cradle to cradle in business sites

PUBLIC RESEARCH CENTRE HENRI TUDOR

ENERGY ASSESSMENT OF BUSINESS SITES

C2C BIZZ PROJECT

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Date September 2014

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

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1 INTRODUCTION

The current climate challenge and growing global energy demands highlight the need for the development of cost-effective technologies for a more sustainable energy economy for Europe. Increasing renewable energy production will enable the EU to cut greenhouse emissions and make it less dependent on imported energy. Interest in renewable energy is also growing worldwide, as well as in innovative strategies for energy systems emerging from new environmental approaches, while renewable energy technologies are becoming increasingly competitive.

Some of the major contributions to the environmental degradation are the energy production processes based on fossil fuels. Therefore a change of strategy is also needed for business sites regarding energy production. The best solutions for energy production from an environmental perspective rely on renewable energies. Accordingly, the present tool has been developed within the C2C BIZZ project in order to systematically assess these forms of energy for business sites. In addition, aspects of energy efficiency and management are also considered, which will increase the potential of renewable energies integration.

1.1 Cradle to Cradle

Cradle to Cradle (C2C) is a quality focused innovation platform developed by Dr. Michael Braungart and the architect William McDonough for designing beneficial economic, social and environmental features into products, process and systems, starting by determining the intended benefits of a product or service rather than minimizing negative environmental impacts. (Mulhall and Braungart 2010).
The concept emphasizes the importance of a wide use of renewable energies, as well as diversifying all the solutions and strategies to enhance well-being, service quality and stakeholder added values.

C2C is divided in three general principles with a common objective for developing a positive impact on the environment, society and economy, according to McDonough, W. (2003):

- **Waste=Food, or everything is a resource for something else:** One of the key aspects of the C2C design methodology is the conception of materials as valuable resources that can circulate indefinitely in cycles of production, use, recovery, and remanufacture at without degrading in quality (McDonough, Braungart et al. 2003). Products and materials should be designed so that they are safe for people and the environment during and after their use and returned to the correct continuous technical or biological metabolism.

- **Use renewable energy:** According to the C2C methodology, human activity aims to produce a net positive impact on its environment. For energy, this means creating products, buildings and sites that generate more energy than they need through the use of rapidly renewable energy from sources like solar, wind, hydro-power, biomass (as long as there is no competition with food production and the biomass source is scalable to meet the intended demand), geothermal and hydrogen fuel cells. The core principle is to use energy that is ultimately generated by the sun or by gravity. For example, shallow geothermal originates from the sun warming the upper layers of the Earth. This goal can be supported by energy application methods that optimize utilization of renewable energy (smart grid, breakthrough energy-efficiency and energy storage concepts).

- **Celebrate diversity:** Diversity makes ecosystems more responsive and resilient in changing conditions. This principle encompasses cultural diversity and the promotion of social fairness, conceptual diversity and technological innovation for developing creative designs and enhancing local biodiversity. It implies integrating a variety of concepts, uses and cultures, adapting to local circumstances, enhancing stakeholder value and users' well-being and enjoyment.

1.2 About C2C BIZZ

In the INTERREG IVB Project C2C BIZZ (Cradle to Cradle in business sites), 11 North-western European partners are, since 2011, working together with the objective of enhancing the implementation of C2C on new and existing business sites. Participating partners include governmental agencies, knowledge institutions and private companies from six European countries (Netherlands, UK, Belgium, France, Germany and Luxembourg). Each partner contributes to the project in terms of its knowledge and expertise.

The three C2C principles should be applied to the entire process of business area (re)development, so that C2C business sites have a positive impact on environment, society and economy, and lead as an example of best environmental practices.

1.3 About this tool

Renewable energy sources are available worldwide, their potential varying according to the location and climatic conditions. Understanding the potential of available renewable energy resources at a given location would allow the identification of the best ways to harvest it with the adequate technologies.

This report has been developed by the Public Research Centre Henri Tudor (CRPHT) in the framework of the C2C BIZZ project, with the objective of supporting the implementation of renewable energy solutions in business sites according to the C2C approach. Its main focus lies on how to evaluate the energy potential of several renewable energies for a specific location. The matching of energy production and demand, an essential step to increase the penetration of renewable energies, is also covered (e.g. Smart Grid).

