SMART AND EFFICIENT

Digital solutions to save energy in buildings

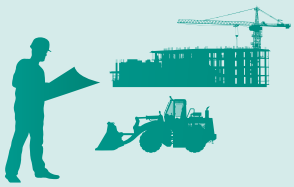
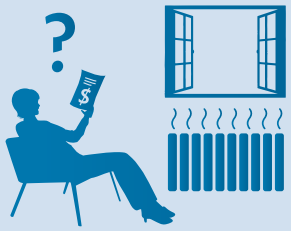
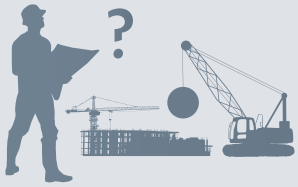
PEEB
PROGRAMME FOR ENERGY EFFICIENCY IN BUILDINGS

EXECUTIVE SUMMARY

The potential to reduce the energy consumption of buildings is massive, but often not realised. The energy demand from the building sector is expected to grow by another 50% by 2050. There is a huge – and still largely unexploited – potential to use digital solutions to make buildings more energy efficient.

Digital tools can support energy efficiency throughout the lifetime of a building. The design phase is particularly important, as many parameters of a building are defined and will remain 'locked-in' for its entire lifetime. The operation phase is also important, as 80 – 85% of all costs occur after the building is finished.

From design to demolition, every phase of the building life cycle brings different needs and challenges. Time pressure, cost constraints, complex building codes and demanding clients keep building sector professionals busy. Energy efficiency is often not a central concern. For some of these challenges, digital solutions can make a difference.

	CHALLENGE	DIGITAL SOLUTIONS	WHAT THEY CAN DO
DESIGN		**Building Energy Modelling (BEM)** **Life-Cycle-Assessment (LCA)** **Web-based tools**	**Simulation and design optimisation:** simulate design options to anticipate and optimise energy demand, comfort, cost and profitability. **Visualisation and marketing:** demonstrate higher comfort and lower energy consumption to clients.
CONSTRUCTION		**Smart Energy Monitoring and Agile Logistics** **Prefabrication and 3D printing** **Virtual reality for communication and education**	**Construction logistics:** digital tools for more productivity and resource savings. **Prefabrication:** use optimised building elements through modular prefabrication. **Training:** train construction workers with digital tools for improved execution of works.
OPERATION		**Applications to measure and optimise the use of energy** **Software for facility management** **'Smart home' applications**	**Monitoring and analysis:** understand drivers of energy consumption, including user behaviour, appliances, and failures. **Intelligent controls:** control and regulate appliances by algorithms to optimise comfort and reduce energy consumption. **Behaviour change:** raise users' awareness and change their behaviour (e.g. 'nudging apps').
REFURBISHMENT OR DEMOLITION		**Data for deep energy retrofits** **3D scans of building elements** **Industrialised, prefabricated modular systems**	**Simulation and design optimisation:** simulate alternative refurbishment options. **Prefabrication:** use optimised building elements through modular prefabrication. **Information for recycling:** use building data to facilitate recycling or disposal of non-reusable parts.

A variety of tools are on the market, from sophisticated to very simple. They cater to projects of different sizes, budgets, complexity and digital capacities. However, buildings do not need to become completely 'smart' to save energy. There is a tendency to increase the use of technology to make buildings more energy efficient, when often 'less is more'. Digital applications can help to optimise the energy performance and thermal comfort of a building – but they cannot replace good building design.

Digital solutions can have a large potential to save energy in buildings. Many applications are already on the market, but there is still much room to integrate existing tools and innovation. A clear focus on users and 'making it simple' is essential.

Be smart about smart solutions. The biggest potential for energy efficiency will likely not be in fully automated buildings, but in smart, easily accessible, and widely used applications that support energy efficiency. There is still much to do to develop and spread simple and user-friendly applications for energy efficiency.

New business models for energy efficiency. New business models like shared living might benefit energy efficiency. If investors do not only build but also operate buildings, energy efficiency can become economically interesting, implemented with the help of digital solutions.

Make sure that 'green' buildings keep their promise. Digital tools can close the gap between planned and real energy performance during operation. They can make it easier to obtain certification, or support municipalities assessing whether buildings are in compliance with standards. Fast and easy tools for monitoring the real energy performance after construction are needed.

Building data: a feedback loop to the beginning. Building data is still a massively underused resource. Benchmarking building performance against the digital model or against data of similar buildings can be a quick and cost-effective way to reveal savings. Artificial intelligence can be used to optimise building design based on data from building operation – a feedback loop to the beginning.

CONTENTS

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www.peeb.build

DIGITALISATION 01

FOR ENERGY EFFICIENCY IN BUILDINGS

The potential to reduce the energy consumption of buildings is massive, but often not realised. The energy demand from the building sector is expected to grow by another 50% by 2050 (GlobalABC, 2016). Making the right choices for the design, construction and operation of a building reduces the amount of energy consumed throughout its lifetime. The required know-how is available and constantly evolving, but too often not put into practice.

Digitalisation holds huge possibilities to save energy in buildings (Berger, 2016; Dena, 2017; IEA, 2017). Digitalisation is changing the way we perceive, relate to and control our environment. It is also slowly changing the way we develop, construct and operate buildings. Technologies such as artificial intelligence, 3D printing and the Internet of Things (IoT), which sounded like science fiction just a few years ago, are already in use.

Nevertheless, most buildings today are not very 'digital'. They are often designed, built and operated the way they used to 20 years ago, with standard designs to keep construction cost low – regardless of the climatic context. The construction sector is still among the least digitalised industries and has been slow to adopt new technologies in the past (World Economic Forum, 2016). The processes in the design, the construction and the operation phases are very fragmented and at the interface of each phase, large amounts of data are lost. Once they are built, many buildings resemble a 'black box', without information on how they were built, and how they should be used.

There is a huge – and still largely unexploited – potential to use digital solutions during design, construction and operation to make buildings more energy-efficient and protect the climate.

'We live in the information era, but we rarely use building data for operation. It's like driving a car without a speedometer.'

DIETMAR GEISELMANN

German Sustainable Building Council (DGNB)

ABOUT THIS PAPER: A THINK-PIECE AND A CATALOGUE OF TOOLS

How can digital solutions improve energy efficiency in buildings? Which digital tools exist, and how do building sector professionals apply them in practice?

This paper gives answers to these questions. It is both a think-piece and a practical guide for building sector professionals. Drawing on the current literature, as well as 28 interviews with experts worldwide, we showcase how digital solutions can support the transition to more energy-efficient buildings, while pointing out the limitations and gaps.

A catalogue of tools highlights solutions for the design, construction, operation and demolition or refurbishment of buildings. Architects, engineers, building developers, construction companies, building owners, facility managers and building users can benefit from these tools. While some tools or applications are more sophisticated and costly, and therefore suitable for larger or more complex building projects, others are simpler, more affordable, or even free of charge.

Disclaimer: This paper provides a snapshot of digital solutions that were identified by the experts and building sector professionals we interviewed. The list of tools is therefore neither exhaustive, nor was it possible in the context of this project to test or compare different solutions. We are aware that the market is in constant evolution, and consider this paper and the selection of tools as a living document which may grow over time.

Any suggestions or comments are welcome: *info@peeb.build*

PEEB publications and resources on energy efficiency can be found on: *w.peeb.build/knowledge-network/downloads*

SMART AND EFFICIENT 02

CONSTRUCTING BETTER BUILDINGS

Design and operation are crucial for energy efficiency

Digital tools can support energy efficiency throughout the four main phases in a building's life: design, construction, operation, and refurbishment or demolition. In each phase, important decisions are made. These decisions influence the building's energy consumption and level of comfort for the next 30 to 50 years or even longer.

The design phase is particularly important, as many parameters of a building are defined and will remain 'locked-in' for its entire lifetime. In this phase, the 'change potential' to influence energy consumption during operations is huge. With low incremental costs during this phase, large energy savings, and therefore cost savings, can be realised.

The operation phase is also important, as 80 – 85% of all building lifetime costs occur after it is finished (Kovacic & Zoller, 2015). Even small improvements can still make a big difference throughout the whole life cycle of the building. The construction phase, as well as refurbishment or demolition, hold some potential for energy efficiency.

