Collection of AZEB factsheets on design optimization tooling

The following factsheets have been developed within AZEB for professionals to use in the design phase, when selecting appropriate tooling to optimize their designs. The factsheets compactly describe per tool the purpose, users, input and output, strengths and weaknesses et cetera. The list of tools is not exhaustive, but representative of the available specialised optimisation tooling for nZEB design.

This collection of factsheets addresses:

- Energy simulation tools
- Passive House Planning Package (PHPP)
- Commissioning tool
- Cooling Systems Tool
- Performance data generation tool for air-to-air heat pumps
- Hygiene tool
- Thermal bridge tool
- Ventilation tool
- Window tool
- Building optimisation tool
- Building LCA tools
- AZEB TCO tool

This information reflects only the author’s view, the European Agency and Commission are not responsible for any use that may be made of the information it contains.
Energy simulation tools

Energy simulation tools can be used in the design phase, allowing comparison of alternatives in terms of energy performance and thermal comfort.

**Purpose**
Performs thermal simulations of building projects, in order to provide designers, engineers or architects, with energy and comfort indicators allowing a project to be evaluated (e.g. heating and cooling needs, number of overheating hours, Brager zones, Givoni diagram).

**Examples of tools**
- ESP (Scotland) http://www.esru.strath.ac.uk/Programs/ESP-r.htm
- IDA (Sweden) https://www.equa.se/en/ida-ice
- PHPP (Germany) https://passivehouse.com/04_phpp/04_phpp.htm
- COMFIE (France) http://www.izuba.fr

Because the AZEB project aims at reducing the cost of zero energy buildings, a tool linked to an optimisation module has been used as an example in the case studies, but the methodology could be applied to other Building Energy Simulation tools.

**Project phases**
Mutual shading effects can be studied during the planning phase. In the sketch phase, energy simulation allows to compare energy performance and comfort level of different architectural forms (compactness, glazing areas...) and major choices (e.g. integration of solar collectors). In detailed design, comparing energy performance and comfort level of different technical solutions (insulation, glazing types, solar protection, equipment, energy sources...) can be based upon simulation results.

**Users**
The main users group corresponds to engineers in charge of energy calculations. But energy simulation can also be performed by urban designers, architects, and contractors.

**Importance**
Essential for Mediterranean climates and large projects, optional for single family houses, advanced in other cases but recommended in order to study the resilience of buildings to climate change.

**Input**
Building geometry, material characteristics, internal gains and schedules, climate, heating and cooling equipment characteristics. In the tool that has been used in AZEB, readable, structured input file is generated by PLEIADES users interface (2-3D modeller).
Output

Energy and comfort indicators: heating and cooling needs, energy consumption, number of overheating hours, predicted percentage of dissatisfied (PPD), predicted mean vote (PMV) etc.

Effects of an overhang are shown at any time of the year
Yearly temperature profiles can be obtained in different thermal zones.

Adaptive comfort level can be shown using e.g. ISO standard 15251 category II.
A Givoni diagram accounts also for humidity

Validation

The example model has been validated by comparison both with other software (Brun, 2009) and experimental measurements, see e.g. (Munaretto, 2017).
Applicability

The example tool can be applied in Europe using appropriate climatic data and possibly customizing construction techniques according to a local context. It runs on windows environment, and the reasonable fee corresponds to an efficient service to users (phone and web contact, users’ forum…) which makes it more economical than most open source software requiring more manpower due to poor user friendliness.

Computer platform

The example tool was developed for Microsoft Windows operating system. The 3D data entry can be performed using the tool itself, or BIM can be imported from other software.

Strength

Links with an aeraulic model, lighting calculations, a life cycle assessment tool and a user friendly interface allows a more global assessment; using default values and possible import from BIM allows for use at early design stage, particularly by architects. The model has been validated by software comparison and experimental validation. A model reduction technique decreases the computation time, allowing thousands of simulation to be performed in an optimisation process, without reducing the precision related to detailed modelling.

Weakness

Importing a BIM requires a precise format of this BIM (IFC4 Reference view, including rooms).

Outcome

Energy simulation allows to evaluate the energy performance of a project, and to check that increasing this performance and reducing cost does not lead to reduce the level of hygro-thermal comfort.

Contact

MINES ParisTech, CES
60 Bd St Michel
75272 Paris Cedex 06 France
e-mail: bruno.peuportier@mines-paristech.fr

References

Passive House Planning Package (PHPP)

The Energy Balance Calculation Tool PHPP (Passive House Planning Package) is to be used from the preliminary design stage through to the completion of the project, allowing comparisons to monitored results.

Purpose

PHPP is an easy to use planning tool for energy efficient building design, for use by architects, building engineers and planning experts. PHPP is used by thousands of Passive House practitioners already and it’s easy to use interface has enabled the accurate and reliable design of tens of thousands of high performance buildings. PHPP results have been validated against dynamic building simulations and confirmed by a significant number of monitoring projects (see Reference [1]). Projects designed with PHPP have shown no performance gap between accurately modelled buildings and their operational performance. PHPP is the ideal design tool for energy efficient buildings like Passive Houses, NZEBs or other efficiency projects and supports designers in making the right decisions related to building components, lay outs or other efficiency measure efficient building projects or deep energy retrofits. Additionally tradespersons, energy consultants and

User

Architects, designers, engineers and consultants in the construction industry who are working on highly energy public agencies or administrations will find the PHPP a valuable tool for determining building energy performance.