Knowing the site's potential for the production of energy as well as the scale of the technologies needed to harvest it can turn crucial for the development of the site itself and the established companies. This report presents simple methods to estimate the production potential and installed capacity for Solar Photovoltaic, Solar Thermal, Wind and Geothermal energies.

This document should, preferably, be used by business site managers with technical background and may be complemented with the C2C RES Calculator tool that was developed In order to facilitate the calculation part of the evaluation of renewable energy potentials. The calculator tool was developed in excel and should be used in close coordination with the explanations on this report, it is also available in the C2C BIZZ website.

The C2C perspective on energy can be found in chapter 2. In chapter 3 the concept of energy optimization in business sites is described. Chapter 4 describes the strategy for combining renewable energy potentials and smart grid concepts in one location. Chapters 5 to 8 present simplified energy potential calculation strategies for the various renewable energy forms.

2 CRADLE TO CRADLE AND ENERGY

According to the Cradle to Cradle® methodology, the primary aim of business sites is to have a net positive impact on its surrounding environment. In terms of energy, this means that the goal of the business site is to become energy positive, meaning that the renewable energy produced on the site is higher than its energy requirements. This implies developing an energy strategy that maximizes the use of renewable energies on the production side combined with increasing energy efficiency on the demand side, and the matching of energy production and demand in order to facilitate meeting the site's energy needs through renewable means.

Cradle to Cradle energy is energy that is generated and applied effectively, using current solar or gravitational income, and material media that are defined as biological or technical nutrients. According to the existing C2C certification standards for technical products, materials (including those that are part of renewable energy technologies) should be designed to have no toxic emissions during their use and to be completely disassembled and recycled at the end of their use.

However, combining C2C material concepts with existing renewable energy technologies can pose a challenge, mainly because the materials used to manufacture these technologies are not yet designed for recycling and of the difficulties to dismantle them at the end-of-life.

Although nowadays a completely Cradle to Cradle renewable energy technology is not yet available on the market, business sites can still make use of the existing technologies to become energy positive, contributing to the transition towards C2C implementation. The following chapter explains the methodology used to make the connection between C2C approach and renewable energies.

2.1 Business Sites Energy Approach in a C2C Context

The energy goal of the business sites should be to become energy positive with the maximization of renewable energy production, and for this to become reality the whole energy concept of the site and the strategy for the integration of renewable energy technologies should be considered from the planning stage.

The integration of renewable energies in business sites should follow a clearly defined strategy to achieve the best solution for each case. But simply installing renewable energy technologies will not optimize the whole energy system. Additional measures need to be taken into account together with the introduction of renewable energy technologies to improve their incorporation in the energy system.

The strategy for the integration of renewable energies here described should be considered as a dynamic process (shown in Figure 1) developed in a continuous feedback loop of information and data relative to the energy supply and demand, construction plans, barriers and constraints, and all other relevant information that proves beneficial to the positive development of the business site. Thus, lessons learned from the construction of one building can be applied in the next development stage, in a cycle of continuous improvement. Even if an energy positive business site is not possible right now, each stage of the development gets the site closer to that goal.

