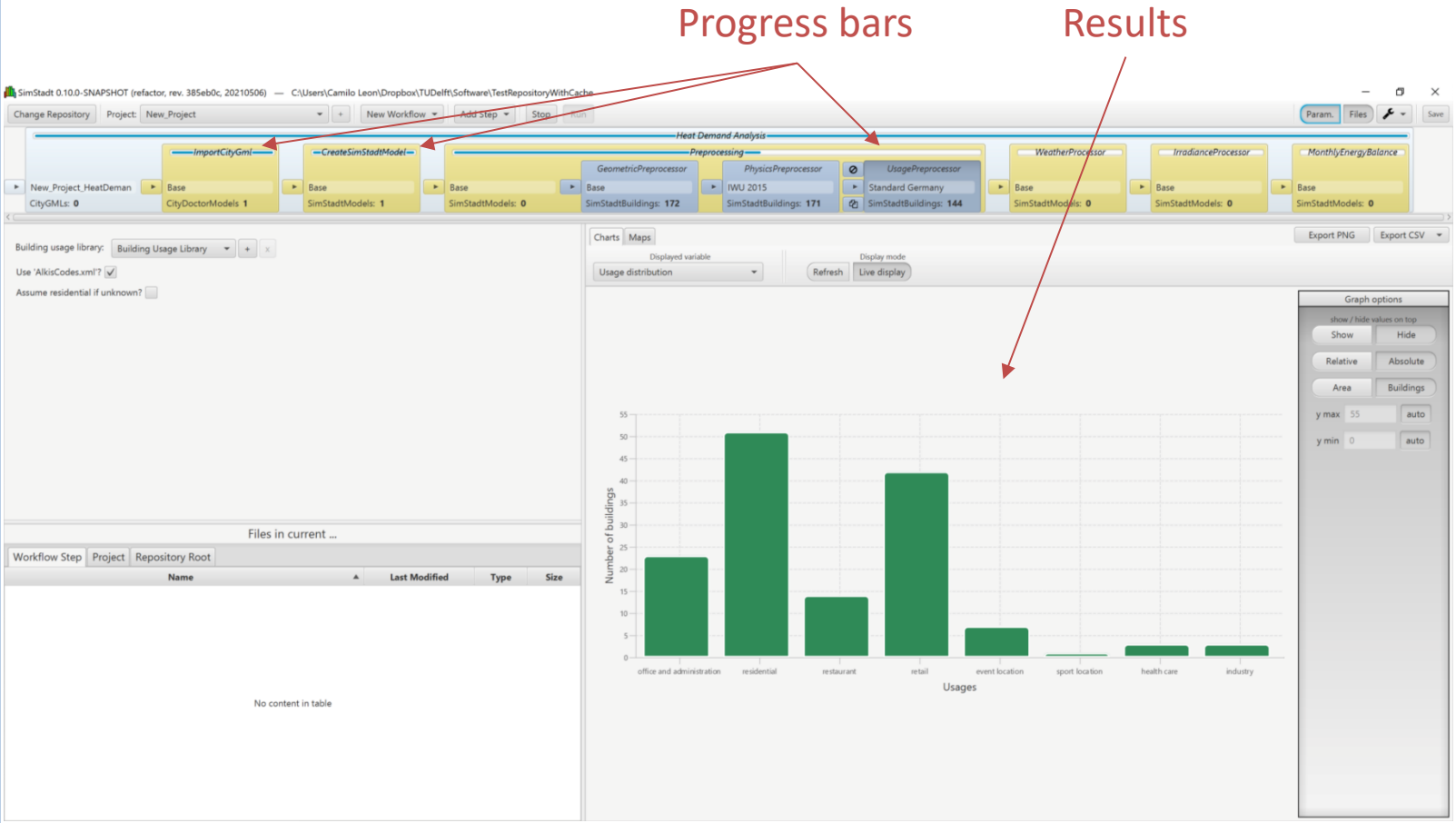


SimStadt GUI

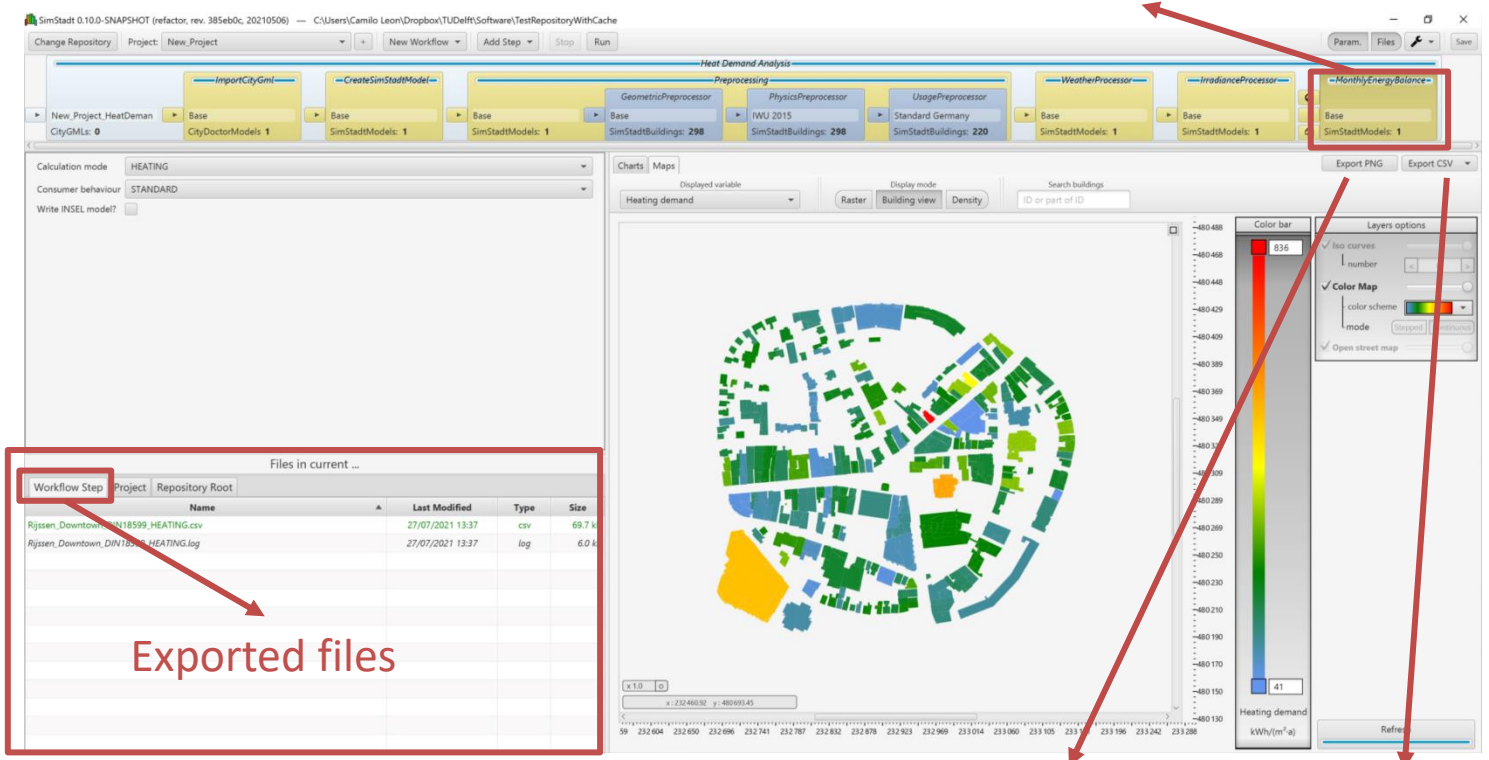


The GUI changes depending on the selected step

SimStadt GUI



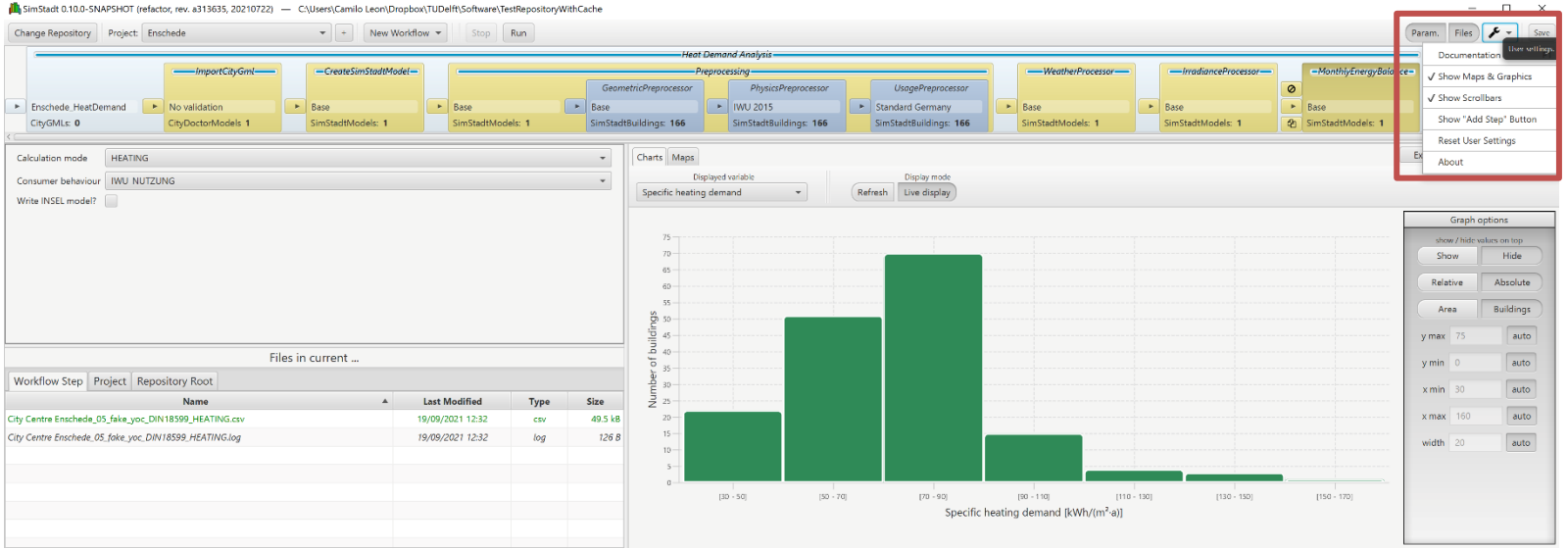
SimStadt GUI



The best way to access an exported file is from the GUI

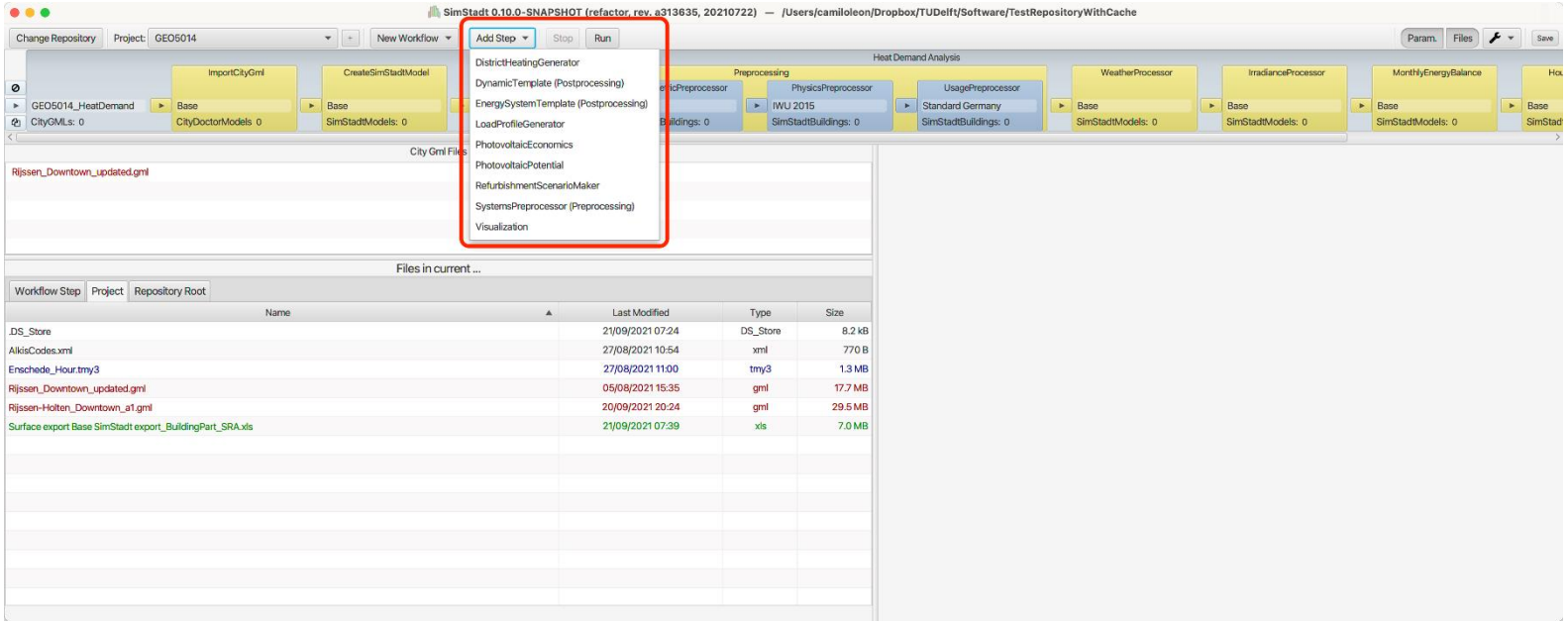
Workflow customisation

- It is possible to customise a workflow by adding additional steps or processors