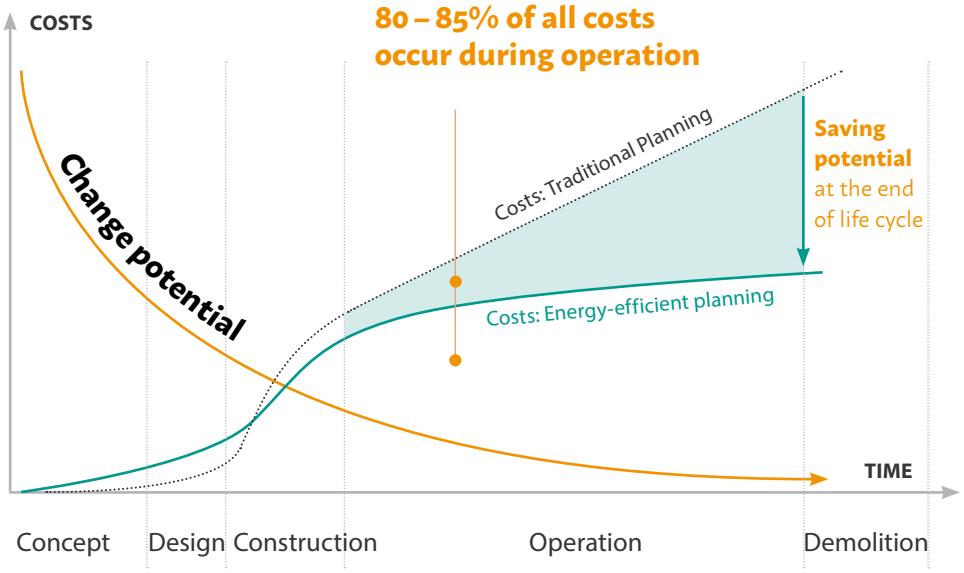


Figure 1 *The design and planning phase is crucial: Change potential to improve building performance throughout the life cycle (based on Kovacic & Zoller 2015)*

What is an energy-efficient building?

Well-designed energy-efficient buildings keep energy consumption low during operation while offering healthy living and working conditions, and a high level of comfort.

Three steps can make buildings energy-efficient:

AVOID — **Building design** adapted to the local climate to avoid high energy demand

SHIFT — **Renewable energy** to replace carbon-intensive energy supply

IMPROVE — **Efficient systems and appliances** to reduce energy consumption

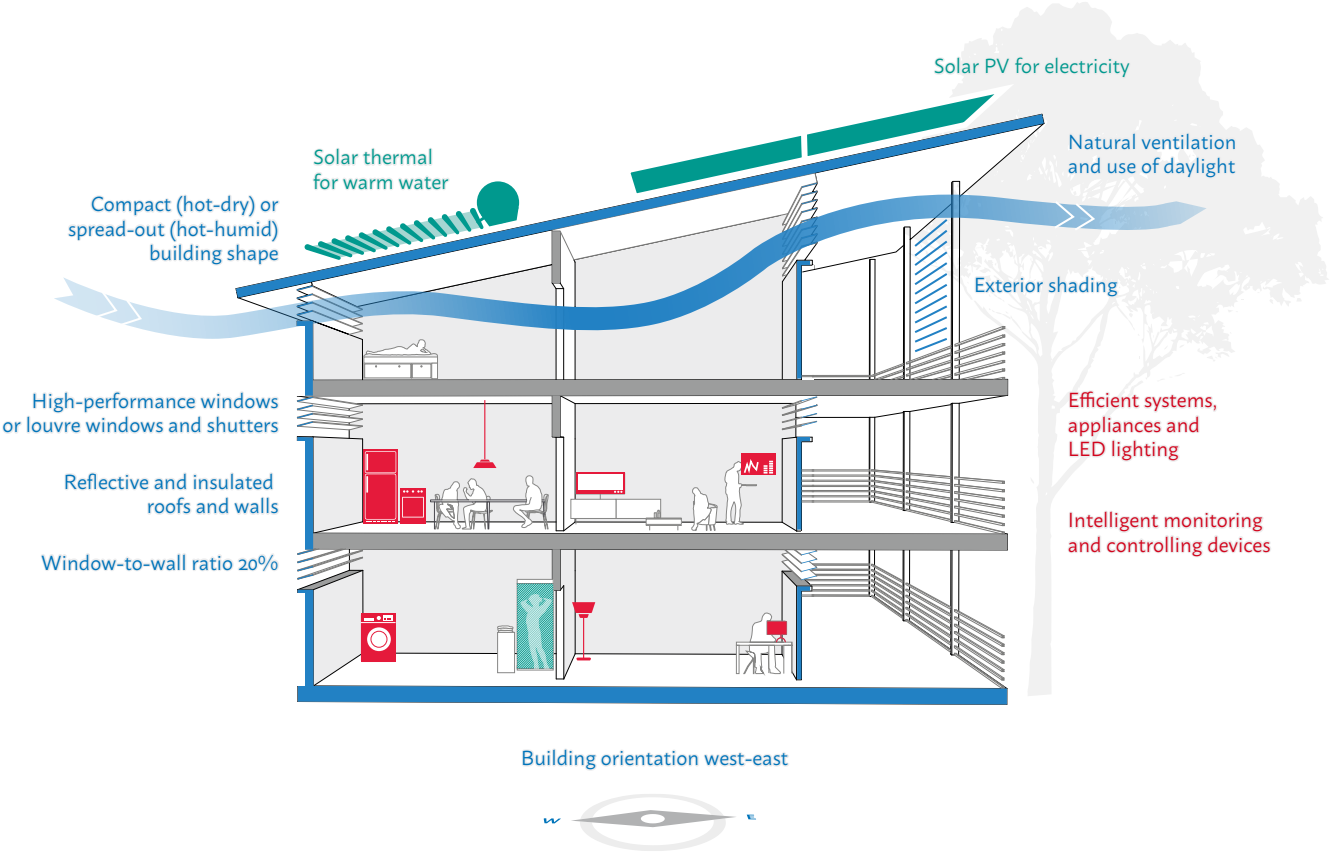


Figure 2 *Energy efficiency measures in a building*

Further readings:

ADEME, 2016. Prospective logements 2050. Comment vivrons-nous dans notre logement en 2050?
www.ademe.fr/logements-2050-evolutions-habitat

Australian Government, 2013. Australia's guide to environmentally sustainable homes.
www.yourhome.gov.au/passive-design/orientation

Programme for Energy Efficiency in Buildings (PEEB), 2019. What is an energy-efficient building? PEEB's Criteria for Buildings.
www.peeb.build/imglib/downloads/PEEB_criteria_june%202019.pdf

UN Habitat, 2014. Sustainable Building Design for Tropical Climates. Principles and Applications for Eastern Africa.
www.unhabitat.org/books/sustainable-building-design-for-tropical-climates/

The building sector is the sleeping giant in the fight against climate change.

In 2017, the construction and operation of buildings were responsible for 39% of global energy-related greenhouse gas emissions which amounted to more than 11 $GtCO_2$ (IEA & UNEP, 2018).

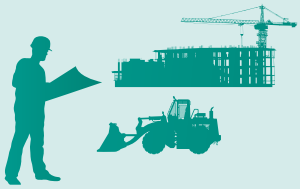
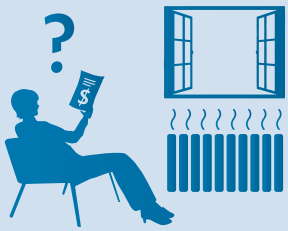
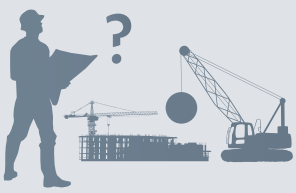
Emissions continue to rise, especially with the current high growth rates in emerging and developing economies. Energy needs for space cooling in warm and hot countries are predicted to triple between 2016 and 2050 (IEA, 2018). In 2018, emissions rose by nearly 2%, following a 1.6% increase in 2017 (IEA, 2019).

To meet the 2°C goal of the Paris Agreement, a massive reduction of greenhouse gas emissions from the building sector is needed. Annual emissions from buildings need to be reduced to one-eighth of current levels by 2050 (IEA, 2019).

Which energy efficiency challenges can digital solutions address?

From design to demolition, every phase of the life cycle of a building brings different needs and challenges. Time pressure, cost constraints, complex building codes and demanding clients keep building sector professionals busy. Energy efficiency is often not a central concern.