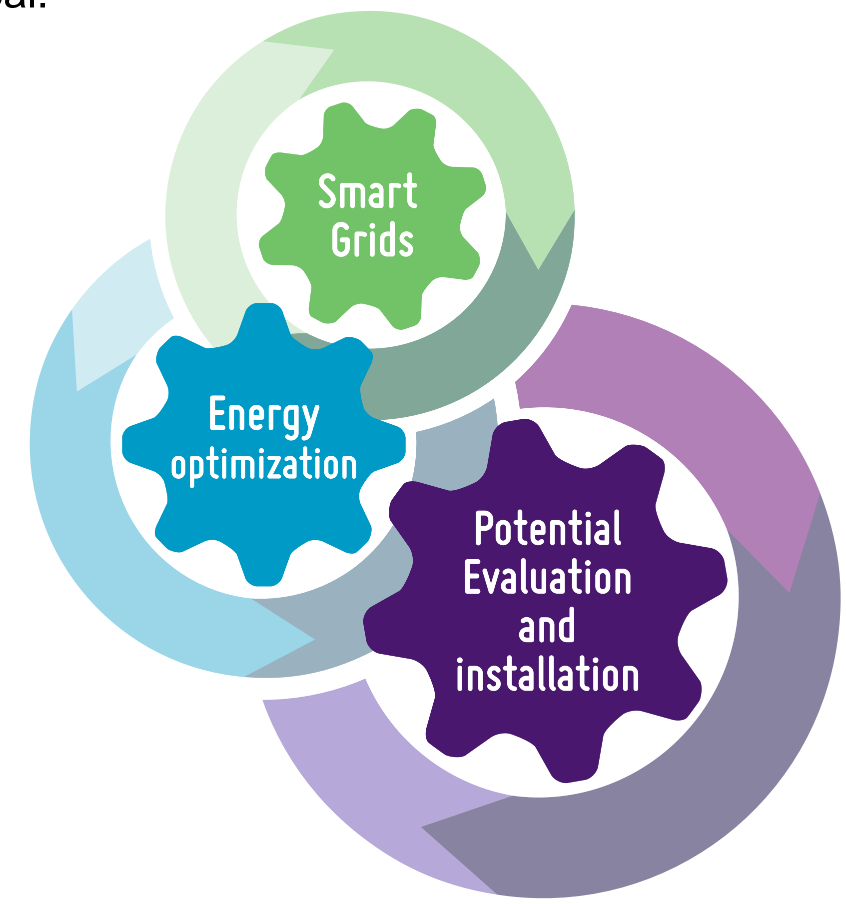


Figure 1: Energy Positive Business Sites Methodology

The evaluation of the renewable energy potentials within the business site area is the step more detailed in this guideline, and must be conducted together with an energy assessment to evaluate all the major energy consuming processes of the business site. The integration of the renewable energy production with the existing demands is done through the smart grid.

Renewable energy technologies are improving continuously, so it is reasonable to expect that production efficiency will increase over time, while installation costs will decrease, so it is important to repeat the energy potential assessment for each new development stage. Depending on the existence, or not, of built environment in the business sites, the renewable energy strategy should be adapted accordingly to obtain an optimum exploitation of all the available opportunities for greenfield and brownfield developments.

2.1.1 Greenfield Development

The Smart Grid concept plays an important role on the continuous optimization and renovation of the energy system. In the case of a new business site, this concept can be applied right from the starting point of the planning definition. This way the whole energy approach of the business site will be based on a feedback loop of information that allows the system to maximize the production from renewable sources and fulfil the energy demands.

The evaluation of the site's potential for production of renewable electricity and heat should also be conducted in the planning phase to understand the site's energetic potential, and the size and number of technologies to install in order to harvest the available energy potential. This evaluation needs to be a continuous process, since the evolution of the business site regarding the number of buildings, persons and energetic demands is also changing over time.

Energy audits need to be part of the business site routine, these evaluation procedures help in the evolution of the site's energetic profile, and should be linked together with the results of the renewable energy potential evaluation and with the future plans for the site to increase the number of available solutions.

2.1.2 Brownfield Development

The energy strategy in the case of already built business sites is similar to the one for future sites but with some differences because the companies are already established in the area, energy systems are installed and in use and the energy demands are known.

For all the existing infrastructures energy saving measures must be taken into account, as currently available solutions do not yet allow to cover 100% of the energy demand with renewable energies while considering standard times of return on investment. This is due to the fact that renewable energies are still not sufficiently implemented. The results of the energy assessment analysis lead to the definition of energy saving measures and the characterization of the loads, which is very important for smart grid implementation.

Similar to the strategy for greenfield developments, the possibility of adoption of a smart grid concept should be evaluated, if not already installed. A smart grid will allow the matching of energy demand with the energy production by switching some loads on and off according to the availability of renewable resources. This approach allows a maximisation of renewable energy use and, hence, a minimisation of fossil fuel use.

2.2 Advantages of Business Sites Energy Perspective

Business sites offer multiple advantages for energy production, distribution and storage when compared to single building perspective.

- The efficiency on energy distribution and storage is increased when multiple locations for production, consumption and storage are accessed in a combined way. More hours of energy consumption mean less need for energy storage, hence higher efficiency on the match between production and demand.

- A large number of buildings also means a large number of production and storage locations which increases the security of supply.

- Individual buildings may, during peak load periods, not be able to have the total energy demand produced in their area/infrastructure, but when connected in a grid the security of supply increases for the peak load periods.

- The access to available renewable sources for a single building is the same as the whole area of the business site when connected in grid. This means that an individual building can consume energy produced and/or stored elsewhere in the business site.