Input

The data entry into PHPP is straight-forward, a result of its Excel format:

- General information: Reference floor area, quantity of residential units or inhabitants
- Building envelope data: external building geometry, component properties of opaque and transparent envelope components, orientation and shading properties
- Ventilation properties: air flow volumes and air exchange rates, heat or humidity recovery efficiency, ventilation duct length
- Location and climate: altitude and climate data (monthly average outdoor temperature, radiation and dew point temperature, heating and cooling load data)
- Distribution losses: Duct length and insulation quality of heating or DHW distribution, DHW storage properties
- Renewable Energy Systems (RES): Geometry, orientation and properties of PV or solar thermal systems
- Electricity: household appliances and auxiliary electricity
- Heating and cooling: Performance properties and energy supply of heating or cooling units/systems
- Contribution margins of heat generation or cooling concepts

Output

All relevant energy efficiency performance results of the building:

- Annual heating demand [kWh/(m²a)] and maximal heating load [W/m²]
• Annual cooling demand \([\text{kWh}/(\text{m}^2\text{a})]\) and maximal cooling load \([\text{W/m}^2]\)
• Comfort in summer through passive cooling: Frequency of overheating [%]
• Primary Energy Renewable and Primary Energy demands for all building energy services \([\text{kWh}/(\text{m}^2\text{a})]\)
• Estimation of annual renewable energy gains \([\text{kWh}/(\text{m}^2\text{a})]\) by PV or solar thermal systems
• The verification of the Passive House or EnerPHit standard

**Computer platform**

The tool was developed in Microsoft Excel for both Microsoft Windows or Macintosh operating systems. For the 3D data entry tool designPH and SketchUP are required.

**Strength**

The accuracy of the energy demand or load calculated with PHPP when compared with measured consumption or heating load in monitored projects from various countries is very good. PHPP can, therefore, be used reliably for the design of highly energy efficient projects. PHPP also has a number of features that enable the rapid and optimised design of highly energy efficient buildings (see Reference [2]). Other strengths include:

- Due to its data entry methodology and calculation methods, international climate data sets and certification criteria, it is applicable for projects not only across Europe, but also worldwide.
- With the PER system for renewable primary energy, PHPP contains one of the only efficiency evaluation methods to evaluate a buildings energy efficiency in a completely renewable energy supply environment, as anticipated for 2050 or later, depending on policy progress.
- PHPP allows the input and calculation of design variants, allowing various design options to be evaluated, components optimised, solutions compared. This concept allows the comparison of the cost-efficiency of certain efficiency measures or entire design concepts.
- Data entry of energy efficiency parameters isn’t self-explanatory for many engineers and designers new to the topic. PHPP, therefore, contains systematic input assistance and error messages, to support inexperienced users with the task of evaluating a project’s efficiency.
- The Microsoft Excel format allows for flexible data entry and even permits additional formulas or side calculations. PHPP is based on a monthly calculation and the entry detail level and effort is moderate when compared to dynamic simulations, and therefore allows an economically justifiable investment for the design of highly energy efficient projects.
- Additionally, a visual and 3D data entry method using designPH is possible users of the popular SketchUP CAD program. Furthermore, PHPP offers connectivity to various BIM tools or other efficiency evaluation tools for the efficient import of project data.

**Challenge**

Data entry into PHPP must be accurate, otherwise the results cannot be considered reliable. This requires more effort for the data entry process when compared to less reliable energy efficiency evaluation methods and in many cases inexperienced users require support to identify the correct parameters to enter.

In addition, the Microsoft Excel format is perceived as old-fashioned by some users.

**Outcome**

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PHPP offers an easy and straight-forward data entry system that requires moderate effort. As described above, projects calculated with PHPP show very reliable results, the basis for the successful completion of any energy efficiency project. The accuracy of the efficiency results is also the basis for any cost optimisation process, as otherwise specific energy efficiency concepts or measures couldn’t be reliably optimised in terms of energy or cost efficiency. PHPP is, therefore, the ideal calculation and design tool to find simple and cost efficient solutions to achieve affordable and highly energy efficient buildings.

PHPP is applicable in any country or climatic zone, and can include and evaluate almost any efficiency measures, which makes its application highly flexible to any design task worldwide. Furthermore, the possibility to enter multiple energy efficiency options allows the careful evaluation and optimisation of component qualities and an economic comparison to find the most cost optimal design solution.

Contact
Passive House Institute, mail@passiv.de

References
[1] https://passipedia.org/planning/calculating_energy_efficiency/phpp_-_the_passive_house_planning_package/phpp_-_validated_and_proven_in_practice
Commissioning Tool

Careful commissioning of the ventilation system is a major prerequisite for efficient operation. Adjustment of the air flow levels and checking the functionality of the system are thus important measures, which simultaneously influence the energy consumption and the cost efficiency of the entire building.

Calculation of the necessary volume flows for ventilation of the various rooms takes place during the planning process. An optimum design process allows for the adjustment of the planned values where necessary and it is required that these values be available in a suitable form. The Commissioning Tool guides the adjustment of the ventilation air flow values and uses the important technical details of the ventilation system.

Phase

The Commissioning Tool is used during the transition from the planning phase to the operating phase (“commission the building services”).

Purpose

The tool will allow all of the components of the ventilation systems to be checked in relation to their energy efficient operation. The measurement data will be retained and well documented.

User

The Commissioning Tool is intended for planners, craftsmen and building owners. Planners use the tool for documenting the calculated air volume flows, run-times, operation modes etc., craftsmen use the data for the implementation of the required adjustments and the building owner receives the documentation of the calculated and adjusted values of the ventilation system.

Input

- Air quantities and volume flows to all rooms for the different operational modes
- Filter type and specification
- Frost protection method and specification
- Information pertaining to maintenance and filter replacement

Output

Documentation of the planned and adjusted air flow values of the ventilation system.

Computer platform

The Commissioning tool was developed with Microsoft Excel and operates under Microsoft Windows.

Strength

At the present many ventilation systems are not adjusted appropriately during their initial commissioning phase. Their operation is unbalanced or the volume flows are not correct for the boundary conditions. The Commissioning tool will serve planners and ventilation system installers in how to communicate the correct operational data and how to adequately adjust a ventilation system.
Challenge

The tool requires the input of a number of different parties in the planning and commissioning phase.