Many barriers to energy-efficient buildings can only be addressed through systemic approaches, such as stricter building codes, financial incentives or capacity-building. Nevertheless, for some challenges that building sector professionals are facing, digital solutions can make a difference. These are outlined in the table below.

		CHALLENGES	DIGITAL SOLUTIONS
DESIGN		**Clients do not 'see' and value the benefits of energy-efficient buildings.** **Energy performance and embodied carbon accounting is not integrated.** **Energy simulation is seen as too complex.**	**Simulation and design optimisation:** simulate options to optimise energy, comfort, cost and **Visualisation and marketing:** demonstrate higher comfort and lower energy consumption to clients.
CONSTRUCTION		**Poor execution of construction defies energy-efficient planning.** **Inefficient construction logistics lead to waste and high energy consumption.**	**Construction logistics:** digital tools for more productivity and resource savings. **Prefabrication:** use optimised building elements through modular prefabrication. **Training:** train construction workers with digital tools for improved execution of works.
OPERATION		**No information about the technical functioning of the building and its energy performance.** **User behaviour, inefficient appliances or buildings technology lead to high energy use.**	**Monitoring and analysis:** understand drivers of energy consumption. **Intelligent controls:** control and control and regulate appliances using algorithms. **Behaviour change:** raise users awareness and change their behaviour.
REFURBISHMENT OR DEMOLITION		**No information about the properties of the building materials.** **Buildings are not designed to be recycled.**	**Simulation and design optimisation:** simulate alternative refurbishment options. **Prefabrication:** optimise building elements through modular prefabrication. **Information for recycling:** use building data to facilitate recycling or disposal.

No magic bullet – the limitations of digitalisation

A variety of tools are on the market, from sophisticated to very simple. They cater to projects of different sizes, budgets, complexity and digital capacities. The degree to which buildings are using digital tools varies widely, from buildings that fully integrate digital technologies (cf. page 17, The Edge), to more 'conventional' buildings that are planned and operated with the help of digital tools.

There is a tendency to increase the use of technology to make buildings more energy efficient, when often 'less is more'. Buildings do not need to become completely 'smart' to save energy.

Digital applications can help to optimise the energy performance and thermal comfort of a building – but they cannot replace good and appropriate building design. Good building design is adapted to the local context and type of building, as well as the needs, behaviour, and technical and financial abilities of its users.

'The technologies we use are often disconnected from local conditions. That is the wrong approach.'

MARGOT GRIM-SCHLINK

e7 Energie Markt Analyse GmbH

The table below shows 'dos and don'ts' for the use of digital solutions in buildings.

DO'S

- **Measure and convince:** Use digital solutions to visualise data about energy demand and consumption and obtain strong arguments for appropriate energy-efficient solutions
- **Focus on users and make it simple:** Match the digital solution with the local context, as well as the knowledge and understanding of users. An app reminding users to close the blinds can be better than intelligent shading systems.
- **Sufficient:** Focus on what is enough, and where additional features bring actual gains in comfort or quality of living.
- **Leave no one behind:** Integrate training and capacity building to ensure that digital transformation is as inclusive and low-threshold as possible.

DONT'S

- **Excessive use of technology:** Avoid complex digital applications to fix problems that could be dealt with through 'analogue' solutions, such as basic bioclimatic and passive design principles.
- **Useless data generation:** Minimise generation of data without explicit purpose. For example, instead of constant measuring of room temperatures, set temperature thresholds and switch cooling on when threshold values are exceeded.
- **Consume more than you save:** Energy-intensive or high standby energy applications for intelligent building systems may dwarf savings.
- **Increase vulnerability**: Reduce the risk of threats, such as technology breakdowns, power cuts, or digital security attacks.

A way forward – gaps and opportunities.

Digital solutions can have a large potential to save energy in buildings. Many applications are already on the market, but there is still much room to integrate existing tools and innovation.

Be smart about smart solutions. Digital solutions can make it easier for planners and engineers to systematically include energy-efficient architecture and bioclimatic design in their daily work. During the long life of a building, digital tools can detect and fix energy losses and influence user behaviour to save energy. The biggest potential for energy efficiency will likely not be in fully automated houses, but in smart, easily accessible, and widely used applications that support energy efficiency. There is still much to do to develop and spread simple and user-friendly applications to support energy efficiency.

'We are missing a strategy for putting digital solutions to the best use for what could most effectively deliver decarbonization of the building sector.'

PETER GRAHAM

PAN Solutions

New business models for energy efficiency. Companies like Uber and Airbnb revolutionised transport and tourism. New business models like shared living might benefit energy efficiency. If investors do not only construct but also operate a building, energy efficiency becomes economically interesting, implemented with the help of digital solutions.

Make sure that 'green' buildings keep their promise. Digital tools can close the gap between planned and real energy performance during operation. Digital tools project the energy performance of a building and make it easier to obtain certification for standards such as LEED, BREEAM and DGNB. These certifications can even increase the value of the building. Fast and easy tools for monitoring real energy performance after construction are needed. Municipalities often have difficulty assessing whether buildings are in compliance with standards. Simple digital tools might help.

'Monitoring systems have been around for a long time – a user-friendly application makes the difference.'

YOMNA SFAXI

Wattnow

Building data: a feedback loop to the beginning. Building data is still a massively underused resource. The digital building model is usually incomplete, rarely updated after construction to generate an 'as-built' model, and poorly shared with the owners or facility managers when the building is handed over. Data generated during operations is often not systematically used.

This data has a lot of potential for energy efficiency. Benchmarking building performance against the digital model, or data of similar buildings can be a quick and cost-effective way to reveal savings (cf. page 42 / examples of ecobee, p. xx; Energy Brain, p. xx). In this sense, artificial intelligence can be used to optimise building design based on data from buildings in operation – a feedback loop to the beginning.

'BIM has to become a life-cycle technology. We need a feedback loop to the beginning.'

ERIK UBELS

EDGE Technologies

DIGITAL SOLUTIONS FOR ENERGY EFFIENCY 03

FROM DESIGN TO DEMOLITION

Architects, engineers, building developers, construction companies, building owners, facility managers and building users can use digital tools to save energy. But which digital tools exist, and how do building sector professionals apply them in practice?

This chapter sets out how digital tools can support energy efficiency during the design, construction, operation and demolition or refurbishment phase. For each building phase, it presents a catalogue of tools.

DESIGN

DESIGN: MAKING THE FUTURE VISIBLE

The challenge: Energy efficiency is just one more 'headache'

The design phase is crucial for energy efficiency. From small houses to complex large buildings, such as hospitals or hotels, designing a building for its optimum future performance can leverage substantial energy and cost savings. With relatively low efforts and costs, future energy demand can be significantly reduced. Early design decisions, for instance, those regarding building orientation, will have a significant impact on energy consumption and cannot be adapted later.

'When designing a building, with just a few lines, you determine for decades to come how much energy this building consumes.'

CHRISTIANA HAGENEDER
PEEB

Clients do not 'see' and value the benefits of energy-efficient buildings.

Energy performance and embodied carbon accounting is not integrated.

Energy simulation is seen as too complex.

Architects, planners, engineers, technical planners, developers, investors and future users are involved at this stage, often under immense time and cost pressure. They develop the design based on the briefing of the client, plan for costs and time and make sure the building complies with building codes and energy regulations.

Energy efficiency is often not a central concern. Investors or project developers do not 'see' and value the benefits of energy-efficient buildings. This can be caused by the more structural 'split incentive'[1] problem, but sometimes also by a lack of information, as economic and comfort benefits are not easily visible. Energy simulation is sometimes seen as too complex. As a result, the energy performance and embodied carbon of a building are often not considered in the design and planning practice and rarely mentioned in client briefings.

'The time for design is very compressed. In Brazil you often start the detailed design while you're already on-site.'

EDWARD BORGSTEIN
MITSIDI

1 Split incentives occur when the building owner and the tenant, are not the same entity. The owner may not be interested in investing in energy efficiency as the benefits of lower energy bills accrue to the tenant.