3 ENERGY OPTIMISATION ON BUSINESS SITES

As presented in chapter 2.1 the approach to maximise the use of renewable energy on business site is divided into 3 steps: energy optimisation, renewable energy potential evaluation, and matching of supply and demand through the installation of smart grids. The energy optimisation step is briefly explained in this chapter.

3.1 Energy auditing

Energy optimization is a very important step to conduct on already built business sites in order to achieve best performance in energy demands.

Identifying the main energy consuming processes and assessing their efficiency are the first steps towards optimised energy consumption.

The major difficulty of the assessing the current situation is to attribute the available energy consumption data (usually monthly gas and electricity bills) to the various processes within a company and the business site. This can be done in the framework of an energy audit, where a specialist (internal or external) can estimate or measure the energy consumption of at least the major processes. The investment in a continuous energy data acquisition system should be considered already at this point.

This system will strongly support the assessor in the analysis as well as provide, later on, data on the effectiveness of the optimisation measures. In the mid-term, the data acquisition system will be useful for the energy demand management of the smart grid system.

The energy auditor should also assess, as far as possible, the efficiency of the various systems, and the possibilities for the implementation of optimisation measures, considering technical and financial constraints. The final outcome of this assessment should be a list of prioritised optimisation measures at the process level as well as at the company's or business site level (integrated approach).

To allow sound decision-taking, this list should include information on:

- The potential energy and/or environmental savings,
- The technical constraints that might occur by the optimisation,
- The costs and/or time of return on investment and
- The adequacy of the measure according to the 3 main C2C principles.

3.2 Energy Saving and Optimisation Measures

The optimisation measures should be implemented according to the priority level defined by the auditor, in collaboration with the concerned company.

In addition to the detailed technical optimisation measures, the following measures should also be included in the audit report:

- Appoint an energy manager (if not existent) to supervise the implementation of the measures and assess their rate of success
- If necessary, carry out further studies on specific equipment (e.g. compressed air, cooling system, boiler, etc.) to extend and refine the optimization measures. Sometimes the manufacturers of such equipment can provide interesting possibilities for optimization.

For further reading on energy efficiency measures, please refer to the reference document on energy efficiency of the European Integrated Pollution Prevention Control Bureau (http://eippcb.jrc.es/reference/BREF/ENE_Adopted_02-2009.pdf).

Once the main optimisation measures have been implemented, the assessment and installation of renewable energy solutions on the business site can be considered in detail.

3.3 Optimization of Building Synergies

Harvesting the maximum renewable energy potential with the intention of having positive energy buildings and business sites is clearly dependent on the installation of the adequate renewable energy technologies in buildings and surface area of the sites.

The interdisciplinary treatment of building technology, renewable energy technology and architecture is vital for the attainment of a positive energy footprint. Exploiting the existing synergies between the installation of renewable energy technologies in buildings and matching these with the design and uses planned for the buildings will allow to improve their design, comfort, usability and a reduction of costs Continuous improvement experiences in building designs, construction and technology integration strategies from one stage of the development to the next should result in a feedback loop of data and information to be used in the concepts for new buildings. In order to lead by example and increase the interest of companies and users in the site, it is encouraged to publish the results of the site's energy performance.

Considering the above strategy for buildings, the business site planning and strategy can be designed as a multi-stage process with a continuous flow of information and data for a constant enhancement and improvement of the site development.

3.4 Important Barriers to Consider

The existence of barriers for the integration of renewable energy technologies in business sites must be assessed and evaluated beforehand so that the planning stages do not run into unexpected delays.

The geographical location and the energy context of the country/region must be the first points to consider when planning renewable energy systems as they can turn out to be critical in terms of grid access restrictions, legislative issues and financing schemes which are crucial when calculating the return of investment.

Some examples of barriers in Europe taken form (ECORYS, 2010):

- **High number of authorities involved in permitting** - In many Member States, stakeholders complained about the excessive number of authorities involved in permitting procedures. This is the case, among others, in Belgium, Cyprus, Estonia, Finland, Hungary, Ireland, Italy, Latvia, Luxembourg, Poland, Romania, Slovenia, Spain and Sweden.

- **Unclear administrative framework** - This barrier includes problems such as legal uncertainty, contradicting legal provisions, excessive discretionary powers of the administration and corruption.

- **Permitting for building integrated technologies** – Most of the European countries do not require permits for small building integrated energy systems, except for monuments/ protected areas. Even though in some of the countries still requiring an authorisation this may be provided swiftly, the very existence of the procedure may discourage potential investors.