Outcome

The Commissioning Tool will allow for superior communication between the planning phase and the operational phase and for improved ventilation system operation. The tool will specifically address the following:

- Avoiding an inadequate adjustment of the ventilation system upon commissioning.
- The adjustment of suitable air flows leading to good indoor air quality, high thermal comfort and low energy demand.
- Improved ventilation system commissioning processes and communication
- Improved documentation of both the planned and adjusted values, aiding the optimisation of the system during its operational life time.

Contact

Passive House Institute, mail@passiv.de
Cooling System Tool

The tool for the calculation of cooling systems is intended to be used at that point of the planning process when cooling systems are selected. It can be helpful for the decision of which type of system should be used and for detailing the required system’s properties.

Purpose

There are three viable and cost-efficient options for cooling Passive Houses:
- Recirculating room air, e.g. by minisplit / multisplit systems or fan-coils
- Cooling the supply air that is provided by the ventilation system for good indoor air quality
- Chilled ceilings or other surfaces, e.g. concrete core activation, ceiling panels, or chilled beams.

The air-based systems usually provide some dehumidification, albeit uncontrolled. Chilled ceilings only provide sensible cooling. An additional dehumidifier may, therefore, be required for any of these systems, particularly in mildly warm but humid climates.

To make Passive Houses affordable it is important to accurately determine the cooling and dehumidification capacity of each of the systems or of their combinations. This avoids unnecessary investment costs for systems that are oversized or not required at all. A realistic assessment of the seasonal energy efficiency ratio also contributes to reductions in costs because it is an essential input to any life cycle cost analysis. Concurrently, the calculation procedure must be simple to use and must provide results, even with limited data, in order to keep planning costs low.

The PHPP 9 software already contains an algorithm that determines the dehumidification contributed by any of the above cooling systems. Building on this method, a stand-alone tool was developed within AZEB with regard to the above-mentioned requirements.

User

The primary target group for the tool are designers of cooling systems. The tool is kept comparatively simple, so that it can also be helpful when coordinating the work of, among others, architects and mechanical systems engineers.

Input

For a particular month: ambient and indoor conditions, cooling demand and treated floor area of the building. Properties of the ventilation system. Properties of the respective cooling/dehumidification system, such as airflow rate, on/off or inverter operation, cooling capacity and energy efficiency ratio.

Output

Sensible and latent cooling demand, contribution of each system, and resulting total electricity consumption. Determination of whether the selected system is able to cover both the cooling and dehumidification demand.

Computer platform

The Cooling Systems tool was developed with Microsoft Excel and operates under Microsoft Windows.

Strength

Different cooling configurations can quickly be entered and compared, so that an informed choice of the appropriate system combination is possible. Simplicity of use and instant display of results supports the workflow.
Challenge

The tool does not provide a detailed, hourly simulation of the behaviour of a cooling system in interaction with the building or with detailed control strategies.

Outcome

In addition to the existing methodology of the PHPP 9 software, which was used as the basis for development, the “Cooling Systems Tool” has the following features:

- Contemporary split units usually use so-called inverter technology, a compressor that can vary its capacity between 100% and, depending on the system, 10 to 60%. Below this limit the units are operating in on/off mode. The tool accounts for this behaviour.

- The sensible capacity of supply air cooling can be enhanced by recirculating additional indoor air over the cooling coil. Alternatively, if required, an internal heat exchanger (e.g. a wrap-around heat pipe) can reduce the sensible heat ratio to provide sufficient dehumidification. Such systems are currently being developed by manufacturers and are now represented in the tool. They can result in significant cost reductions because the functions of ventilation, heating, cooling, dehumidification, and possibly hot water production are integrated in one single unit.

- A detailed calculation of the energy efficiency ratio is implemented for all cooling methods.

- Stand-alone dehumidifiers typically release their waste heat (generated from the condensation process and electricity consumption) to the room. In most cases this will lead to an increased sensible cooling demand, which in turn increases the dehumidification by the cooling system. A thorough review of the existing analytical solution showed that it provides the best possible estimate.

- Split units or fan-coils can usually operate with different ratios of airflow and cooling power. For low airflow volumes the dehumidification capacity is high, but the sensible cooling capacity is lower than rated. For high airflow volumes the full sensible cooling capacity is available, but little dehumidification is provided. In the tool the user is able to enter two different operation modes. The tool automatically chooses the most appropriate mode for providing the cooling and dehumidification required at the lowest possible energy demand.

- An important input for the analysis of supply air cooling is the airflow rate. Whilst it can be assumed to be constant for residential buildings, there will be intermittent operation in many non-residential applications. This changes the behaviour of the system, particularly the dehumidification performance. The tool takes into account how many hours per day and days per week the system is operating.

- The operating time also affects the part load ratios of the systems and possibly the contribution of each system to the total cooling demand.
### Cooling systems

<table>
<thead>
<tr>
<th>Month</th>
<th>Outdoor air temperature</th>
<th>Humidity ratio exterior air</th>
<th>Useful sensible cooling demand</th>
<th>Dehumidification demand</th>
<th>Sensible heat ratio (SHR)</th>
<th>Operating time</th>
<th>Days per week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>29.8°C</td>
<td>15.0%</td>
<td>500 kWh/m2</td>
<td>196 kWh/m2</td>
<td>72%</td>
<td>4 hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 days/week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Treated floor area</th>
<th>Temp setpoint</th>
<th>Humidity setpoint</th>
<th>Internal humidity sources</th>
<th>Airflow volume ambient air</th>
<th>Efficiency heat recovery</th>
<th>Efficiency humidity recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 m²</td>
<td>25.0°C</td>
<td>12.0%</td>
<td>2.0 g/h</td>
<td>20 m³/h</td>
<td>75%</td>
<td>60%</td>
</tr>
</tbody>
</table>

#### Supply air cooling

- **Test point 1**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 2**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 3**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 4**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 5**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 6**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.
- **Test point 7**: Supply air temperature 40°C, outdoor air temperature 27°C, SHR 0.81.