- The user must enable the Show “add step” button

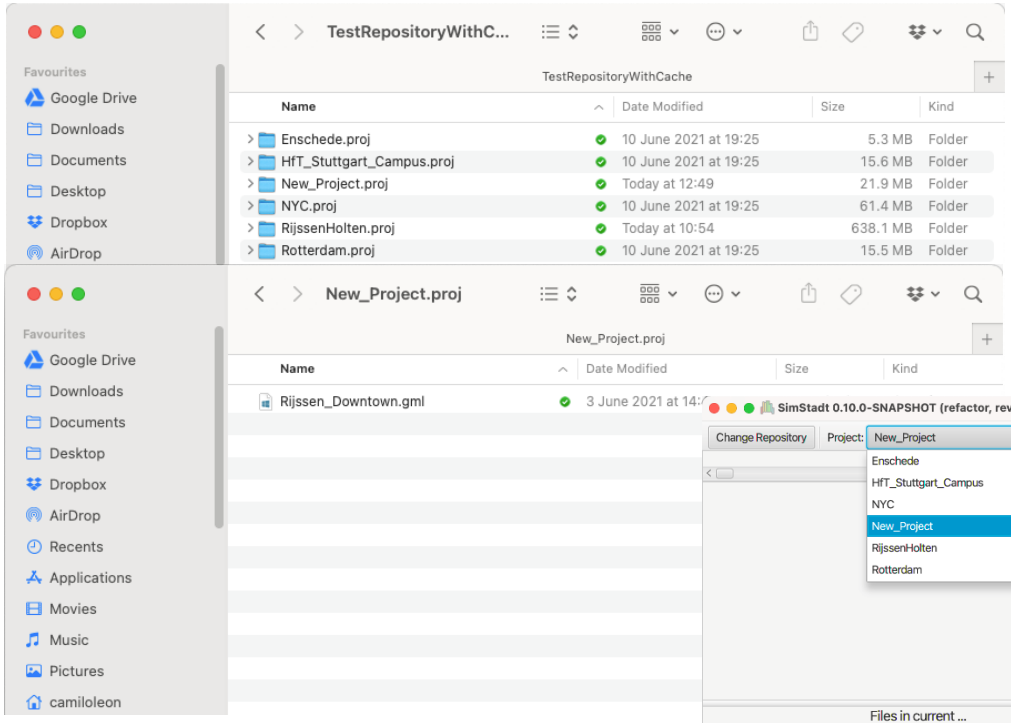


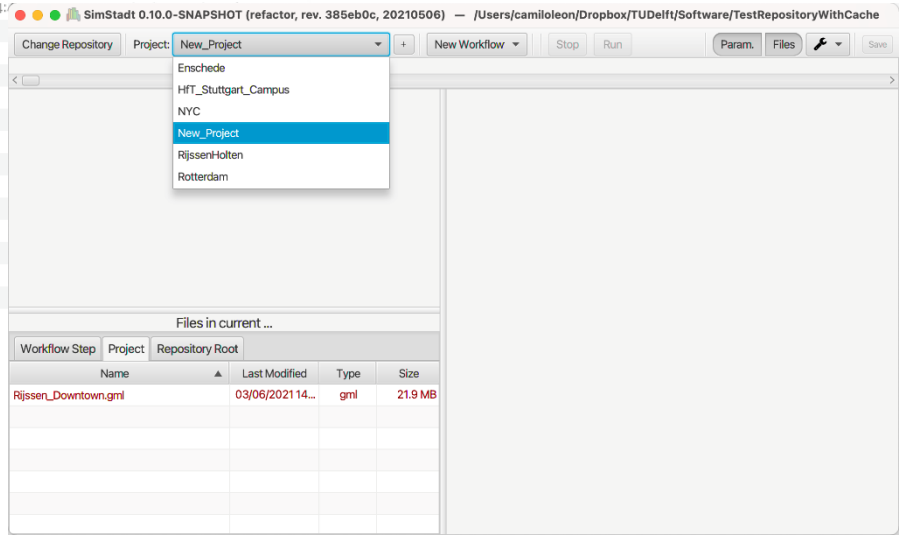
Workflow customisation

- It is possible to customise a workflow by adding additional steps or processors:
- The user must enable the Show “add step” button
  - The available processor depends on the active workflow