DESIGN

Digital solutions: Optimise and demonstrate

Digital tools can help architects and planners to quickly compare different design options and optimise energy performance, cost, comfort and other variables. Visualising the results of simulations in a clear and appealing way can be useful when engaging in dialogues with investors, project developers and future owners or tenants (Dodge Data & Analytics, 2018). Digital tools also make it easier to assess compliance with sustainable building labels and certifications, which play an increasing role in real estate valuation. No matter which tool is used, to be effective it has to be integrated into the planning process right from the beginning.

Simulation and design optimisation:
simulate options to optimise energy, comfort, cost and profitability.

Visualisation and marketing:
demonstrate higher comfort and lower energy consumption to clients.

There are several tools available for planners to do this. The tools are clustered into software for simulation (either directly integrated in BIM software or as spreadsheet-based tools) and simple web applications.

Tips for designers and planners

- Optimise building performance – whether with a simple web tool or sophisticated modelling.
- Use quick simulations as early as possible to show the monetary and comfort benefits to clients.
- Make sure all digital building data is transmitted to the owner or operator during handover.
- Define the business model for operation in the design phase to make sure operation works in practice.

DESIGN

Business Innovation

The Edge in Amsterdam: energy efficiency to a maximum

This Edge is an extreme case of using digital tools to plan an energy-efficient building. The building has currently the highest BREEAM rating in the category 'Sustainability'. It is an office building that produces more energy than it needs. The building systems are fully automated and devices connected to communicate autonomously, driving energy efficiency to a maximum. Energy comes from solar panels, rainwater is collected and a groundwater heat storage pump ensures cooling.

Occupants use a mobile app to connect with the building. In return, the building remembers individual preferences, adapts and gives recommendations for action.

More information: *www.plparchitecture.com/the-edge.html*

DIGITAL TOOLS FOR DESIGN

Simulation and design optimisation: Software

Simulation software packages can compare and optimise different design options and their energy performance, environmental impact, comfort and costs. Simulation software can be combined with existing BIM models (*see box on next page*), facilitating energy performance simulation and life cycle analysis. Spreadsheet-based tools can have similar functionalities. The relevant data in spreadsheet format can be generated manually or automatically taken from an existing BIM model.

Building Energy Modelling (BEM) simulates the energy performance of a building. BEM software often uses building data from existing BIM models. The software takes as input the building size, orientation, envelope, lighting, heating, cooling, ventilation, occupants or appliances, while also including external factors such as climate and location in simulations. Architects can find the expected energy and cost performance of the design options, describe potential ecological and economic savings in the building and adapt the design accordingly. BEM is also used to ensure compliance with building standards and green certifications.

Life-Cycle-Assessment (LCA) software analyses the environmental footprint of processes and products during the whole building life cycle. It calculates advantages and disadvantages of reusing or recycling construction products or using materials with low embodied energy, for example. Most software takes as input the common building information as mentioned above plus the building's energy performance and data on the building materials' carbon footprint.

Building Information Modelling (BIM)

Building-Information-Modelling' (BIM) allows for integrative planning, construction and operation in a **single 3D model environment.** The result is a virtual building (the 'digital twin') that includes numerical data (length dimensions, material thicknesses, thermal conductivities, etc.) and alphanumeric data (product information, material quality, operating instructions).

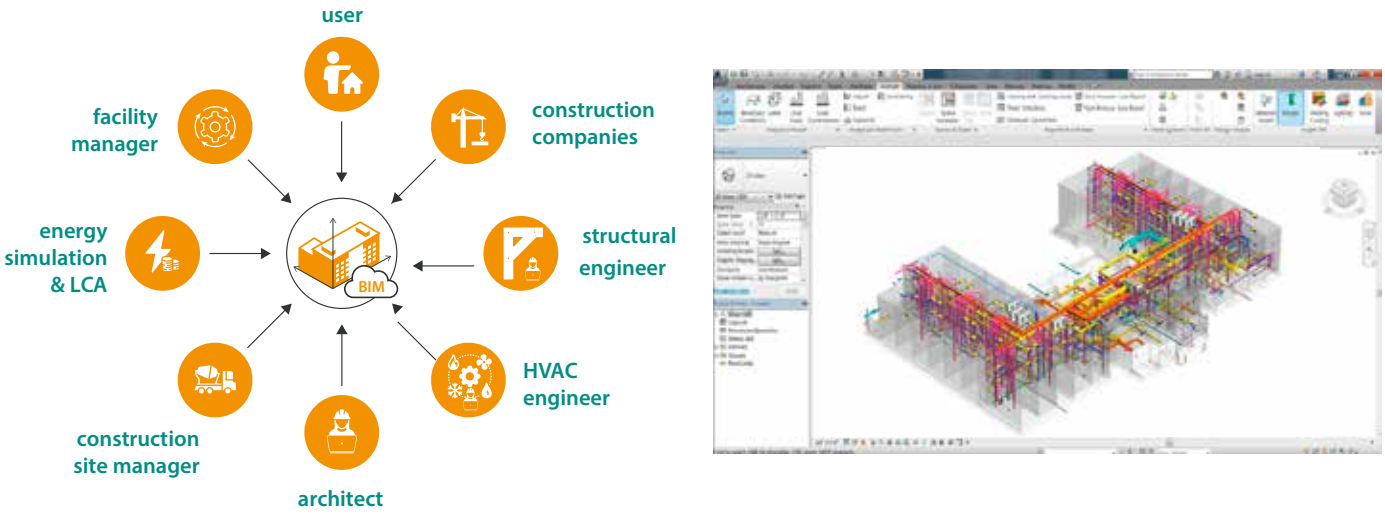


Figure 3 *Collaboration using Building Information Modelling (BIM)*

In the **design phase**, using BIM can facilitate communication between architects, engineers and construction companies and make project implementation faster and more reliable. BIM 4D (time) and BIM 5D (costs) are especially interesting for the **construction phase.**

After construction, the BIM models should be handed over to building owners and facility managers for the **operational phase.** With an energy management system included, facility managers can control the actual building performance. During the **demolition phase**, the model provides information for rehabilitation, recycling or dismantling.

However, BIM is only efficient if all actors involved in the design phase feed in their data and if the model and database are then effectively transferred to the building operators. Nevertheless, this is often not the norm. Data exchange still needs to be improved to ensure optimal building energy performances (Mousa, Luo & McCabe, 2016).

DESIGN
SOFTWARE

ClimateTool

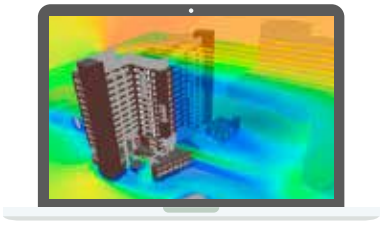
ClimateTool enables detailed climate analysis for every location worldwide. The tool allows the evaluation of different facade concepts for any location worldwide. These planning aids for architects and planners are specifically intended to be implemented at the concept development stage.

Costs & Complexity

Full Version is free of charge, Weather Data (based on Meteonorm)
~ EUR 80 per location
Professional training probably not necessary.

More information: *www.climate-tool.com*

DesignBuilder



DesignBuilder simulates the energy performance of a building. It can be fed with BIM or CAD data, and also includes a 3D-modeller within the software. The tool is suitable for early-stage modeling to test different building design concepts. It covers all climate zones. The software simulates energy use, heating and cooling demand, daylight performance, occupant behaviour, thermal comfort and HVAC performance, and uses CFD (Computational Fluid Dynamics) to visualise flows of air heating or cooling etc. Proofs compliance with green certifications.

Costs & Complexity

Price ranges from EUR 750 to 2,800, depending on installed modules
Professional training recommended,
free training resources available online

More information: *www.designbuilder.co.uk/*

EDGE

Edge calculates the cost-effectiveness of energy-efficient measures against a base case. Edge recently switched from software to an online web tool. The tool is suitable for early-stage modeling to test different building design concepts. It covers all climate zones and it is widely known by financial institutions. Edge calculates ecological and economic savings of default energy efficiency measures regarding energy and water use as well as embodied carbon. Proofs compliance with EDGE certifications.