| Temperature reduction dry ca. | 0.7 K | 2.8 K |

#### Recirculation cooling

- **Test point 1**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 2**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 3**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 4**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 5**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 6**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.
- **Test point 7**: Supply air temperature 45°C, outdoor air temperature 27°C, SHR 0.66.

| Temperature reduction dry ca. | 15.2 K | 22.7 K |

#### Additional dehumidification

- **Vane heat to room**: check as appropriate
- **Energy efficiency ratio**: "x" 

#### Panel cooling

<table>
<thead>
<tr>
<th>Test point 1</th>
<th>Supply air temperature</th>
<th>SHR</th>
<th>Efficiency ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply point</td>
<td>12°C</td>
<td>1.00</td>
<td>5.32</td>
</tr>
<tr>
<td>Indoor point</td>
<td>25°C</td>
<td>1.00</td>
<td>5.32</td>
</tr>
<tr>
<td>SHR</td>
<td>1.00</td>
<td>1.00</td>
<td>5.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>Sensible energy indoor + Latent energy indoor</th>
<th>SHR</th>
<th>Electricity demand indoor</th>
<th>Sensible fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>2.8</td>
<td>1.0</td>
<td>2.0</td>
<td>72%</td>
</tr>
</tbody>
</table>

**Energy efficiency ratio**

### Figure: Screenshot from Cooling System tool

### Contact

Passive House Institute, mail@passiv.de
Performance data generation tool for air-to-air heat pumps

The tool is to be used during the early design stage by architects, engineers and designers.

Purpose

To evaluate a heat pump with sufficient precision its performance under different outside temperatures must be known. This type of data is not commonly available from manufacturers. However, manufacturers commonly provide so-called Seasonal Performance Factor (SPF) for heating or Seasonal Energy Efficiency Ratio (SEER) in the case of cooling. Those values are calculated by two separate standards. In this report two standards, one European (EN 14 825 [1]) and one American (AHRI 210/240 [2]), were used for the investigation. The concept behind these values, as their name suggests, is to evaluate heat pumps over the whole year period. The intentions of their creators were most likely to provide customers an estimate about a unit’s performance. There are, however, arguments why these metrics do not provide the necessary information to consumers.

To calculate SPF/SEER values, just one example building and one example climate were selected for use with the applicable standards. The unit will, however, work differently in different climates and different buildings. Additionally, the energetic performance of the reference building in both standards corresponds to an average building, rather than a highly performing building. In highly performing buildings, the same unit will most probably work at a lower capacity (lower part-load operation) in comparison to an inefficient building. This will influence the performance and depends on the part-load and whether it is negative or positive.

The team suggests an evaluation of the unit for each particular case - for particular building and particular climate.

Input

Required inputs: the SPF or SEER and nominal capacity of unit. Inputs derived following either EN 14 825 [1] or AHRI 210/240 [2] can be used, see Figure 1 and Figure 2.

Figure 1: Input for heating in Tool for heat pumps

<table>
<thead>
<tr>
<th>SCOP</th>
<th>HSPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 14 825 [1]</td>
<td>12.6</td>
</tr>
<tr>
<td>Capacity (KW)</td>
<td>Capacity (Btu/h)</td>
</tr>
<tr>
<td>8700</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Input for cooling in Tool for heat pumps

<table>
<thead>
<tr>
<th>SEER</th>
<th>SEER</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 14 825 [1]</td>
<td>22.0</td>
</tr>
<tr>
<td>Capacity (KW)</td>
<td>Capacity (Btu/h)</td>
</tr>
<tr>
<td>9600</td>
<td></td>
</tr>
</tbody>
</table>
Output

Performance data (COP for heating, EER for cooling) and available power of an air-to-air heat pump for different outside temperatures are returned as results. The output of the tool can be used as input for various building performance software packages, see Figure 3.

<table>
<thead>
<tr>
<th>Output data</th>
<th>SI units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: 1-Outdoor air</td>
<td></td>
</tr>
<tr>
<td>0_source °C</td>
<td>0_sink °C</td>
</tr>
<tr>
<td>Test point 1</td>
<td>9.2</td>
</tr>
<tr>
<td>Test point 2</td>
<td>4.2</td>
</tr>
<tr>
<td>Test point 3</td>
<td>-0.8</td>
</tr>
<tr>
<td>Test point 4</td>
<td>-5.8</td>
</tr>
<tr>
<td>Test point 5</td>
<td>-8.3</td>
</tr>
<tr>
<td>Test point 6</td>
<td>-13.4</td>
</tr>
</tbody>
</table>

Figure 3: Output data

Computer platform

The Performance data generation tool was developed in Microsoft Excel and operates under the Microsoft Windows

Strength

Every single heat pump needs to be evaluated, especially for a particular case, in order to get a precise picture about its performance. This process allows for more efficient operation of a unit as installation of oversized units can be avoided. What is more, investment costs can be lowered as well, as larger units often cost more. An oversized unit will also often cycle ON and OFF, having a negative result on life expectancy of the compressor. Finally, a properly designed unit will also consume less energy over the life-time of the unit.

Challenge

The generated performance values are approximated. The methods behind the calculation of the SPF and SEER values, provided by standards EN 14 825 [1] and AHRI 210/240 [2], was reverse engineered for the developed tool (the calculation methodology was followed in reverse). This means that input data were calculated from “results” delivered when following that particular standard. The tool was however tested on a large sample of different air-to-air heat pumps (from the EU and US markets) and provided performance values with sufficient precision. Nevertheless, when the performance data from a manufacturer is available, that data should be preferred.

Outcome

The tool generates approximated performance data for air-to-air heat pumps, data not generally supplied by the manufacturer. Different tools available on the market can be used to evaluate the use of heat pumps for a concrete building in a particular location. The output values form the Heat pump tool can be used and entered in energy balanced calculation tools, for example in the Passive House Planning Package.
Contact
Passive House Institute, mail@passiv.de

References


Hygiene Tool: Tool on f_{Rsi} (Climate-adjusted hygiene criterion)

The “Hygiene Tool” is to be used during various design stages by planners and builders who want to estimate the risk of mould.