Data repository structure



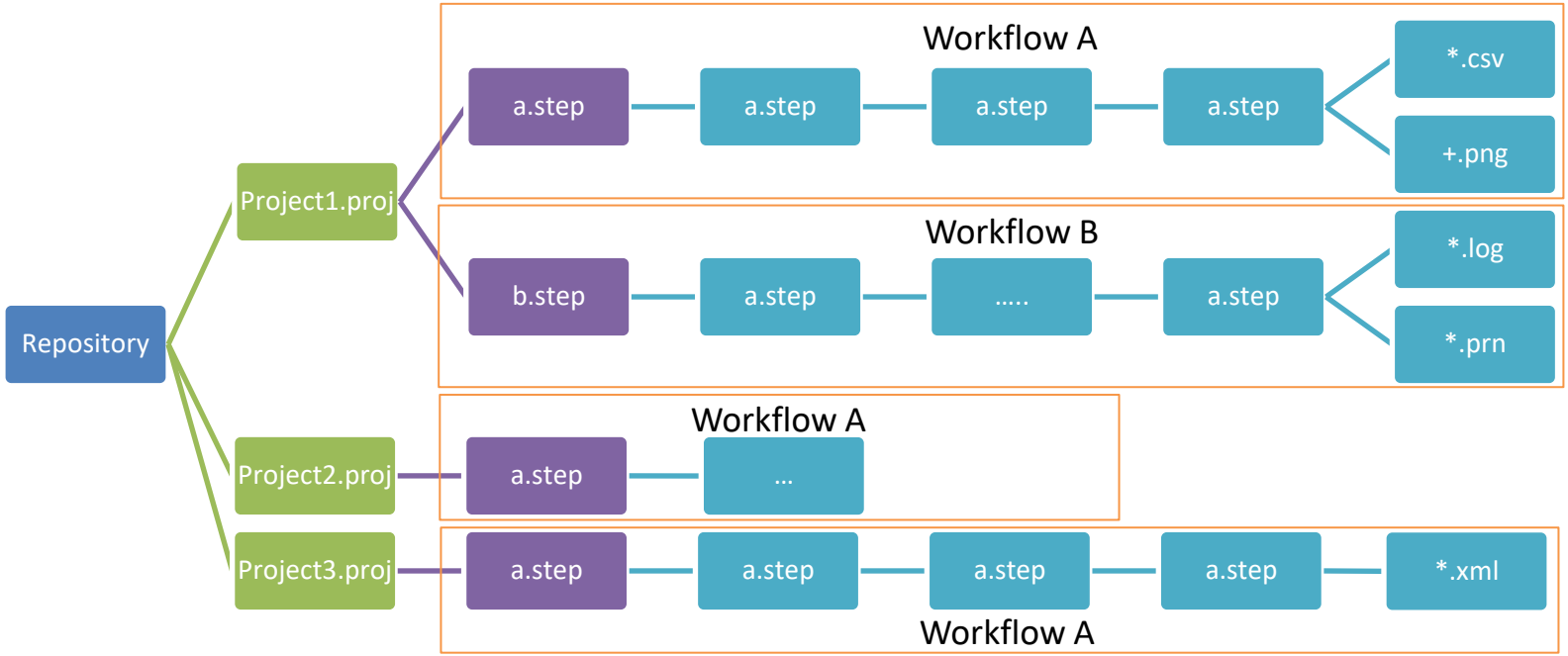


A *repository* in SimStadt is the root folder in which you collect and save all your projects.

All necessary input files (CityGML, weather data, etc.) must be copied within the folder of each project to be used from SimStadt.

Data repository structure

Due to its complexity, it is better to access files from the GUI

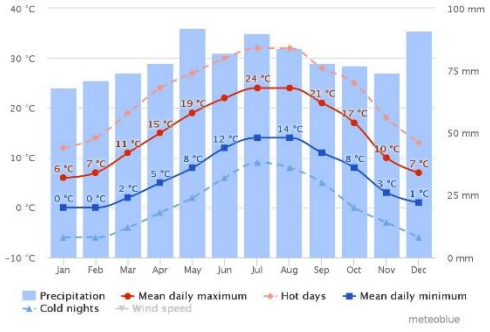


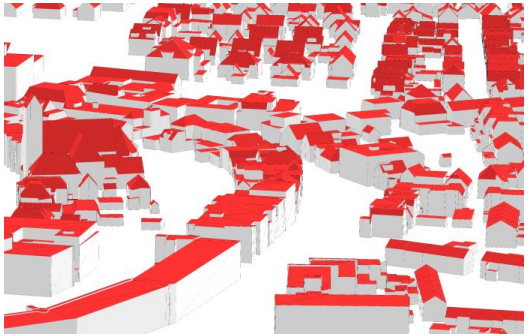
Input data requirements

The required input data depend – obviously – on the simulation purpose.

In general, typically input data are:

1) **Weather data**
2) **A 3D city model**, containing building geometries and some attributes
3) **Libraries** containing sets of parameters (e.g. for building physics, occupancy, etc.)





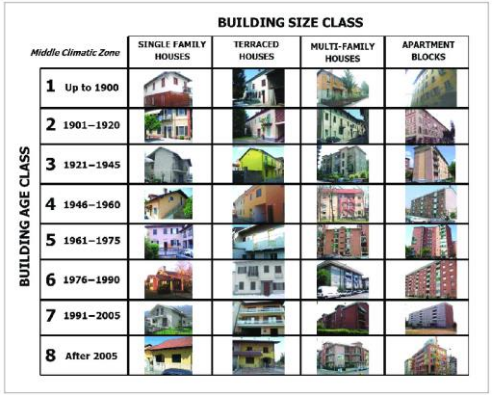


Image source: https://mb-richtexteditor.s3-eu-west-1.amazonaws.com/20151014095814_chart-8.jpg

Input data: weather

Weather data (3 options)

a) INSEL offline database

b) Photovoltaic Geographical Information System (PVGIS) online database

c) Tmy3 file (hourly/monthly). Mandatory parameters:

- Location
- *GHI*, "Global Horizontal Irradiance"
- *DNI*, "Direct Normal Irradiance"
- *DHI*, "Diffuse Horizontal Irradiance"
- *Dry-bulb*, "Dry-bulb ambient temperature"

→

- Energy Plus (EnergyPlus, 2021)
- NSRDB: National Solar Radiation Database (NREL, 2021)

Input data: weather

- Weather data is stored in a **tmy3 file**. It is a simple csv file!
- First line:
  - siteCode(integer), locationName (string), , 1, lat (in dec. deg.), long (in dec. deg.), elevation (in m a.s.l.)
  - You can adapt the needed columns, all others can be renamed to NaN and will be ignored
- Encoding rules: https://www.nrel.gov/docs/fy08osti/43156.pdf

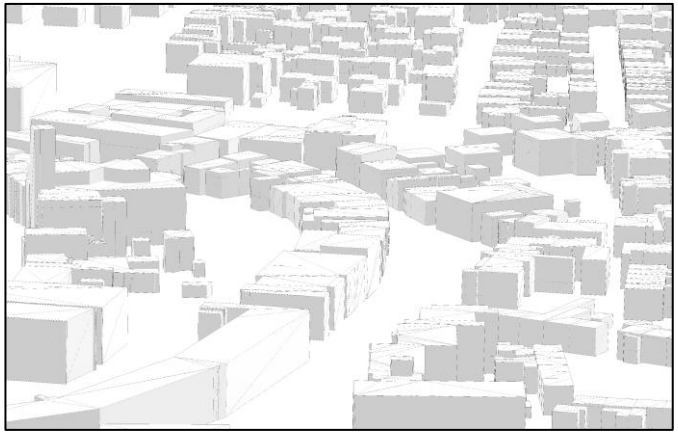
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	107370	Stuttgart			1	48.833	9.2	318							
2	Date (MM/DD/YYYY)	Time (HH:MM)	ETR (W/m^2)	ETRN (W/m^2)	GHI (W/m^2)	GHI source	GHI uncert (%)	DNI (W/m^2)	DNI source	DNI uncert (%)	DHI (W/m^2)	DHI source	DHI uncert (%)	GH illum (lx)	GH illum source
3	01/01/2005	01:00	0	0	0	3	0	0	3	0	0	3	0	0	3
4	01/01/2005	02:00	0	0	0	3	0	0	3	0	0	3	0	0	3
5	01/01/2005	03:00	0	0	0	3	0	0	3	0	0	3	0	0	3
6	01/01/2005	04:00	0	0	0	3	0	0	3	0	0	3	0	0	3
7	01/01/2005	05:00	0	0	0	3	0	0	3	0	0	3	0	0	3
8	01/01/2005	06:00	0	0	0	3	0	0	3	0	0	3	0	0	3
9	01/01/2005	07:00	0	0	0	3	0	0	3	0	0	3	0	0	3
10	01/01/2005	08:00	0	0	0	3	0	0	3	0	0	3	0	0	3
11	01/01/2005	09:00	35	426	4	3	10	0	3	20	4	3	10	546	3
12	01/01/2005	10:00	198	1412	94	3	10	363	3	20	43	3	10	9684	3
13	01/01/2005	11:00	331	1412	174	3	10	475	3	20	63	3	10	18248	3