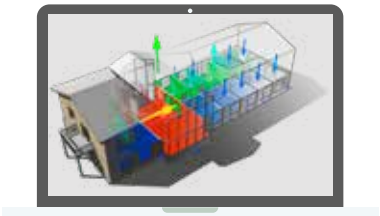
Costs & Complexity

Free
Professional training recommended,
free training resources available online

More information: *www.edgebuildings.com/*

DESIGN
SOFTWARE

IDA ICE – Indoor Climate and Energy



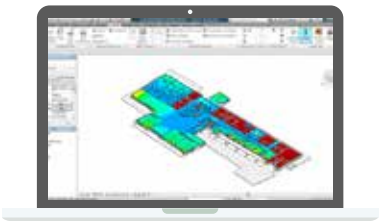
IDA ICE is a dynamic multi-zone simulation application for the study of thermal indoor climate as well as energy consumption of a building. The tool can be used globally, and is adapted to local languages and requirements (climate data, standards, special systems, special reports, product and material data).

Costs & Complexity

~ EUR 1.200/year
Professional training recommended, additional free training resources available online.

More information: *www.equa.se/en/ida-ice*

INSIGHT



Insight simulates the energy performance of a building with a focus on graphic visualisation. It runs directly within the 3D-model environment.
The software simulates and visualises energy use, heating and cooling demand, daylight performance, occupant behaviour, thermal comfort, HVAC performance, PV potential and energy cost. Checks compliance with green certifications.

Costs & Complexity

~ EUR 2,100 – 3,700/year, only runs as part of Autodesk AEC Collection or Revit
Professional training probably not necessary, free training resources available online

More information: *www.insight360.autodesk.com/oneenergy*

PHPP Passive House Planning Package

PHPP simulates the energy performance of a building. PHPP works for all building types.

The software simulates energy demand and loads for heating and cooling, renewable energy potential and respective savings, as well as compliance with green certifications. PHPP provides a 3D tool, which runs as a plugin for SkechUp.

Costs & Complexity

EUR 70 to 190 for the PHPP Planning Package and optional EUR 270 to 420 for 3D plugin.
Professional training recommended, additional free training resources available online

More information: *www.passivehouse.com/04_phpp/04_phpp.htm*

DESIGN
SOFTWARE

RETScreen Clean Energy Management

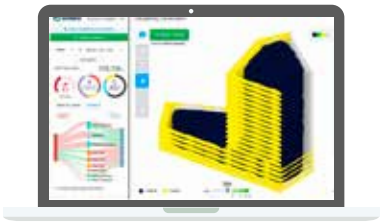
RETScreen calculates the cost-effectiveness of energy-efficient measures against a base case.

The software simulates energy use and savings, costs and emission reduction. RETScreen analyses financial viability, risks for various types of renewable energy and energy-efficient technologies and ongoing energy performance.

Costs & Complexity	Professional training recommended, additional free training resources available online

More information: *www.nrcan.gc.ca/energy/retscreen/7465*

SEFAIRA



Sefaira simulates the energy performance of a building with a focus on graphic visualisation. It runs directly within the 3D-model environment.

The software simulates and visualises energy use, heating and cooling demand, daylight performance, occupant behaviour, thermal comfort, HVAC performance, PV potential and energy cost. Checks compliance with green certifications.

Costs & Complexity	~ EUR 1,100/year, only runs as part of SketchUp Studio Professional training probably not necessary, free training resources available online

More information: *www.sketchup.com/de/products/sefaira*

Visualisation and marketing: Web applications

Web applications for simple simulations can be good for quick comparisons of design options. Prior experience with the tools is often not required and climate data for different geographical zones are already integrated within these applications.

Even if they produce less accurate results, a quick and easy assessment can have large benefits for decision-making on design, especially at the beginning of a project. This is more interesting for smaller offices with less financial or human resources. Project developers and prospective building owners might even use these tools on their own.

Online tools with default settings for climate and building components usually have more simple interfaces than advanced simulation software. Depending on the tool, planners can either set default design parameters or add building information. Tools allow rough calculations on energy performance, environmental impact and potential savings. They are also appropriate for users without sound technical knowledge.[2]

2 More academic tools, mostly in the shape of small web applications, have been developed by researchers and educational institutions such as Andrew Marsh (*www.andrewmarsh.com/software/*), UCLA (*www.energy-design-tools.aud.ucla.edu/*), and UC Berkeley (*www.cbe.berkeley.edu/resources/tools/*). They enable a more conceptual and in-depth understanding of energy consumption patterns in buildings depending on an extensive variety of factors.

Interactive Guide for Energy Efficiency in Buildings (Brazil)

The Guia interativo de eficiência energética em edificacoes (Guide for Energy Efficiency in Buildings) is an online tool that helps developers and designers select and understand the best solutions for energy efficiency in the buildings they build and operate. The tool has been developed for the Brazilian context.

The application gives recommendations on energy efficiency measures for building construction, lighting, heating and cooling, equipment, controls and renewables. To generate these recommendations users have to select a building type and feed in basic building information, such as size, construction type and location, as well as the available budget for future measures.

Costs & Complexity
Free
No training required

More information: *www.guiaenergiaedificacoes.com.br/*

CBE Thermal Comfort Tool (US)

This tool is a web-based interface for thermal comfort prediction. It can identify a range of temperature values providing adequate comfort while minimising energy use. Conversely, the tool can be used to assess the comfort level of energy-efficient building designs. It offers predictive models for conventional building systems including comfort criteria, and can simulate the effect of variable airspeeds.

It is in line with the US American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 55 and the European Norm EN 15251. The compliance verification feature can also be used for LEED credits.

Costs & Complexity
Free
No training required

More information: *www.comfort.cbe.berkeley.edu/*

ECO-NIWAS (India)

Eco-Niwas is an online application to calculate energy savings by applying energy efficiency measures. The tool is developed for medium-sized buildings in the Indian context.

The application performs a life cycle analysis and costing, embodied carbon calculation, circularity assessment and carbon benchmarking. A database of construction material is integrated into the tool.

Costs & Complexity
Free
No training required

More information: *www.econiwas.com/tool/*

ONE CLICK LCA

One Click LCA is an online application for life cycle analysis and energy-efficient design. It can be combined with common BIM and BEM software.

The application calculates life cycle analysis and cost, embodied and life-cycle carbon, circularity assessment, materials passport and carbon benchmarking. It supports certifications such as LEED, BREEAM and DGNB, and integrates global material databases. It also includes an early design carbon reduction module.

Costs & Complexity	Price ranges from 790 to 3000 EUR for typical core modules. Add-ons exist. Professional training not necessary, free training resources available online

More information: *www.oneclicklca.com/*

THESIM 3D

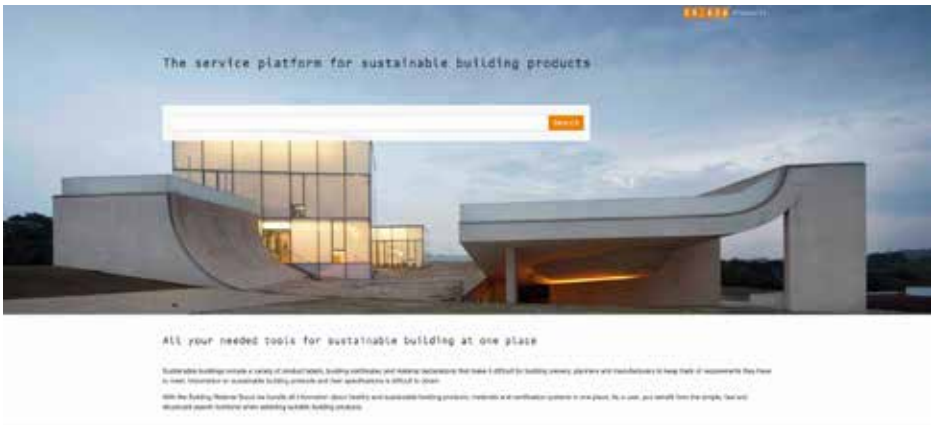
Thesim 3D is an online application to simulate operative room temperature. It simulates the operative indoor temperature of a building in summer.

The 3D model can be built within the application. Based on this model, Thesim3D can assess the effect of energy-efficient measures on the model. App users can select between default building design options.

Costs & Complexity	Free No training required

More information: *www.thesim.at/3d/thesim.html?v=0.99*

Business Innovation



Building Material Scout

New international labels and standards to improve the energy performance of buildings confront planners and product manufacturers with a major challenge: manufacturers often do not know the certification requirements, while planners need information on required material properties. New buildings should also be planned with BIM in such a way that materials can be recycled later on. Traditional product databases often miss information on the sustainability of products.