**Purpose**

From personal experience we know: In spots that are colder than the surrounding, condensation may occur. An illustrative example is a cold beer glass in summer, where moisture precipitates. Or condensate, which can form on the bathroom window after showering. The reason for this is that the moisture storage capacity of air decreases with decreasing temperature. The warm air of the summer evening cools down on the beer glass till it no longer is able hold the moisture, the dew point is exceeded and the glass fogs up.

As the beer warms up, less and less new condensate is formed. It’s the same in the bathroom. The warmer the surface of the window, the less condensate is formed. In addition to the outside temperature, the surface temperature depends on the thermal quality of the window. The higher the thermal quality, the higher the surface temperature, the lower the risk of condensation or mould growth. However, as a rule, the higher the thermal quality, the higher the investment costs for the window.

Another important influence is the moisture balance of the building. As a rule, the absolute humidity in Europe is lower on the outside than on the inside during the cold season, as the indoor air is enriched by people and their activities with moisture. The higher the outdoor air change rate, the higher the removal of moisture, the lower the humidity in the room, the lower the risk of mould and condensation.

At the same time, air changes as well as the outside temperature and outside air humidity in connection with the internal temperature and humidity sources influence the hygral comfort.

In this context, the tool sets in and enables optimization of thermal quality, air exchange and hygral comfort for entered boundary conditions.

**User**

Planners and builders who want to estimate the risk of components with different thermal qualities in terms of mould, condensate and air change rate as well as hygral comfort for a construction project in a particular climate.

**Input**

Ambient temperature (by choosing the projects location from a list) and relative humidity of the ambient air. Air exchange rate. Air change rate during pressure test as well as other parameters to determine the infiltration air change rate. Moisture production, number of persons. Internal temperature.

**Output**

Dew point and the absolute humidity outside. Infiltration and total air change. Moisture production. Indoor relative humidity. Indoor dew point with associated minimum temperature factor. Indoor mould point with associated minimum temperature factor.

**Computer platform**

The Hygiene tool was developed in MS Excel, and operates on Microsoft Windows.
**Strength**

Provides a quick and easy prediction of the expected hygral quality based on the relative humidity and the suitability of a component with regard to its temperature factor for the simulated situation, even without a deep knowledge of physical processes.

**Challenge**

Moisture production as well as the air exchange and pressure test results must be known.

**Outcome**

The “Hygiene Tool” is simplifying the design and optimisation process of energy-efficient buildings. This will save time and maybe trouble as well as money by using suitable components. The hygienic quality of the building might be improved. Thereby the effectiveness of the design itself is supported and the cost effectiveness of affordable NZEBs is improved, construction costs and furthermore maintenance costs may be saved.

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**Figure 1: Screenshots from Hygiene Tool**

<table>
<thead>
<tr>
<th>DE0036a-München</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Select climate</strong></td>
</tr>
<tr>
<td><strong>Exterior boundary conditions</strong></td>
</tr>
<tr>
<td>Elevation (optional)</td>
</tr>
<tr>
<td>Air temperature θe [°C]</td>
</tr>
<tr>
<td>Relative humidity ϕe [%]</td>
</tr>
<tr>
<td>Dew point</td>
</tr>
<tr>
<td>Absolute humidity</td>
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<tr>
<td><strong>Ventilation and humidity production</strong></td>
</tr>
<tr>
<td>Air change</td>
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<tr>
<td>Infiltration [1/h]</td>
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<tr>
<td>Building net volume [m³]</td>
</tr>
<tr>
<td>Air change rate @ pressure test n50 [1/h]</td>
</tr>
<tr>
<td>Sum [1/h]</td>
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<tr>
<td>Sum [m³/(P*h)]</td>
</tr>
<tr>
<td>Humidity production [g/(P*h)]</td>
</tr>
<tr>
<td>Number of persons</td>
</tr>
<tr>
<td>Sum</td>
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<tr>
<td>Sum</td>
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</tbody>
</table>

**Interior conditions**

| Air temperature θi [°C] | 20 | 20 | 20 |
| Relative humidity ϕi [%] | 25.8% | 61.2% | 37.6% |
| Dew point | -0.17 | 12.33 | 5.13 |
| fRsi, min | 0.19 | 0.69 | 0.41 |
| Mould point | 2.91 | 15.73 | 8.35 |
| fRsi, min | 0.31 | 0.83 | 0.53 |

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### Checking the hygiene criterion

#### General
- **Building net volume (m³):** 480
- **Number of persons:** 5
- **Humidity production [g/(P*h)]:** 100
- **Air change rate @ pressure test n50:** 6.0

#### Ventilation
- **Manually ventilation (m³/h):** 40
- **Ventilation unit (m³/h):** 0
- **Intended air change rate [1/h]:** 0.08
- **Infiltration [1/h]:** 0.42
- **Sum (1/h):** 0.50
- **Sum (m³)/(P*h):** 48

#### Exterior boundary conditions
- **Air temperature [°C]:** 20
- **Relative humidity:** 40%
- **Absolute humidity [g/m³]:** 2.0
- **Dew point:** -4.9 °C

#### Humidity production
- **Humidity production [g/(P*h)]:** 100
- **Air change rate:** 242 m³/h
- **Relative humidity:** 26%
- **Mould point:** 2.9 °C
- **Humidity production 500 g/h**

#### Intended air change rate
- **Intended air change rate [1/h]:** 0.08
- **Infiltration [1/h]:** 0.42
- **Sum [1/h]:** 0.50

#### Contact
Passive House Institute, [mail@passiv.de](mailto:mail@passiv.de)
Thermal Bridge Tool

The Thermal Bridge Tool is to be used during various design stages.