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	107370	Stuttgart		1	48.833	9.2	318								
2	Date (MM/D	Time (HH:MM	NaN	NaN	GHI (W/m^2)	NaN	NaN	NaN	NaN	NaN	DHI (W/m^2)	NaN	NaN	NaN	NaN	NaN
3	01/01/2005	01:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
4	01/01/2005	02:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
5	01/01/2005	03:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
6	01/01/2005	04:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
7	01/01/2005	05:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
8	01/01/2005	06:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
9	01/01/2005	07:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
10	01/01/2005	08:00	0	0	0	3	0	0	3	0	0	3	0	0	3	
11	01/01/2005	09:00	35	426	4	3	10	0	3	20	4	3	10	546	3	
12	01/01/2005	10:00	198	1412	94	3	10	363	3	20	43	3	10	9684	3	

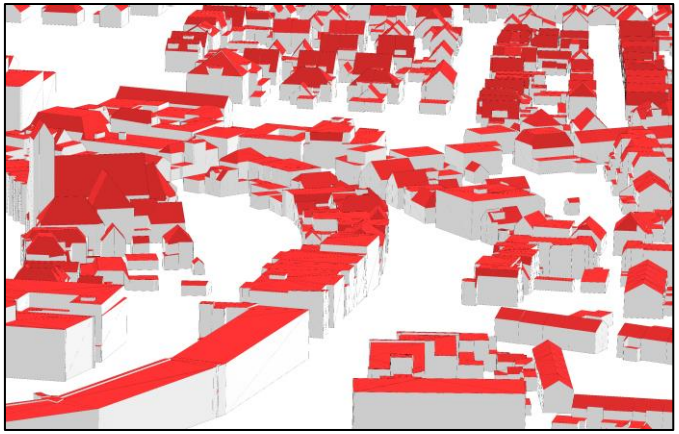
Input data: 3D city model

Building data

- A valid (XML-encoded) CityGML file
  - Geometries are validated upon import by CityDoctor (Coors et al., 2020)
    - LoD1
    - LoD2
  - Minimum set of attributes is discussed in upcoming slides



LoD1



LoD2

Input data: 3D city model

Building data

To perform energy demand simulations, buildings must have at least information for:

- Year of construction
- Usage

Please note: building usage must be written in attribute "function" (so, neither building "class", nor building "usage"!)

```
23      <core:cityObjectMember>
24          <bldg:Building gml:id="NL.IMBAG.Pand.1742100000004313">
25              <gen:stringAttribute name="ground_height">
26                  <gen:value>11.495</gen:value>
27              </gen:stringAttribute>
28              <gen:stringAttribute name="lod2_area">
29                  <gen:value>18.7</gen:value>
30              </gen:stringAttribute>
31              <gen:stringAttribute name="lod2_volume">
32                  <gen:value>62.39</gen:value>
33              </gen:stringAttribute>
34              <bldg:class>woonfunctie</bldg:class>
35              <bldg:yearOfConstruction>1948</bldg:yearOfConstruction>
36              <bldg:roofType>slanted</bldg:roofType>
```

This will not work!

Input data: 3D city model

Currently, SimStadt supports only the German encoding definitions – ALKIS (AdV, 2018)

For non-German buildings, **two ways** to set up the function values properly:

1) Edit/Update the function attribute(s) in the CityGML file and substitute it with the proper numeric value as per ALKIS codelist

2) Write an XML-based mapping file that SimStadt uses to convert "on the fly" the values in the CityGML document to the corresponding ALKIS values
   - This mapping file must be named **AlkisCodes.xml**

Input data: 3D city model

Building data

1) Edit/Update the function attribute(s) in the CityGML file and substitute it with the proper numeric value as per ALKIS codelist

```
23      <core:cityObjectMember>
24          <bldg:Building gml:id="NL.IMBAG.Pand.1742100000004313">
25              <gen:stringAttribute name="ground_height">
26                  <gen:value>11.495</gen:value>
27              </gen:stringAttribute>
28              <gen:stringAttribute name="lod2_area">
29                  <gen:value>18.7</gen:value>
30              </gen:stringAttribute>
31              <gen:stringAttribute name="lod2_volume">
32                  <gen:value>62.39</gen:value>
33              </gen:stringAttribute>
34              <bldg:class>woonfunctie</bldg:class>
35              <bldg:function>1010</bldg:function>
36              <bldg:yearOfConstruction>1948</bldg:yearOfConstruction>
37              <bldg:roofType>slanted</bldg:roofType>
```

1) Function as ALKIS code

Input data: 3D city model

Building data

2) Write an XML-based mapping file that SimStadt uses to convert "on the fly" the values in the CityGML document to the corresponding ALKIS values

```
25      <bldg:Building gml:id="NL.IMBAG.Pand.1742100000005418">
26          <gml:name>Building_1200</gml:name>
27          <core:relativeToTerrain>entirelyAboveTerrain</core:relativeToTerrain>
28          <gen:stringAttribute name="pand_id">
29              <gen:value>1742100000005418</gen:value>
30          </gen:stringAttribute>
31          <bldg:class>Non-residential (single-function)</bldg:class>
32          <bldg:function>overige gebruiksfunctie</bldg:function>
33          <bldg:yearOfConstruction>1979</bldg:yearOfConstruction>
34          <bldg:roofType>single horizontal</bldg:roofType>
35          <bldg:lod0FootPrint>
```

```
1  <?xml version="1.0" encoding="ISO-8859-1"?>
2
3  <codes xmlns:buLib="http://www.simstadt.eu/BuildingUsageLibraries" xmlns="http://www.simstadt.eu/AlkisCodes">
4
5  <codesForBuildingUsageLibraryNamed>Germany_DIN18599</codesForBuildingUsageLibraryNamed>
6
7    <code from="overige gebruiksfunctie" to="9997"/>
8
9  </codes>
```