Building Material Scout tries to fill this gap by setting up a product database especially for sustainable products and building materials. Building Material Scout works as a database that supports sustainable products and complies with international labels and standards to support 'recycling management'. The database collects information about products, impurities and pollutants and provides building and material documentation through all phases of the building's life cycle.

Services for product manufacturers:

- Assessment of how a product performs against green building standards
- Product Verification: Sustainability generates a data sheet for communication between manufacturers and planners.

Services for project planners:

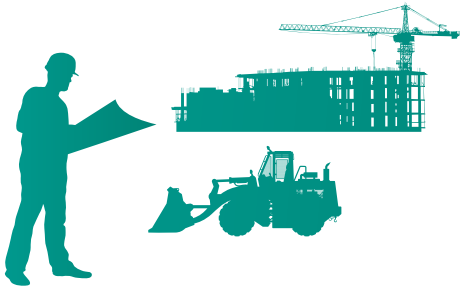
- Material Passport for buildings: project documentation related to building materials
- Building material information regarding disassembly and sustainability can be linked to existing BIM models

More information: *www.building-material-scout.com/en-us/*

CONSTRUCTION: ENSURING QUALITY AND REDUCING ENERGY USE

The challenge: Good planning is only half the battle

The construction phase is critical as the best energy-efficient design does not work if implemented poorly. The quality of construction must be up to standards to ensure that energy-efficient design works as planned. Also, construction sites are energy- and material-intensive – huge amounts of waste are generated.

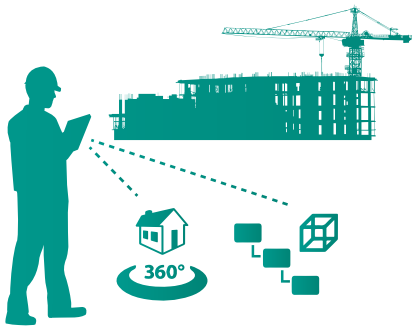


Poor execution of construction defies energy-efficient planning.

Inefficient construction logistics lead to waste and high energy consumption.

Digital solutions: Ensuring construction quality and reducing energy use on site

Digital tools can be used for construction management, quality assurance and commissioning[3]. This is inherently important to properly implement energy-efficient design and to make the construction process simpler. Digital solutions for construction site logistics and supply chain management can reduce the environmental impact of on-site activities and keep CO_2-intensive material waste to a minimum. Beyond these project management tools, several new and innovative digital approaches can support energy efficiency (Roland Berger, 2016; EY, 2018).



Construction logistics: digital tools for more productivity and resource savings.

Prefabrication: use optimised building elements through modular prefabrication.

Training: train construction workers with digital tools for improved execution of works.

CONSTRUCTION

Smart Energy Monitoring and Agile Logistics: These solutions measure energy use on site during the construction phase. Sensors monitor ambient conditions, the energy use of temporary electrics and equipment as well as fuel consumption. The data allows users to detect energy and cost reduction opportunities. In the next step, agile building site logistics optimise energy efficiency during construction. Combined with smart supply chain management, building materials can be delivered on-demand, saving large amounts of unnecessary material waste.

'We build unique buildings. No one is like the other. With digital prototyping, we produce in series, like the automotive industry 20 years ago. The building sector transforms from a manufactory to a mature industry..'

AXEL SEERIG

University of Lucerne

Business Innovation

SEKISUI HOUSE IN JAPAN

Sekisui House develops prefabricated residential buildings for sale, which produce more energy than they consume. Sekisui's net-zero energy houses have life cycle CO_2 emissions of only 183 tCO_2 – versus 483 tCO_2 per household in comparison to traditionally built houses. Most savings occur in the operational phase. Houses have the following features:

- High energy and environmental performance at a comparatively low upfront cost and with very low operating costs.
- Pre-fabricated and modular 3D modules can be combined according to individual needs.
- 'After sales service' to customers which may include data and energy management as well as maintenance support.

More information: *www.sekisuihouse-global.com/*

4 The comparative energy consumption of 3D printing is still under research (Yang et al., 2017)

CONSTRUCTION

Prefabrication and 3D printing: Prefabrication shifts production off-site. Building components can be industrially prefabricated according to energy efficiency standards before they are assembled on the construction site (cf. Sekisui, below). Mistakes in construction which might downgrade building energy performance can be avoided.

3D printing can help to avoid material waste. In recent experiments, robotics printing out the building from a mixture of rapid hardening cement, industrial waste, rubber and glass following a 3D construction plan saved up to 60% of construction materials and produced little waste[4] (Roland Berger, 2016).

'3D glasses can be used to train students on machines.'

ABDOULAYE SECK

SenergyS Africa

Virtual reality for communication to construction companies: For large building projects, explaining detailed project specifications to construction companies can be time-consuming and exhausting. Virtual reality (VR) can support this communication and explanation process by enabling them to see the project as it should be. Often this is much easier than countless clarifications and difficulties explaining specifications in construction jargon. This also decreases the possibility of misinterpreting what the client had in mind, preventing expensive 'making goods' and reworks.

Virtual tools for education: New innovative training methods, such as mobile apps or VR experiences, can be used for training in the construction sector. This can improve construction quality and lead to better building energy performance. Such training methods can be low-threshold and inclusive, which is especially important for low-skilled workers.

Tips for construction supervisors, construction companies and manufacturers:

- Consider using virtual reality models for a better explanation of project and construction details to construction companies.
- Smart Energy Monitoring solutions can save energy on site.
- Consider using digital solutions for prefabrication of delicate building components which are critical for the overall energy efficiency concept.
- Consider using 3D modelling of individual building parts to save material and cost.
- And: regularly control construction quality on site! The experienced eye of the construction supervisor can not be replaced by digital tools.

OPERATION

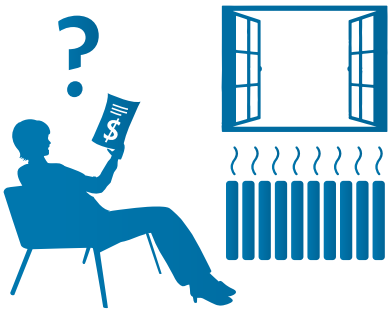
OPERATION: HOW BUILDINGS STAY IN SHAPE

The challenge: The performance of a building is a 'black box'
The design of a building has a large influence on its energy consumption. But once it is completed, the behaviour of users, facility management and the choice of appliances drive energy consumption. Even in buildings which are designed to be energy efficient, good operation is needed to ensure optimal performance. Users and facility managers have a common objective: proper functioning of all systems and a high level of comfort while maintaining operating costs as low as possible.

'Measuring energy consumption? Often only the electricity bill does that, and many people don't understand it.'

BRAHAMANAND MOHANTY

Asian Institute of Technology Bangkok



No information about the technical functioning of the building and energy performance is unknown.

User behaviour, inefficient appliances or buildings technology lead to high energy use.

Energy consumption and its drivers are often not visible or well-understood. For individual users, energy bills are usually the only connection to their consumption. Even in larger buildings, there might be no clear picture of what is driving consumption: inappropriate user behaviour, inefficient appliances or badly regulated systems might lead to high energy use.

As a result, the energy performance of buildings is often unknown. Usually, facility managers use energy management to monitor and steer the energy consumption only in larger or more complex buildings. Building automation is not new. However, current solutions have not reached their full potential and do not match with real-time user activities.

OPERATION

Digital solutions: Measure and manage

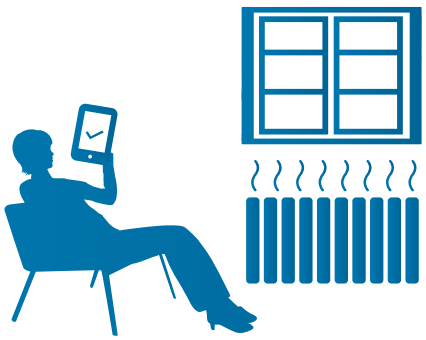
Digital tools for the operational phase of a building mostly provide three functions: monitoring energy consumption, giving recommendations to influence the behaviour of users, or reducing energy consumption through intelligent controls.

Digital applications can visualise the building performance and help to make it understandable. They can also identify drivers of consumption. Visualising consumption with tools that are intuitive and easy to use can already create incentives to save energy and money. Many tools can also give recommendations, often based on intelligent 'self-learning' systems, to promote behaviour change or control the equipment directly.