Purpose

Thermal bridges cause energy losses and the risk of low surface temperatures, which can lead to high energy consumption, low comfort, or in the worst case mould or condensation. This is unacceptable for nZEBs or Passive House buildings! The connection details of the building envelope therefore should carefully be designed, despite the expertise necessary to calculate thermal bridges and the time required to determine two-dimensional heat-flow-calculations.

To offer easy-to-use evaluation and decision for the designers, the Passive House Institute (PHI) has pre-calculated a huge range of thermal bridge coefficients of typical connection details, various insulation thicknesses and thermal conductivities, in order to facilitate evaluation and decision making.

To organize results from more than several hundred calculations including extra evaluations, while quickly and easily providing designers an answer to their analysis, PHI developed the “Thermal Bridges Tool”. It allows a designer to choose a connection, enter lambda value and the insulation thickness, and based on interpolation formulas he or she can extract more exact Ψ-values and fRsi-values with ease. This allows for 1) demonstrating how the Ψ-value of a certain connection changes across the insulation quality and thickness from 0 to 400 mm; and 2) shows for which insulation qualities there would be problems with mould or comfort by indicating the fRsi-factors of the connections.

This enables designers to optimise connections by adding or reducing insulation thickness, or improving the connection with flanking insulation, thus allowing them to take informed decisions in how best to carry out the design of connections in NZEB or Passive House designs in the most-cost effective way, while safeguarding against energy loss, mould and comfort issues.

User

Designers who are not familiar with Ψ-value and fRsi-values can easily use the tool to check thermal bridge coefficients and surface temperature factors of similar connection details. Then using those factors as a basis for evaluating a project, designers can easily determine the connection quality, improve it and optimise the design’s cost efficiency.

Input

Connection name; construction system type (brick wall/concrete wall); optimisation (yes/not); thermal conductivity of the insulation material; insulation thickness.

Output

Wall U-value; Ψ-value; fRsi-factor.

Computer platform

The thermal bridge tool was developed with thermal bridge programs and Microsoft Excel, and operates under Microsoft Windows.
Strength

The tool is performance-oriented, focuses on highly energy efficient details and building, much more flexible than a thermal bridge catalogue, and much faster than a thermal bridge program. Therefore, the use is time-saving for designers and consultants. Many configurations are implemented in the tool allowing users a wide range of input possibilities. The user can play with different inputs, receiving straightforward feedback, which allows fast optimisation. Thermal bridge catalogue with many details and variants especially for high performance new buildings. In addition, it is also important and useful for renovations.

Challenge

A background knowledge about thermal bridges and a certain knowledge is necessary. The designer needs to be able to judge if the result presented by the “Thermal Bridges Tool” can be transferred or used in case of his individual project.

Outcome

The “Thermal Bridges Tool” simplifies the design and optimisation process of energy-efficient buildings. Time and effort by the designers is saved in the thermal bridges calculation process. The tool also very easily facilitates the evaluation and optimisation of the most common connections in terms of hygienic quality and cost efficiency. Accordingly, the effectiveness of the building design is supported, construction costs are saved, and affordable nZEBs’ cost effectiveness is improve.

Figure: Screenshot from Thermal bridge tool
Contact

Passive House Institute, mail@passiv.de
Ventilation tool

A lack of independent information concerning controlled ventilation with heat recovery is one of the central obstacles to the growth of energy efficient ventilation with heat recovery in residential buildings [Vond18]. This results in the installation of other systems (e.g. exhaust ventilation or free air ventilation) and sees the energy-saving potential of heat recovery lost.

Phase

The ventilation tool provides independent information at the very beginning of the planning process.

Purpose

The tool provides independent data for ventilation units with heat recovery. With very specific and simple input parameters, the tool provides a selection of applicable ventilation units for specific projects.

User

The ventilation tool is meant for building owners and other interested parties planning to install a ventilation unit in their home. Furthermore, it delivers effective arguments to energy consultants and designers in order to convince customers to invest in an energy and cost-efficient ventilation unit with heat recovery.

Input

- Number of persons
- Number and kind of extract air rooms
- Available space for a ventilation device (storage room, bathroom wall/ceiling, kitchen wall/ceiling, living room façade integrated)

Output

- Required air flow rate
- List of suitable ventilation devices for the specific boundary conditions
- Calculated electric energy consumption for the selected ventilation unit, calculated savings of ventilation heat losses for the selected ventilation unit and specific air flow rate
- Additional information

Computer platform

The Ventilation tool was developed in Microsoft Excel and operates under the Microsoft Windows.

Strength

The tool offers collected information for customers such as building or flat owners. Currently, it’s hard to find good independent information for controlled ventilation, which in [Vond18] was found to be one of the main reasons for deciding against a controlled ventilation system with heat recovery.

Challenge
The tool is used in the early decision phase before the real planning process starts. Designers of ventilation units or installers might need further information and assistance in order to design and install a cost and energy efficient ventilation unit.

**Outcome**

The Ventilation Tool will specifically address the following:

- Avoidance of ‘over-dimensioning’, therefore ensuring savings from correct selection of a ventilation device. Additionally, the operation at lower air change rates is more cost efficient.
- Providing information for different installation options in order to find the option that best fits a specific project (helping to reduce installation costs e.g. for additional casing...)
- The calculated savings of ventilation heat losses and power consumption will hopefully convince customers to decide for a ventilation unit with a highly efficient heat recovery process as well as low electric power consumption.
- The additional information help in considering required components from the beginning in order to avoid failures, which helps to reduce the overall costs of ventilation with heat recovery.

![Ventilation Tool Screenshot](image-url)

*Figure: Screenshot from Ventilation tool*
Contact

Passive House Institute, mail@passiv.de

References


Window tool: Tool on LCC windows

The “Window Tool” is to be used during various design stages by planners, builders and other interested people who want to know which window is best in terms of comfort, hygiene and life-cycle costs.