2) CityGML with AlkisCodes.xml

Input data: libraries

Building physics library

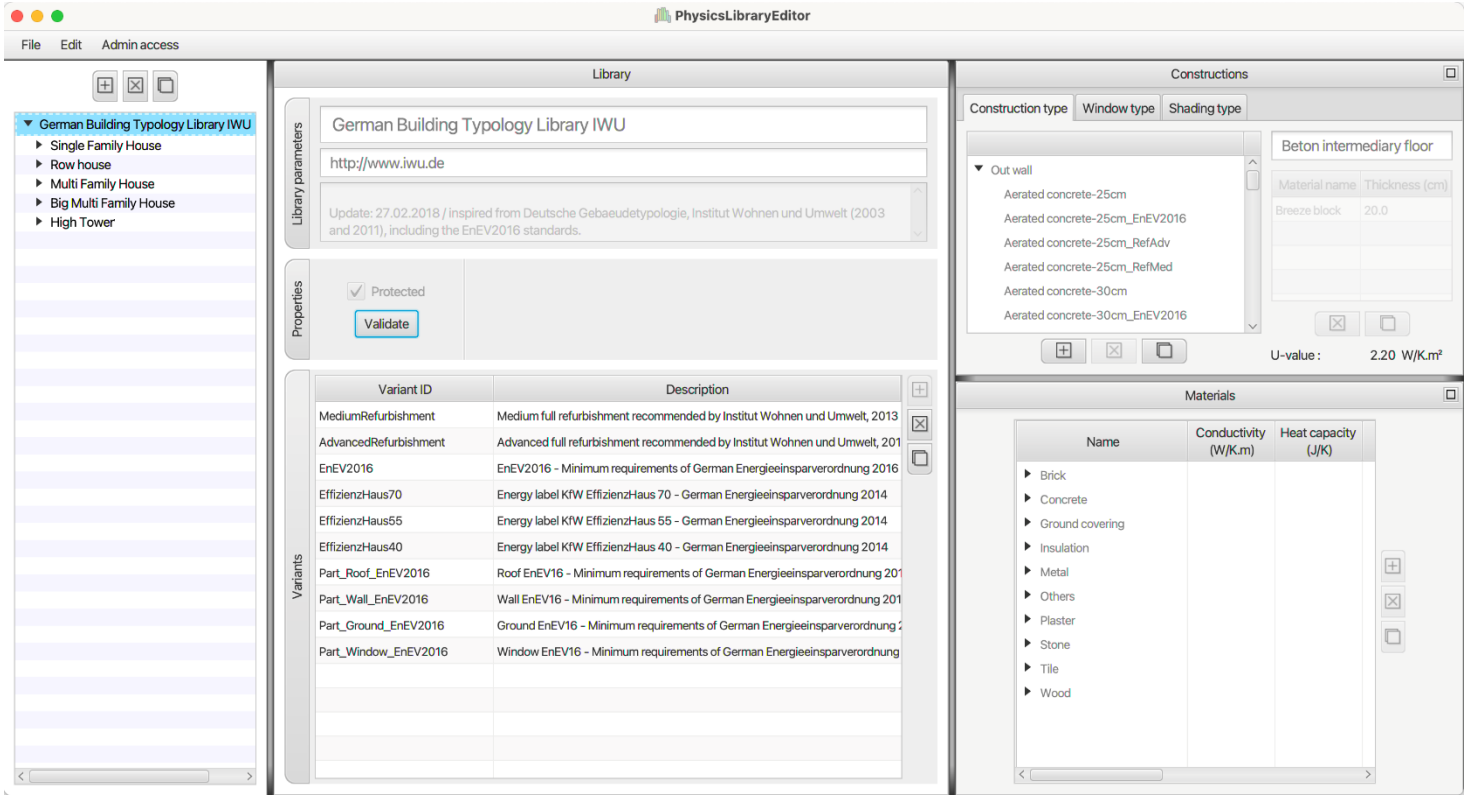
- Building physics parameters are required for energy demand simulations
- The building physics library contains parameters regarding
  - Constructions & Materials
  - U-values of the different building elements
  - G-values of glazing surfaces
  - Average thermal bridges, etc.

- Currently SimStadt only supports building parameters for German and NYC typologies

- (It seems that) it can be customised
  - …but currently it is not clear how it should be done and whether it works…
  - For the time being, simply use the existing library

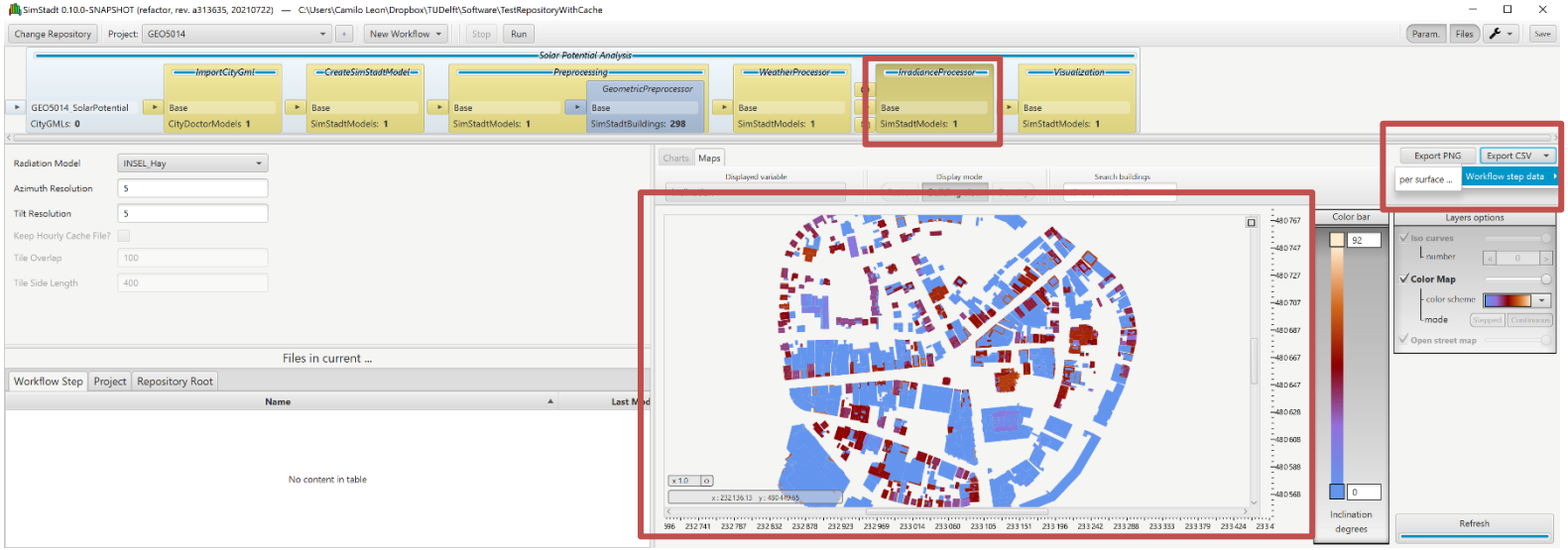
Input data: libraries

Building physics library



Data export

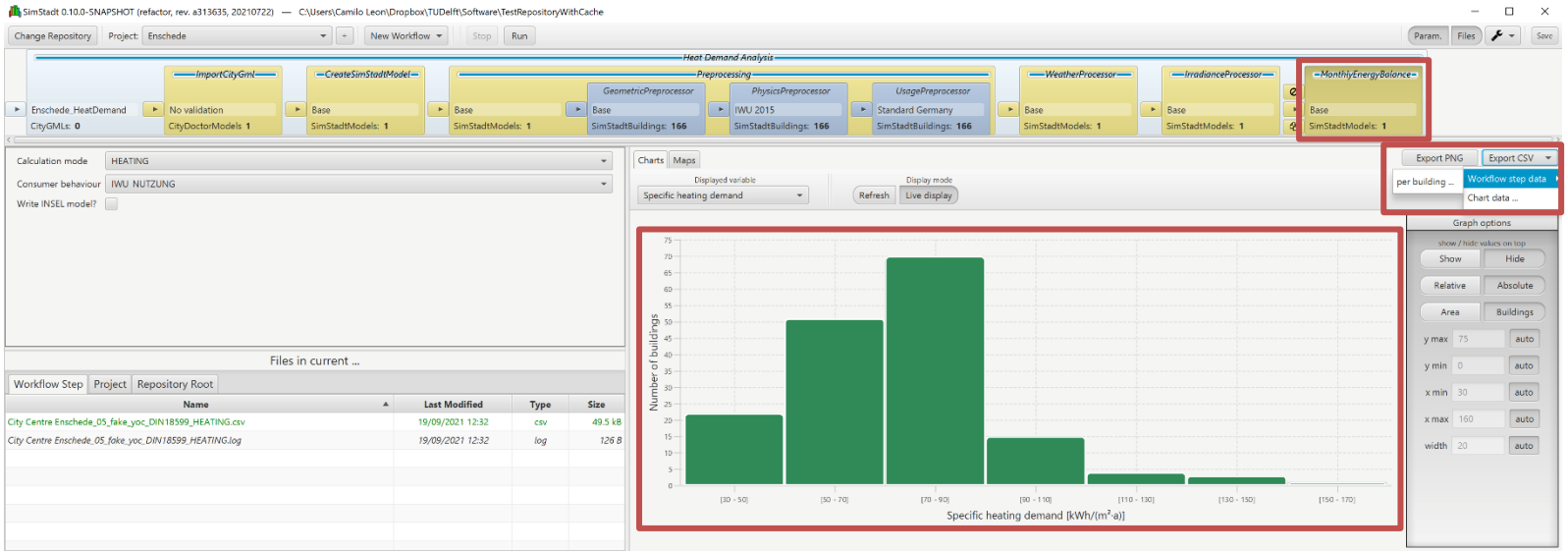
- Using the GUI, results from each processing step can be exported as:
  - PNG images (current visualisation)
  - CSV files