'A defective pump must understand for itself that it is broken and order the right technician plus invoice.'

KLAUS DEDERICHS
Drees&Sommer

Intelligent controls range from simple solutions, often called 'smart home applications', where the user can control electricity use, shading, light or interior temperature, to complex smart and self-learning artificial intelligence (AI) solutions, turning the building into an autonomously functioning system. Comprehensive intelligent software and AI can manage complex buildings almost autonomously.



Monitoring and analysis: understand drivers of energy consumption.

Intelligent controls: control and regulate appliances using algorithms.

Behaviour change: raise users awareness and change their behaviour.

There are several tools available for facility managers and individuals to do this. We have clustered these tools into applications to measure and optimise the use of energy and intelligent controls, either for professional facility management, or as 'smart home' applications.

Tips for facility managers and individual users:

- Use digital tools to measure and visualise energy consumption.
- Regularly check that a building performs as efficiently as planned; detect and fix failures.
- Use apps to nudge user behaviour to save energy. Include intelligent controls to optimise energy use, for example, based on weather data and energy market signals.

OPERATION

Business Innovation

Project Akilee: reducing electricity bills and increasing grid global efficiency in Senegal

Akilee provides a software to monitor and control the energy use of one or several builidngs to reduce energy consumption and expenses. It also develops power grid monitoring softwares for asset management and loss control.

Akilee has been bought up by the National Electricity Company of Senegal (SENELEC). It tries to support the energy consumer in understanding their actual energy use and reducing electricity bills.

Akilee monitors and analyses energy use and CO_2 impact in real-time, measures equipment performance, and visualises energy consumption and saving potential.

www.senelec.sn/projet-akilee-de-senelec/

Business Innovation

Energy Brain: faster energy audits in Brazil

High-quality energy diagnosis can help detect energy wastage and implement energy efficiency measures.

The Brazilian start-up Energy Brain tries to make energy audits faster and cheaper, targeting small- and medium-sized commercial, industrial and service facilities.

Energy Brain uses updated data on the distribution of energy consumption and prices in the various Brazilian production sectors to calculate the benefits of energy efficiency measures more quickly.

www.energybrain.com.br/

DIGITAL TOOLS FOR OPERATION

Monitoring and behaviour change
Applications to measure and optimise the use of energy

Apps or systems for intelligent energy use help to easily review and control (electricity) consumption. They are accessible on familiar devices such as smartphones or tablets. Users are provided with recommendations on potential savings.

Users can review and control their consumption easily from familiar devices such as smartphones or tablets and receive recommendations on potential savings. Users can influence their energy consumption by switching loads off and on in response to market signals or weather data for demand side management.

AKEEMA (Senegal)

Akeema helps to monitor, understand and reduce the actual electricity use of a building and is available in Senegal.

Occupants or facility managers can use Akeema to measure real-time electricity use, analyse the impact of user behaviour on energy use, learn about anomalies and achieved performances, and receive recommendations to reduce energy use and costs. The only requirement is the purchase of electricity from the state-owned electricity supplier SENELEC.

Costs & Complexity
Starting from EUR 1.00 (FCFA 650)/month, depending on the size of electricity bill.
Energy usage breakdown using NILM.

More information: *www.akilee-by-ines.com*

Energy Star Portfolio (EPA) Portfolio Manager (U.S.A.)

EPA Portfolio Manager is an online interactive resource management tool that enables the user to track and assess energy and water use in one or more buildings.

It can help to implement every step of an energy management programme, from setting a baseline and identifying which buildings to target to setting goals and tracking improvements. The energy and water performance of a building can be compared to similar buildings (benchmarking). Portfolio Manager is also the portal for applying for the ENERGY STAR certification and recognition.

Costs & Complexity
Free
No training required, guidelines available online

More information: *www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager*

Energy Tracker

Energy Tracker is a nudging app that helps the user manage meter readings to record their electricity, water, gas and heat consumption. Dates and meter readings are detected and processed automatically to provide a graphical analysis of the user's energy consumption. It creates a report comparing consumption trends throughout the year and highlights saving potentials.

Costs & Complexity
Free on iOS
No training required

More information: *www.apps.apple.com/us/app/energy-tracker-manage-and-analyze-meter-readings/id1193010972*

Hotel Energy Solutions (HES) e-Toolkit for Hotels

Hotel Energy Solutions offers an online toolkit providing hoteliers with a report assessing their current energy use, and recommends appropriate renewable energy and energy efficiency technologies.

It further suggests what savings on operating expenses hotels can expect from green investments through a return on investments calculator.

Costs & Complexity	Free Available in English and Spanish. No training required, user´s manual available online.

More information: *www.hotelenergysolutions.net/node/33251*

JouleBug

JouleBug is a nudging app turning energy saving into a game. It helps the user to easily keep track of their energy consumption and encourages real-time action through playful and interactive user experience. The app also provides advice on how to improve the user's habits through statistics, videos, links, etc.

Costs & Complexity	Free on Android and iOS No training required

More information: *www.joulebug.com/*

WATTNOW (Tunisia)

Wattnow helps users to understand and reduce the actual electricity use of a building.

Occupants or facility managers can measure real-time electricity use and analyse the impact of user behaviour on energy use. It informs users of anomalies or achieved performances and gives recommendations to reduce energy use and costs.

Costs & Complexity	(no information available on the website) Installation provided without additional costs for most products

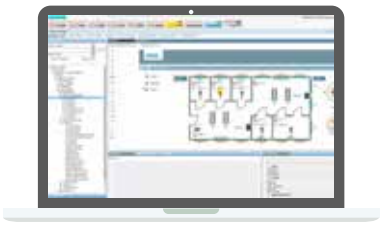
More information: *www.wattnow.io*

Intelligent controls 1:
Software for professional facility management

Software for facility management monitors and regulates the building's equipment regarding energy efficiency and comfort. Instead of manually controlling the building's performance, smart management systems collect external data and internal data provided by sensors in order to synchronise heating, cooling and lighting with actual user activity. Intelligent building management is mostly applied to large-scale buildings with professional facility management.

As there are a variety of different energy management software providers, only a selection of tools is introduced here. Internet platforms such as Capterra provide information and links to further software: *www.capterra.com/energy-management-software/*

DESIGO



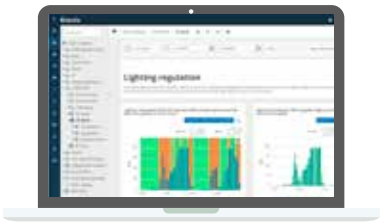
Desigo is an automation and management system to connect, monitor and operate a facility. It combines all operation units in one central system.

Desigo can be used to operate and optimise the performance of operating units in a whole building or for single rooms. Using AI, Desigo steers ventilation, indoor climate, heating, cooling, lighting and shading in line with the dynamic use of a building. Facility managers can predict potential energy savings, CO_2 reduction and cost benefits.

Costs & Complexity	Costs vary depending on the complexity and size of the building.

More information: *www.new.siemens.com/global/en/products/buildings/automation/desigo.html*

ENERGIS.CLOUD

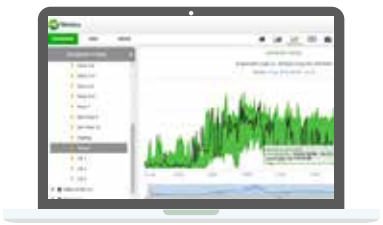


Energis.Cloud is an online energy management platform capable of processing data from a variety of external sources such as weather forecasts, IoT, or hardware, to generate forecasts, alerts and optimisation options using AI algorithms. Its open application programming interface (open API) enables remote device control. The platform is highly flexible and its interface can be customised to address the needs of the user.

Costs & Complexity	Subscription fee starts at EUR 3.50/month, depending on building volumes. Easy and adaptable tool with free demos available online.

More information: *www.energis.cloud/en/platform/*

WATTICS



Wattics is a web-based energy management software adapted to small and midsize businesses. The tool integrates with various sensors, meters and data systems to enable energy consumption monitoring and cost analysis.

Wattics helps to set up saving projects and manage user behaviours, and can automatically send alert notifications.

Costs & Complexity	Subscription fees up to EUR 45.00/month for unlimited users and sites. Easy and adaptable tool with free demos available online.