Purpose

What window is suitable for which climate in terms of comfort, energy efficiency and life cycle costs at a specific location? This questions are up for anyone who wants to build a house or replace old windows. Windows with poor quality for instance are cheaper in investment, but they might lead to thermal discomfort and hygienic issues. And in the end to high costs because of high energy losses. Windows with high thermal quality on the are on the other hand more expensive but are leading to high thermal comfort, lower risk of mould and condensation as well as to lower energy prices. The aim of this tool is to provide a solid ground based on a life-cycle cost analysis, what window best to choose for a specific location and to give a hint regarding comfort and hygiene criterion by comparing alternative windows.

Input

Choose of a climate data set from a list or manual input of ambient climate as well as shading characteristics. Temperatures the specific location. Indoor climate characteristics. Geometric and thermal properties of windows by choosing from a list or manual input. Investment costs of windows. Costs for heating energy, service life and interest rate.

Output

U-values of the window, heat losses and gains, energy balance of the window. Evaluation of the window regarding comfort and hygiene. Life cycle costs of the window, figure that compares different variants.

Computer platform

The Window tool was developed in Microsoft Excel and operates under the Microsoft Windows.

Strength

Provides an overview regarding life-cycle costs, hygiene and comfort for comparison of different windows. Easy to use by choosing windows and locations from a list. Manual input also possible for experts. The live cycle costs are adjusted by consumer price index and construction price index to a specific country and year.

Challenge

Summer climate data are available for locations in the climate data list. Other summer climate data have to be provided by manual input. The life-cycle cost adjustments based on the consumer price index to convert prices from one country to another are giving only a rough estimation. The life-cycle cost adjustment for the construction price index is using the index for Germany. To have a precise adjustment for other countries overwriting of Germany’s data manually by the index from the recent country is possible.
Outcome

The “Window Tool” provides an overview regarding life-cycle costs, hygiene and comfort for comparison of different windows. For locations in Germany it is proven, that high energy efficient windows (with higher investment costs) are leading regularly to lower life-cycle costs compared to standard windows (see figure below). By enabling people to test that with this tool themselves, they might be convinced to go for more efficient windows and by that reducing the impact of buildings on climate change.

Figure 1: Screenshot from LCC Window tool

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Acknowledgement

The tool includes the equations of the Hygiene tool elaborated in AZEB. The tool contains the outcomes (thermal data and prices) of the COMPONENT AWARD 2019, Windows for the future, which was also part of the AZEB-Project.

Contact

Passive House Institute, mail@passiv.de
Building optimisation tool

A building optimisation tool can be used in the design phase to identify alternatives with best performances considering several criteria, e.g. cost and energy performance.

**Purpose**

Determines the most influential parameters, and helps optimizing a project to find best compromises between cost, energy performance and comfort. Allows considering statistical occupants’ behaviour. Quantifies the risk attached to a guaranteed level of energy performance.

**Example of a tool**

In the AZEB project, the optimization tool AMAPOLA has been used because it is linked with Building energy simulation and life cycle assessment.

**Project phases**

Identify in the design phase non dominated solutions in terms of energy performance, environmental impacts and costs, considering in the sketch phase architectural design parameters like glazing area on different facades, and in the detailed design technical parameters like insulation thickness, area of solar collectors etc. At the end of the design, a guaranteed consumption threshold with adjustment corresponding to e.g. 5% risk can be determined, and integrated in an energy performance contract. After completion of the construction, an adjusted energy consumption (in terms of climate, indoor temperature, hot water consumption etc. according to the energy performance contract) can be calculated and compared with the measured consumption.

**Users**

The main users group corresponds to engineers in charge of energy calculations. But optimization can also be performed by urban designers, architects, contractors and facility managers.

**Importance**

Optional in single family houses, advanced in other projects.

**Input**

Building geometry, material characteristics, internal gains and schedules, climate, heating and cooling equipment characteristics. Probabilistic variation of input parameters can be added in order to perform uncertainty calculations. Technical characteristics can be complemented with costs for multi-criteria optimization.
Series of simulations are then launched to evaluate uncertainties using a Monte Carlo method, or to optimize the project using a genetic algorithm.

**Output**

Parameters' sensitivity (Morris’s method), Pareto fronts allowing optimal solutions to be identified, adjustment polynomial allowing energy performance contracts to be elaborated.
Sensitivity of the results to input parameters is shown on a Morris' graph.

The most influential parameters (in red) have the largest average effect $\mu$ and the largest standard deviation $\sigma$.

Internal gains are derived from a statistical occupancy model.
Validation

The optimisation module, based upon an evolutionary algorithm, has been validated by comparison with a systematic evaluation of 4 million solutions, and it has been presented during an international conference (Recht, 2016).

Applicability

The tool can be applied in Europe using appropriate climatic data and possibly customizing construction techniques according to a local context. It runs on windows environment, and the reasonable fee corresponds to an efficient service to users (phone and web contact, users’ forum…) which makes it more economical than most open source software requiring more manpower due to poor user friendliness.

Computer platform

The example tool was developed for Microsoft Windows operating system. The 3D data entry can be performed using the tool itself, or BIM can be imported from other software.

Strength

Complements usefully energy simulation and life cycle assessment, in relation with a user friendly interface are automatically calculated; using default values and generic data allows for use at early design stage, particularly by architects.

Weakness

Optimization and uncertainty calculations require a large number of simulations and the computation time can be high (e.g. a whole night, allowing to obtain results the next day).

Outcome

Optimization allows to propose non dominated solutions in terms of energy performance, environmental impacts and costs. These solutions can then be discussed with the client in order to make a final decision. An energy performance contract can be based upon the results of uncertainty calculations, and the building energy performance can be checked using a measure and verification protocol.
Contact

MINES ParisTech, CES
60 Bd St Michel
75272 Paris Cedex 06 France
e-mail: bruno.peuportier@mines-paristech.fr

References

Building LCA tools

Building LCA tools can be used in the design phase, allowing comparison of alternatives and benchmark values in term of environmental performance.