IrradianceProcessor

Data export

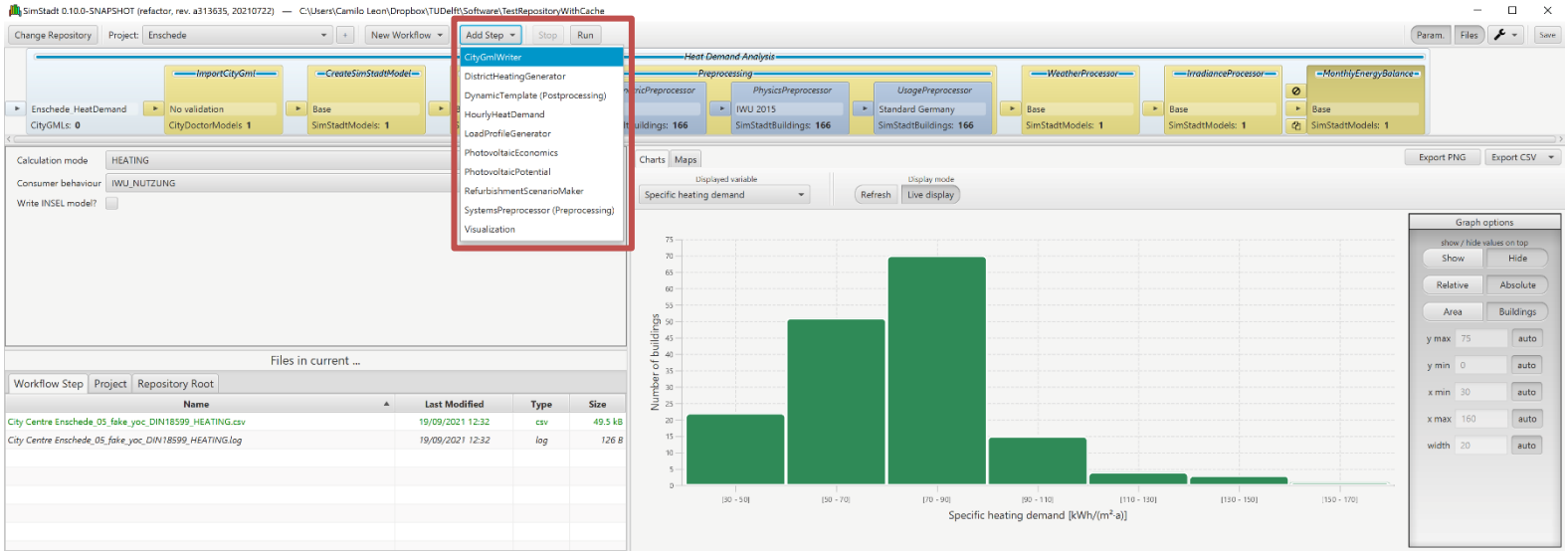
- Using the GUI, results from each processing step can be exported as:
  - PNG images (current visualisation)
  - CSV files



MonthlyEnergyBalance

Data export: CityGML

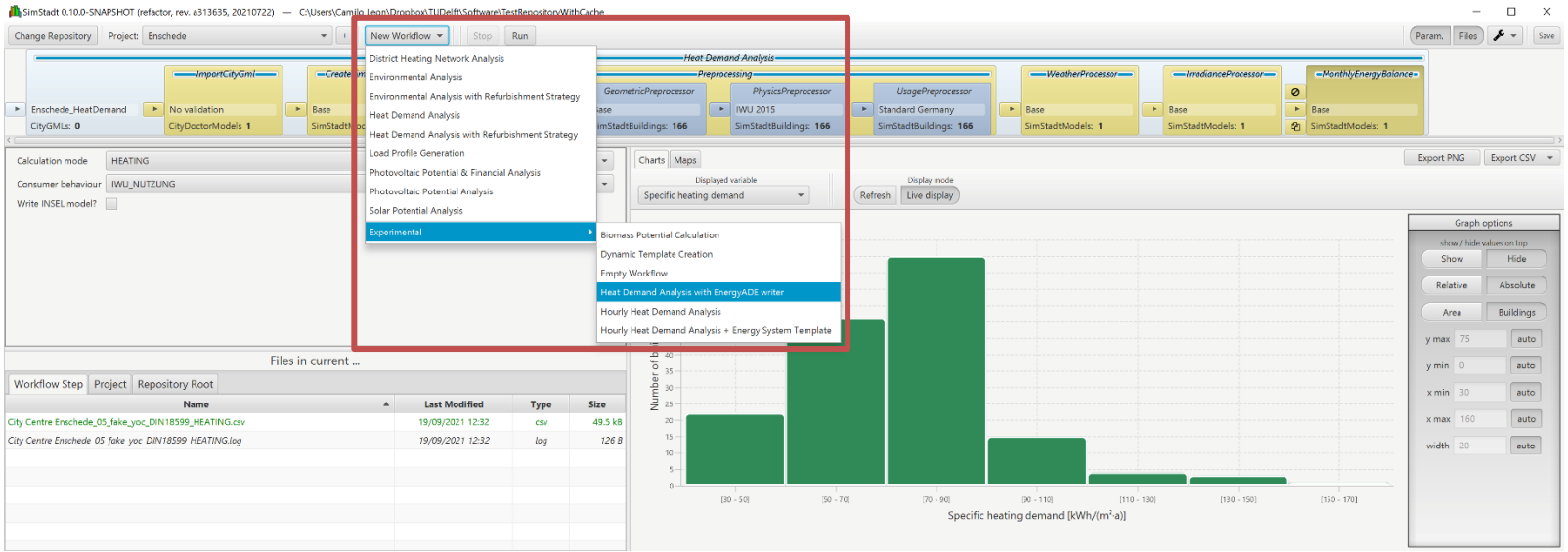
- There are two possibilities to export results in CityGML
  a) Adding a new *CityGMLWriter* step to the workflow



Step CityGMLWriter

Data export: CityGML (+ Energy ADE)

- There are two possibilities to export results in CityGML
  b) Using the specific workflow "Heat Demand Analysis with the Energy ADE writer"



Heat Demand Analysis with the Energy ADE writer

CityGML + Energy ADE

Please note: as of autumn 2024, the exported CityGML + Energy ADE file

- contains only data according to the Energy ADE KIT profile
  - https://www.citygmlwiki.org/images/4/41/KIT-UML-Diagramme-Profil.pdf
- contains some errors and is therefore not valid. For example:
  - The tag energy:timeInterval contains the value "month". It is not a valid Time Unit Type
    - A workaround is to express it as 0.083 of a year
  - FloorArea and EnergyDemand elements are missing the corresponding property tag

If you want to go this way, it is therefore recommended to adjust/correct the file (e.g. in FME). Only once the file is valid, it can be imported in the 3DCityDB with the Energy ADE plugin.

More details can be found in:

León-Sánchez, C., Giannelli, D., Agugiaro, G., Stoter, J., 2021,
Testing the new 3D BAG dataset for energy demand estimation of residential buildings.
ISPRS Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLVI-4/W1-2021, pp. 69–76
https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLVI-4-W1-2021/69/2021/ (open access)

CityGML + Energy ADE


```
54615        </bldg:WallSurface>
54616      </bldg:boundedBy>
54617      <energy:FloorArea>
54618        <energy:type>energyReferenceArea</energy:type>
54619        <energy:value uom="m2">4.200314056665326</energy:value>
54620      </energy:FloorArea>
54621      <energy:EnergyDemand>
54622        <energy:energyAmount>
54623          <energy:RegularTimeSeries>
54624            <energy:variableProperties>
54625              <energy:TimeValuesProperties>
54626                <energy:acquisitionMethod>simulation</energy:acquisitionMethod>
54627                <energy:source>SimStadt 0.10.0-SNAPSHOT (refactor, rev. a313635, 20210722)</energy:source>
54628              </energy:TimeValuesProperties>
54629            </energy:variableProperties>
54630            <energy:timeInterval unit="month">1.0</energy:timeInterval>
54631            <energy:values uom="kWh">5.668709945894079E-11 7.408296198718745E-12 4.718447854656915E-15 0.0 0.0 0.0 0.0 0.0 0.0
                 8.859579736508749E-14 2.8244073746463982E-11 7.866063356232189E-11</energy:values>
54632          </energy:RegularTimeSeries>
54633        </energy:energyAmount>
54634        <energy:endUse>spaceHeating</energy:endUse>
54635      </energy:EnergyDemand>
54636      <energy:EnergyDemand>
54637        <energy:energyAmount>
54638          <energy:RegularTimeSeries>
54639            <energy:variableProperties>
54640              <energy:TimeValuesProperties>
54641                <energy:acquisitionMethod>simulation</energy:acquisitionMethod>
54642                <energy:source>SimStadt 0.10.0-SNAPSHOT (refactor, rev. a313635, 20210722)</energy:source>
54643              </energy:TimeValuesProperties>
54644            </energy:variableProperties>
54645            <energy:timeInterval unit="year">1.0</energy:timeInterval>
54646            <energy:values uom="kWh">0.0</energy:values>
54647          </energy:RegularTimeSeries>
54648        </energy:energyAmount>
54649        <energy:endUse>domesticHotWater</energy:endUse>
54650      </energy:EnergyDemand>
54651    </bldg:Building>
54652  </core:cityObjectMember>
```