- **Problems concerning connection to existing electricity networks** - For many renewable electricity generation projects connection to the electricity network represents a serious problem, especially when it is necessary to undertake technical adaptations and extensions of the existing grid. The main reasons for this are the following: Lack of smart networks - Insufficient grid capacity; Unpredictability of most renewable energy systems; Lack of compensating power plants.

Barriers specific to each renewable energy are further detailed in the corresponding chapter.

4 TOWARDS AN ENERGY POSITIVE BUSINESS SITE

The objective of this chapter is to give an overview of what can be an integrated approach of demand side management and renewable energy technologies, in order to produce, in the long term, more energy than what is actually consumed on a business sites.

4.1 Matching energy production with demand – A Smart Grid Overview

Due to the variability of the sources (variations in wind, clouds, etc.), renewable energy production does not always correspond to with energy demand at a given moment. Currently, in case of strong or weak renewable energy production, electrical and thermal systems are usually managed in such a way as to supply the demands by decreasing or increasing the use of fossil fuels.

A business site that is to rely on 100% renewable energy can address this variability through different solutions, like, for example, smart grids. Due to the demand-driven structure of thermal energy systems, the smart grid concept is currently only applied to electrical systems.

A smart grid system is defined in this document as a management tool that allows the matching of energy production and demand. As the renewable energy production should be maximised (excess energy being stored for periods of insufficient production), a major focus is given to the demand side. So far, energy demanding processes (heating, cooling, lightning, compressed air, etc.) were used with the assumption that the necessary energy was available at all times.

Now, with the variability of renewable energy production, the concept behind a smart grid is to, at least partially, adapt the demand to the production by switching loads on and off according to energy availability. A signal, triggered by the grid manager during times of high renewable energy availability, for example of strong solar income, is sent to switch on energy using processes that can be launched any time. Although developed for increased renewable energy production, this solution can also be applied to current systems, in order to reduce peak energy demand and therefore, depending of energy contract's conditions, avoid financial penalties linked to high punctual energy use.

A smart grid is composed of an energy monitoring system, providing information on energy consumption to the grid manager. It also includes a communication system that allows the control of various energy demanding processes, as well as, preferably, a weather forecast system, in order to estimate the energy production (quantity, but also type) over the next days, and energy storage systems for periods of exceeding production. These various elements enable improved energy management, therefore maximising the use of renewable energies.

It is not necessary to install smart grid control units on all processes. Instead, businesses should concretely:

- Inventory their energy consuming processes or devices (e.g. elaborated in the framework of an energy audit)
- Identify those processes that can be regulated in case of important renewable energy production, but without putting the overall activity of the business at risk. Equipment that could be used as energy storage (e.g. compressed air systems) should also be listed.
- Install the SmartGrid system to optimise renewable energy production and use.

The installation of smart grid systems on business sites must be done by consensual agreement of all the companies that are part of the site, as these can entail high installation costs, despite their potential for long-term energy savings. In addition, the companies have to actively provide input to the data management system in order to adequately operate the smart grid system.

4.2 Smart Grid and C2C

The 3 principles of Cradle to Cradle reflect the benefits of smart grids. Some of these are presented below:

- Smart grid will become a necessity for the use of renewable energies, in order to address the variability of their availability. Therefore, this solution is directly in line with the second principle, which is to maximise the use of solar energy.
- The variability of renewable energy sources, currently a major difficulty for energy networks, increases with the number of sources. As the use of smart grid addresses these difficulties, this concept clearly supports the use of diverse energy sources, and therefore also the diversity principle of C2C.
- The third principle is also clearly reflected in the technical necessity to include multiple actors (and therefore controllable processes) on the demand-side.

5 EVALUATION OF PHOTOVOLTAIC POTENTIAL

5.1 Introduction

The use of solar income is one of the three basic principles of Cradle to Cradle. Harvesting solar radiation to produce electricity represents the transformation from the main source of energy to the principal energy carrier used in our society. Photovoltaic systems convert solar irradiance directly into electricity using solar cells. These systems, which can produce, although in a limited quantity, electricity even under weak irradiance conditions (e.g. heavy clouds, rain, etc.), can generate large quantities of electricity depending on numerous factors, including local weather conditions and the construction boundaries/constraints (like orientation, slope of the PV modules, system balance, quality of the components, etc.).