Purpose

Performs life cycle assessment of buildings, in order to provide designers, engineers or architects, with environmental indicators allowing a project to be assessed (e.g. climate change, impacts on health and biodiversity, exhaust of natural resources...).

Examples of tools

LEGEP (Germany) https://legep.de/?lang=en
GREENCALC+ (The Netherlands) https://www.dgbc.nl/
ECO-BAT (Switzerland) http://www.eco-bat.ch
EQUER (France) http://www.izuba.fr/
ECOEFFECT (Sweden) http://www.ecoeffect.se/
ELODIE (France) http://www.elodie-cstb.fr/default.aspx
OPEN LCA (Germany) http://www.openlca.org/

Because the AZEB project is related to zero energy buildings, an LCA tool linked with thermal simulation has been used as an example in the case studies, but the methodology could be applied to other Building LCA tools. An optimisation module is also used to reduce both costs and impacts. The ecoinvent database is used for material fabrication and other processes (energy, water, waste, transport) because it is well documented and provides more comprehensive inventories (around 4,000 elementary flows) than most other LCA bases. It is an international database, allowing imported products to be considered.

Project phases

LCA can be used at the inception phase, e.g. to compare new building and refurbishment, to compare different building sites, and to evaluate target values of impacts to be required in a program (e.g. less than 20 kg CO2/m2/year). In the planning phase, it can be useful to compare environmental impacts of different morphologies, rank different contributions (heating, hot water, electricity, materials, transport, waste treatment...) in order to prioritize efforts for improvement. It can also be used in the early design to compare environmental impacts of different architectural forms (compactness, glazing areas...) and major choices (e.g. wood versus concrete structure), or rank more precisely different contributions (heating, hot water, electricity, materials, transport, waste treatment...). During detailed design, comparing environmental impacts of different technical solutions (materials and products) can be based upon LCA results.

Users

The main users group corresponds to engineers, e.g. in charge of energy calculations. But LCA can be also used by urban designers, architects, and contractors.

Importance

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Essential in countries where LCA is included in the building regulation, optional in single family houses, advanced in other projects.

**Input**

Building geometry, material characteristics, internal gains and schedules, climate, heating and cooling equipment characteristics. Water consumption, waste generation and transport issues may be taken into account, depending on the goal of the study. In the tool that has been used in AZEB, readable, structured input file is generated by PLEIADES users interface (2-3D modeller).

**Output**

Example environmental indicators: contribution to global warming (IPCC indicator), acidification, eutrophication, exhaust of abiotic resources, smog and odours (CML 1992-2001 indicators), human toxicity and ecotoxicity (from Ecoindicators 99), primary energy and water consumption, radioactive and other waste production.
AZEB TCO tool - Version 1.0

The TCO tool supports integral decision making in the design of buildings. It helps in all design steps in the quest for high quality and low total cost. Also, it illuminates the expected performance and quality of the building once in operation. It is to be used by engineering-teams to identify cost trade-offs, and to help their clients understand the effect of investments in quality and energy-efficiency on costs in the long run.

Objective

The tool fosters finding the optimum between low construction costs and high quality (user satisfaction) as well as good performance (low running costs). To this end the tool reveals the relation between the building’s foundation costs, its operating and maintenance costs and its quality. This way it shifts the conventional focus on low investment costs for merely an acceptable energy performance and permissible quality level towards the full needs of the building’s end users. Used as a growing document the tool assists throughout the entire design process of development. It helps to keep control during all phases, not only over foundation costs and TCO, but also of expected levels of comfort, health impacts and the practical suitability of the building. This way the TCO tool facilitates the integral design for the successful realisation of very energy efficient buildings.

In the long run the TCO tool can empower an optimal approach to design, financing, construction and operation by creating benchmarks (optimal price-quality ratios) for specific types of buildings.

Input

1. Financial boundary conditions (VAT, inflation etc.)
2. Energy price per energy carrier and price trend
3. Geometrical data (GFA, volume etc.)
4. Foundation costs (calculated per element)
5. Maintenance costs (calculated per element)
6. Value of the building
7. Conditions of financing (income, loans, duration of pay off, interest, etc.)
8. Amount of energy use, energy generation and storage (per month, per energy carrier)
9. Requirements for quality aspects
10. Results of TCO analyses of reference buildings

Output

1. Total cost of ownership
2. Foundation costs
3. LCA/environmental costs
4. Ratio housing costs / income
5. Distribution of maintenance costs over time
6. Indicators:
   - Costs (ratio to maximal costs)
   - Comfort & Usability (ratio to maximal quality)
   - Health & Safety (ratio to maximal quality)
7. Graphs e.g. equity and value development over time

Computer platform

The tool was developed in MS Excel for anyone to use.

Strength

The tool provides an overview of the building’s foundation costs, operating and maintenance costs in relation to its quality.

Weakness
TCO-calculation includes assumptions that can considerable influence the results. A clear presentation of all assumptions might help users overseeing the conditions leading to present results. For a full analysis with the TCO-tool, a large amount of data is required from different disciplines of a design / construction team. The generation of this data will be time-consuming and possibly some familiarizing might have to take place. But collecting this data in the TCO-tool facilitates design optimisation and quality assurance and therefore will lead to lower total costs and a higher users satisfaction.

Outcome

The TCO tool assists an integral design approach towards healthy, comfortable, safe and user friendly buildings with a high energy performance and low operating costs. Extra investment costs to higher quality level are related to the potential of lower total costs for the user/owner of the building.

Contact

Clarence Rose, clarence@kennisinstituutkern.nl

Acknowledgment

Development of the TCO-tool

Clarence Rose, DNA in de Bouw, The Netherlands
Harrie Beernink, DNA in de Bouw, The Netherlands
Hans Zwiep, DNA in de Bouw, The Netherlands

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