It should be inside tag energy:floorArea

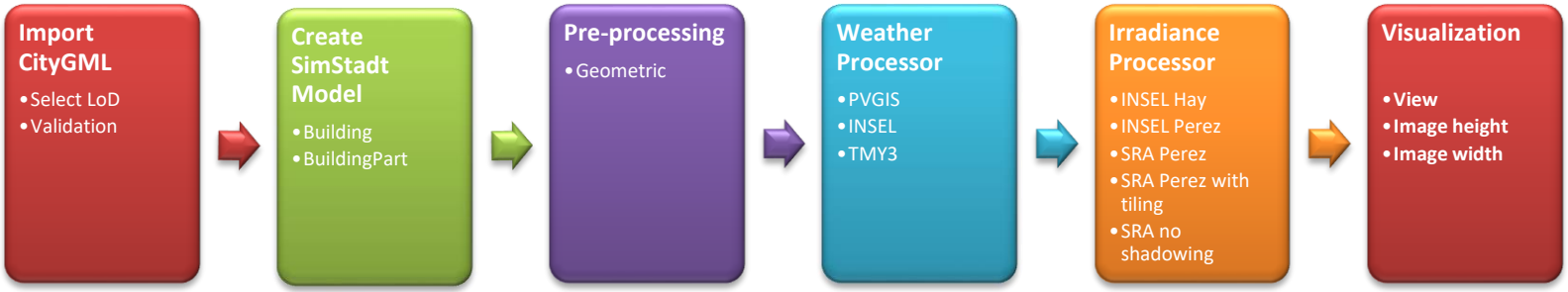
It should be inside tag energy:demands

Incorrect time interval

Example of some errors in the CityGML + Energy ADE file from SimStadt

Solar analysis

These are the typical steps that compose the "Solar Potential analysis" workflow in SimStadt



Sky Model
John Hay
Richard Perez

Irradiance processor

When performing solar analysis, some specific simulation parameters must be set. Here some of the most relevant ones.

Of particular relevance is whether the effect of shadow-casting objects must be considered or not. SimStadt offers the following radiation models.

Radiation models

- **INSEL_Hay**: computationally fast, without shadows
- **INSEL_Perez**: computationally fast, more detailed and possibly more accurate than Hay, without shadows
- **Perez Simplified Radiosity Algorithm**: computationally slow, should not be used for larger models, considering shadows
- **Perez Simplified Radiosity Algorithm on tiles**: optimised for larger models (split in smaller tiles), considering shadows
- **Perez Simplified Radiosity Algorithm** on a geodesic dome: computationally fast, can be used for comparisons with other SRA calculations, without shadows

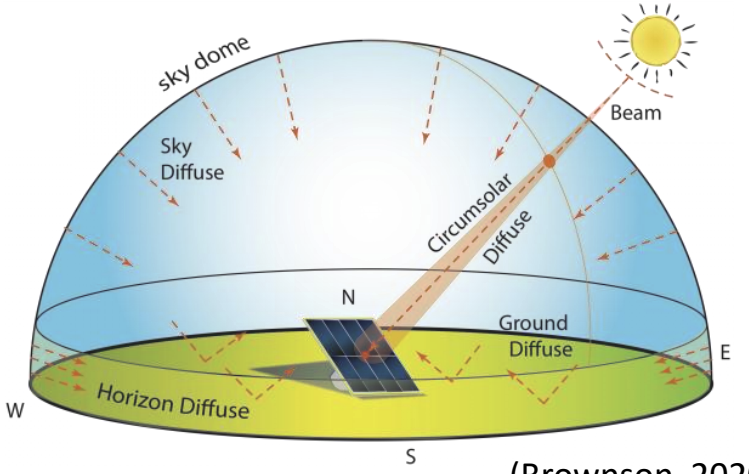
Irradiance processor

When performing solar analysis, some specific simulation parameters must be set. Here some of the most relevant ones.

For INSEL:

The sky dome is discretised, and irradiance is computed considering a "grid" defined by azimuth and tilt (inclination) resolution. Both values indicate the "size" in decimal degrees of each grid cell.

- Azimuth resolution: **int, unit [°]**
  - e.g. 5°
- Tilt resolution: **int, unit [°]**
  - e.g. 5°



(Brownson, 2020)

Please note: the smaller the values of the angles, the longer the time needed by the simulation (obviously!)

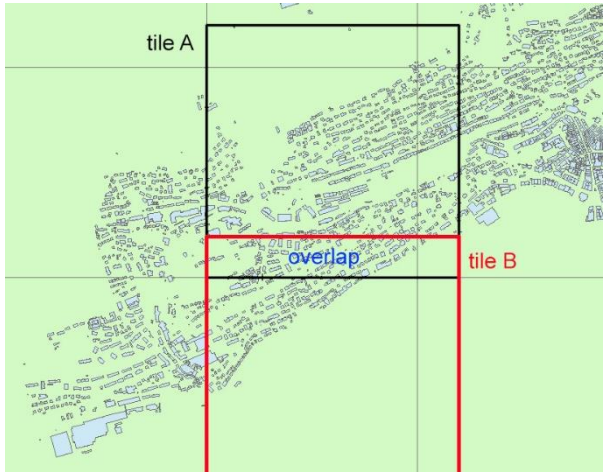
Irradiance processor

When performing solar analysis, some specific simulation parameters must be set. Here some of the most relevant ones.

For SRA_Perez_with_tiling

The complete 3D model is split in smaller tiles before shadows are calculated. In order to consider shadows for the buildings located on the edge of the tiles, tiles must overlap

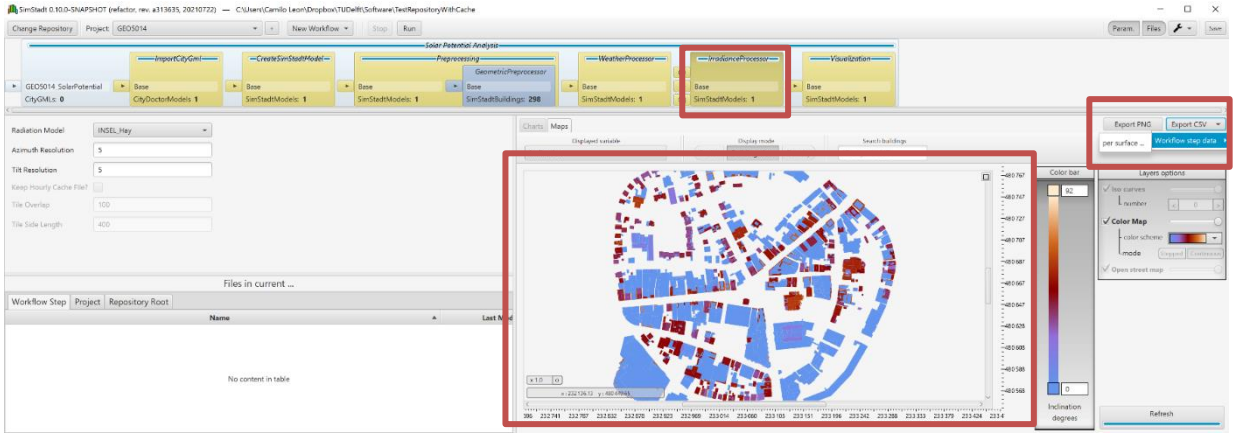
- Tile side: **int, unit [m]**
  - e.g. 400 m
- Tile overlap: **int, unit [m]**
  - e.g. 100 m



Please note: if you use tiling, you MUST provide an overlap values > 0 to assure that no buildings are missed