More information: *www.wattics.com/*

e3m – Active Energy Management

e3m is a scalable energy data management system. It enables users to centrally manage and analyse meter data, key figures and reference values for their properties at a local, national or global level.

e3m is modular in design and can be used from the acquisition of measured values to complex evaluations. It allows integration of external systems at individual property level (DDCs and building control software) and centrally (asset and facility management software).

Costs & Complexity	Costs vary depending on the complexity and size of the building.

More information: *www.e3m.ch/en/active_energy_management/overview/*

Business Innovation

CrowdComfort: 'when humans are the sensors'

CrowdComfort's Human Sensor Network platform is a mobile platform that empowers every building user with a smartphone to report comfort or maintenance issues. Using a proprietary geolocation method, reports include location that is precise down to the nearest square foot. This real-time crowd-sourced user feedback allows facilities and property management teams to improve energy efficiency, prevent failures and maintenance, and increase safety and comfort in the building.

The cloud-based tool requires no hardware sensors and little training. It can function as a stand-alone solution but can also be integrated into the building's existing management systems.

More information: *www.crowdcomfort.com/*

Intelligent controls 2:
'Smart home' applications to control and optimise equipment

Smart home applications enable appliances, sensors and electronic devices to communicate with each other and with users to optimise energy use and comfort. Users can either control appliances remotely or use artificial intelligence to give recommendations or automate certain processes within the building.

Applications for energy efficiency measure, visualise and optimise the building's performance and can achieve up to 30% energy savings (GlobalABC, 2016). Currently, there are a variety of product-bound smart home solutions on the market. A few providers offer solutions unifying different smart home products into one single application.

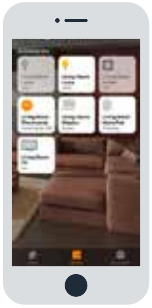
HOMEE

Homee is central control app that connects different smart home equipment. The central control app is compatible with various products, for example, smart home sensors or thermostats. Users can create different scenarios, remote control equipment intelligently via if-then-rules and (sub)meter energy and electricity use in the home. Users can activate automatic actions in the house on demand.

Costs & Complexity	Free app, plus EUR 129 for a starter kit and additional costs for smart devices Easy, online support available

More information: *www.hom.ee/*

HOME KIT



HomeKit is central control app that connects different smart home equipment. The tool is compatible with various products, for example smart home sensors or thermostats, but only runs on Apple products. Users can create different scenarios, remotely control equipment intelligently via if-then-rules and (sub)meter energy and electricity use in the house. The app sends notifications in case of anomalies.

Costs & Complexity	Free app, plus additional costs for smart devices Easy, online support available

More information: *www.apple.com/ios/home/*

TADO

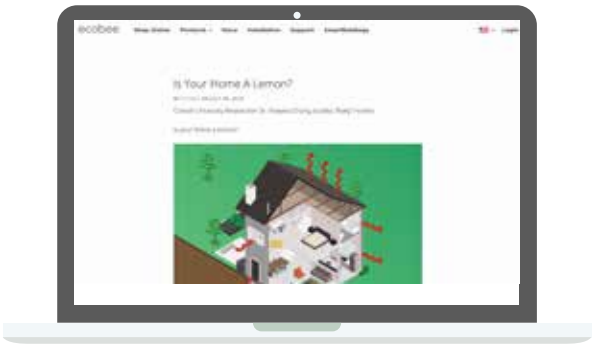
Tado is a product-bound application for smart heating and cooling.

Using Tado, occupants can measure and control heating and cooling equipment manually or automatically, set up individual modes (e.g. away, night, weekend) and request statistics on energy use and savings. Sensors detect open windows or abnormal behaviour of equipment. The app provides troubleshooting and gives recommendations to users.

Costs & Complexity	EUR 0.00 to 2.99/month for the app plus EUR 130 to 200 for a starter kit Additional costs for extra heating thermostat: ~ EUR 80 per unit Easy and self-installable, professional service available

More information: *www.tado.com*

Business Innovation



Ecobee: Smart thermostats meet science to check building performance

Sharing anonymised data from smart thermostats can help scientists to collect data on national building stock and user behaviour.

Researcher Dr. Howard Chong (Cornell University) in cooperation with smart thermostat provider Ecobee has developed a method to find out the actual building performance of many buildings at the same time. The models produce a score for each home which indicates how effectively it retains the interior temperature.

Occupants using Ecobee smart thermostats can use 'Home' and 'Away' functions to save energy. Chong then uses this data to track indoor temperature changes. If the temperature drops quickly, the building insulation performance is low.

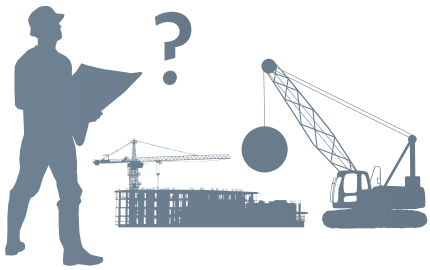
To get as much data as possible, Ecobee cooperates with public housing institutions and organisations in North America. Collecting national data on building energy performance helps builders and regulators understand how codes are operating in practice and derive recommendations for future decision-making processes.

More information:
www.ecobee.com/donateyourdata/
www.ecobee.com/2018/07/is-your-home-a-lemon/

REFURBISHMENT OR DEMOLITION: THE END CAN BE A NEW BEGINNING

The challenge: Who thinks about what happens some decades ahead?

In many if not most cases, buildings are simply not designed and built to be refurbished when they are run down, when users change, or when new, contemporary requirements have to be met. But reality shows that most buildings need to be refurbished at least once in their lifetime – office buildings even more. Each refurbishment effort is an opportunity for incorporating new ambitious energy efficiency measures.



No information about the properties of the building materials.

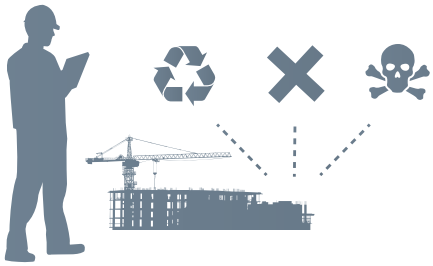
Buildings are not designed to be recycled.

Most planners and builders do not consider making demolition easy. With basic information about the specifications and properties of building materials and components, most of them could be systematically dismantled, recycled, and reused – instead of "blasting" the building and collecting and disposing of the leftovers.

Digital solutions: BIM again and industrialised refurbishment

Digital tools can be used to assess refurbishments options, and produce building elements for deep retrofits.

Data for deep energy retrofits: Deep energy retrofits – as opposed to 'simple' energy renovations or upgrades of individual systems, such as lighting or HVAC systems – will apply the 'whole building approach' and the overall building energy performance. Energy simulation can play a vital role in determining alternative deep retrofit options and their performances. It can also help to visualise refurbishment options and facilitate well-informed refurbishment decisions and improved communication among the parties involved.



Simulation and design optimisation: simulate alternative refurbishment options.

Prefabrication: optimise building elements through modular prefabrication.

Information for recycling: use building data to facilitate recycling or disposal.

3D scans of building elements or parts can be used for large and complex building refurbishments for which little or no data is available. There are different solutions for 3D scans of buildings ranging from manual and terrestrial laser scanners to drones that create 3D models of buildings from the air.

Industrialised, prefabricated modular systems for deep energy retrofits: Off-site industrialisation of the production of prefabricated building elements for deep energy retrofits represents an enormous opportunity in the construction value chain. Modular systems can be digitally developed and various retrofit projects aggregated for massive deep retrofits of similar building types or uses, such as residential buildings.

Business Innovation

Energiesprong: affordable and quick retrofitting

New industrialised retrofitting concepts supported by software can help to increase comfort, shorten rehabilitation processes and optimise energy efficiency.

The Dutch company Energiesprong transforms existing buildings into NetZero-standard retrofits targeting a large consumer base. After the retrofit, buildings will be highly energy efficient and will produce just as much energy for heating, warm water and electricity as they actually need.

By using prefabricated elements, smart heating and cooling and insulated rooftops equipped with solar panels, Energiesprong shortens retrofitting down to one week, reducing retrofitting costs to a minimum.

More information: *www.energiesprong.org/*

Tips for architects, construction companies and developers:

- From the design phase, think about the data needed for refurbishment or demolition.
- Use energy modelling to compare refurbishment options.
- Industrialised or modular refurbishment 'packages' can be developed with digital prefabrication.

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