Irradiance processor

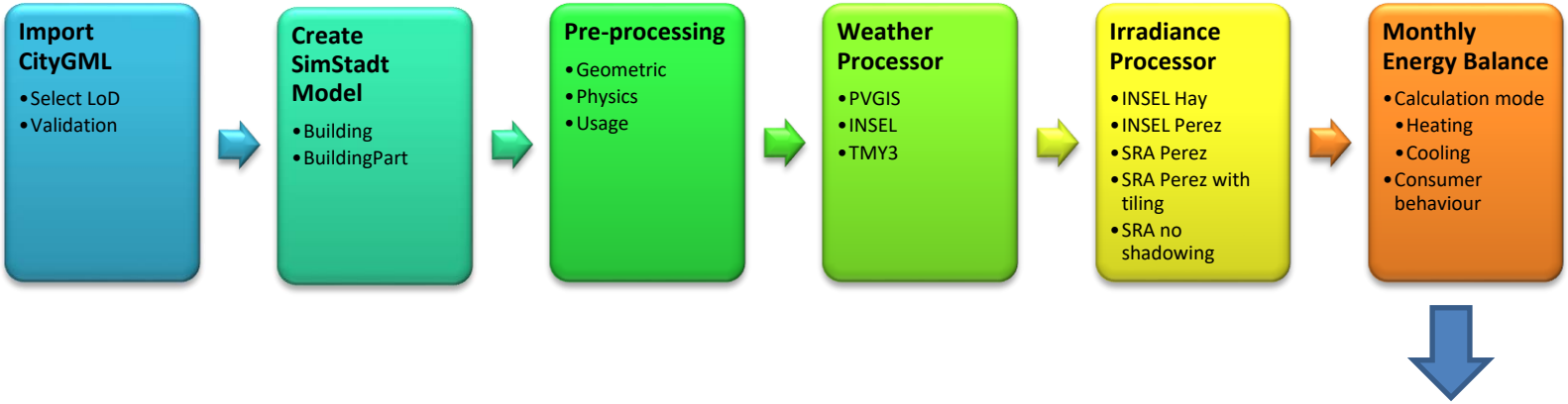
- Results are only available as PNG and CSV
- The exported csv file looks like:



```
Surface ID,Building ID,Type,Azimuth [º],Inclination [º],Area [m2],Irradiance [W/m2]
WallSurface_UUID_42d30a68-22bf-4fc2-a042-e089b1843de1,NL.IMBAG.Pand.1742100000005721,WALL,263.00,90.00,11.95,79.10
RoofSurface_UUID_58c1509e-6b37-4b8c-8890-edbcaaca02cb,NL.IMBAG.Pand.1742100000005721,ROOF,180.00,0.00,44.15,118.73
WallSurface_UUID_34860986-b28e-4005-8a4b-b3d5af196933,NL.IMBAG.Pand.1742100000005721,WALL,173.00,90.00,28.21,92.12
WallSurface_UUID_bf60ac11-be10-437f-b06c-00585dd9a392,NL.IMBAG.Pand.1742100000005721,WALL,352.00,90.00,0.00,0.00
WallSurface_UUID_0ad442b8-c7c6-4b4f-bc3a-20867d78797a,NL.IMBAG.Pand.1742100000005721,WALL,83.00,90.00,12.29,75.87
GroundSurface_UUID_1b3ec8f8-f907-44a5-a05e-ab95522b3ed5,NL.IMBAG.Pand.1742100000005721,GROUND,180.00,180.00,44.15,0.00
RoofSurface_UUID_54778d6f-0704-49a5-8433-e8cbe77db2a3,NL.IMBAG.Pand.1742100000005720,ROOF,180.00,0.00,47.61,118.73
WallSurface_UUID_2b4f15f8-d16f-4053-b5c2-cb11ffe3669d,NL.IMBAG.Pand.1742100000005720,WALL,353.00,90.00,28.75,52.40
WallSurface_UUID_e4d0cd42-6930-4689-b7f0-458cc311b9ec,NL.IMBAG.Pand.1742100000005720,WALL,83.00,90.00,13.11,75.87
```

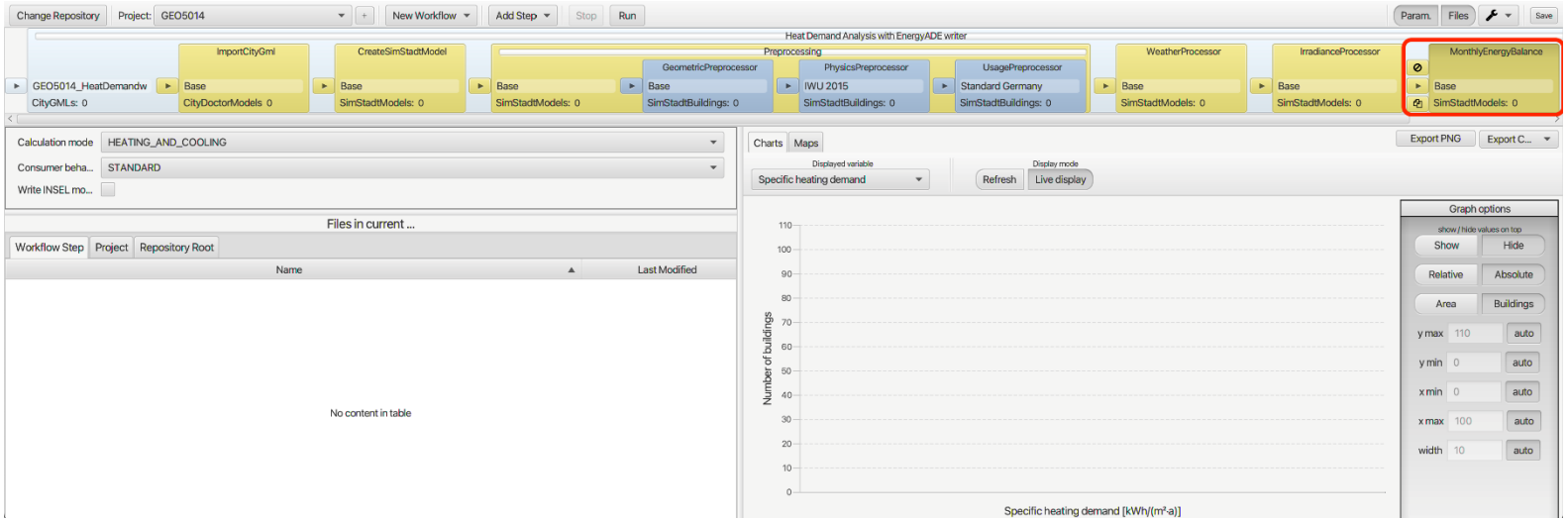
Energy demand analysis

These are the typical steps that compose the "Heat Demand Analysis" workflow in SimStadt



Please note: Heating analysis includes domestic hot water (DHW) production

Energy demand analysis



Overview of the "Heat Demand Analysis" workflow

Energy demand analysis

- Results can be exported as
  - CSV file
  - CityGML + Energy ADE (see previous slides)


```
## SimStadt DIN18599 Monthly Energy Balance
#
# Weather data source;meteonorm tmy3 file 2000-2009
# Location;Twenthe Enschede AP
# Coordinate reference system;EPSG:28992
# Latitude;52.27;°
# Longitude;6.89;°
# Radiation model;meteonorm_Hay
# Calculation Mode;HEATING_AND_COOLING
# Consumer behaviour;IWU_NUTZUNG
#
# Building physics library;German Building Typology Library IWU (http://www.iwu.de)
# Building usage library;Building Usage Library (based on UsageLibrary.xlsx, sheet: Germany)
# Has custom building usage codes?;true
#
# SimStadt version;0.10.0-SNAPSHOT (refactor, rev. a313635, 20210722)
# Created at;2021/09/19 21:05:14
# Cache version;7
#
GMLId;ParentGMLId;Latitude;Longitude;X-coordinate;Y-coordinate;LOD;Year of construction;Year of refurbishment;Refurbishment Variant;ALKIS
[-];[-];[°];[°];[?];[?];LOD;[YYYY];[YYYY];[-];[-];[-];[m²];[-];[m²];[-];[m²];[m²];[m²];[m²];[m²];[m²];[m³];[0/1];[m³];[m];[m];[-];[m];[-]
NL.IMBAG.Pand.1742100000005721;;52.30851;6.52004;232256.01;480665.09;LOD2;1996;;Original;1630;non-heated;35.8;none;0.0;RH;44.2;47.8;0.0;5
NL.IMBAG.Pand.1742100000005720;;52.30855;6.52003;232255.46;480669.52;LOD2;1996;;Original;1630;non-heated;38.8;none;0.0;RH;47.6;50.3;0.0;5
NL.IMBAG.Pand.1742100000004755;;52.30660;6.52066;232301.40;480452.80;LOD2;1948;;Original;1000;residential;127.4;none;0.0;EFH;138.3;185.4;
NL.IMBAG.Pand.1742100000005723;;52.30851;6.52046;232284.49;480665.48;LOD2;1933;;Original;1000;residential;131.8;none;0.0;RH;104.4;144.5;0
NL.IMBAG.Pand.1742100000005722;;52.30843;6.52041;232281.42;480656.06;LOD2;1933;;Original;1000;residential;20.9;none;0.0;RH;35.2;58.2;0.0;
NL.IMBAG.Pand.1742100000004754;;52.30677;6.52074;232306.67;480471.86;LOD2;1948;;Original;1000;residential;242.3;none;0.0;EFH;129.4;261.3;
```

Example of heat demand analysis results exported as CSV file

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