Silicon solar cells are the most commonly used in PV modules. There are 3 basic types of PV modules:

- **Monocrystalline** – these cells are cut from a single crystal of silicon, forming one large slice of crystal. These cells achieve the highest efficiency, but on the other hand are the most expensive to produce.

- **Polycrystalline (or Multicrystalline)** – these cells are composed of a large number of crystals. Due to this factor they are less efficient than the ones made from a single crystal.

- **Amorphous** cells are made from a thin film of amorphous silicon (with no crystals). They are the least efficient silicon cells, but they are also the cheapest to produce. Their electrical production diminishes in the first few months, after which it remains stable.

5.2 Potential barriers to solar PV use

Solar photovoltaic installation may face some hurdles regarding technical, legal or other aspects, which are presented in Table 1. These items need to be assessed in an early stage to confirm the feasibility of PV systems on the considered site.

Table 1: Possible obstacles to solar PV use in business sites

TECHNICAL	LEGAL	OTHER
Available area too small for installation	National/Municipal legal restrictions to PV electricity production (e.g. architectural considerations)	High costs / long time of return of invests depending on location
Important shading effects	Long duration to obtain the necessary authorisations	Surface conflict with solar thermal system
Electrical system outdated / inadequate capacity for additional energy generation system	No feed-in tariffs / no subsidies for investments	-

5.3 Simplified Energy Potential Calculation Methodology

5.3.1 General Equation

(5-1)

$$E = AvSol \times A \times OPVEf \times InvEf$$

5.3.2 Average Solar Radiation

To evaluate the **Solar Photovoltaic Potential (E)** (Wh/time) of one site, it is first necessary to estimate the **Average Solar Radiation (AvSol)** in Wh/m2 for that location. Many meteorological stations nowadays measure solar radiation and the values are normally in Wh/m2/day. The measured data should be available for purchase or free download. When the data for solar radiation is not available from the meteorological station, or the station is too far away (more than 20-30 kilometres from the considered site), there are ways to calculate/simulate them (simulation of PV potential is explained below) to obtain a least a good estimation of the radiation values.

> Be aware of the time frame of your data. If the solar radiation is in Wh/m2/year then your results will represent the estimation of total production of the PV modules per year.

5.3.2.1 Simulation of PV potential

To simulate the PV potential for a given place in Europe the Photovoltaic Geographical Information System (PVGIS) tool can be used. This tool makes a geographical assessment of solar resource and also an evaluation of the performance of photovoltaic technologies.

The tool was developed for the Joint Research Centre of the Institute of Energy and Transport of the European Commission. PVGIS is available at: http://re.jrc.ec.europa.eu/pvgis/. The results for the monthly global irradiation are presented in Wh/m2/day and can be directly inserted into Equation 5-1.

5.3.3 Area of PV Modules

The second step is to determine the Area of PV Modules (A) to install.

If the system is to be mounted on an inclined surface then the **Area of PV Modules (A)** equals the available roof or wall surface, taking into account the most suitable orientation (showed in Table 2, p.23).

If the available surface is almost horizontal (a slope of maximum 7° should be considered to achieve a self-cleaning effect), then the modules can be mounted either horizontally or at angle. In the case of horizontal modules, the available surface is used at a maximum, but the system will have a smaller yield (see again Table 2 p.23), and therefore a longer time of return on investment. If the modules are mounted at angle, the yield is higher (implying a shorter time of return on investment), but the available surface is not used at its maximum.

In absolute energy production terms, horizontal modules will bring, for the same available surface, more energy than modules at an angle, but with a higher time of return on investment. Therefore:

- In case of horizontal modules, the available horizontal area equals the Area of PV Modules (A).
- If the modules are mounted at angles, the following equation should be considered:

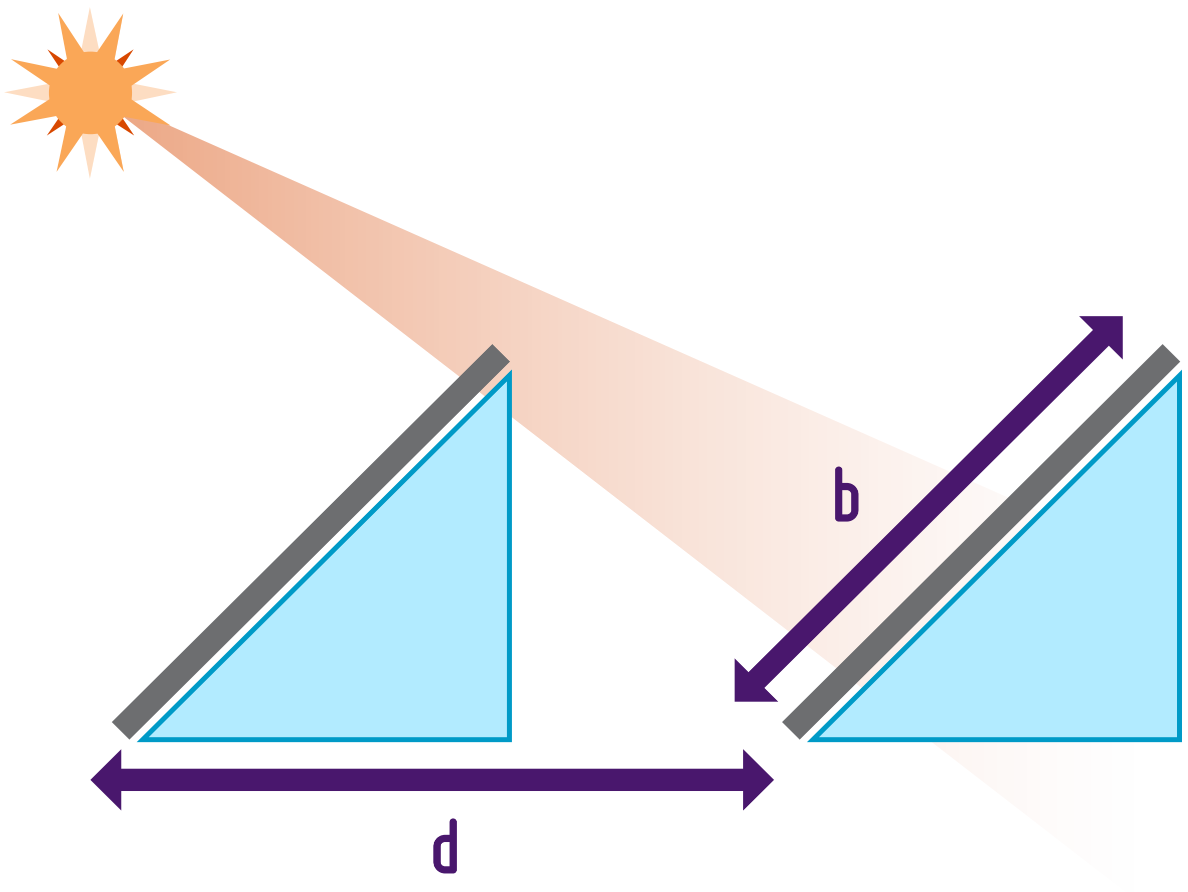
$$A = \text{Exploitation Factor} \times \text{Available Area} \quad (5\text{-}2)$$

To specify the utilization of a specific flat area, the area **Exploitation Factor (f)** is used (see (5-3)). This is defined by the ratio of the module width (b) to the module row distance (d):

$$f = \frac{b}{d} \quad (5\text{-}3)$$

This calculation usually results in an area exploitation factor of between 0% and 100%. A factor of 100% exploitation of the area with inclined modules, would, however, cause considerable mutual shading of the individual module rows.

Figure 2: Exploitation Factor parameters.



The following rule-of-thumb for a tilt angle of 30° for North-West Europe taking into consideration optimum area exploitation is usually considered:

Distance d = 3x module width b, which will count as 33% of exploitation factor

Shading effect – be aware of shading on the modules from elements such as chimneys, trees, publicity signs, air vents and other objects. The effect of this shading on the modules output has to be calculated case-by-case due to the specifics of each object and the shading that it produces. In cases where the shading is significant and/or persists for a large part of the day, one can decide not to install modules in that area because the costs would be too high compared to the expected benefits.

5.3.4 Overall Efficiency

At this point it is necessary to decide on the type of PV modules to install and to know their **Overall Efficiency (OPVEf)**.

$$\text{OPVEf} = \text{PV Module Efficiency} \times \text{Percentage of Optimum} \tag{5-4}$$

The simple and general expressions presented here give only an estimate of the annual solar energy output.

The PV Modules Efficiency change for each type of module:

- For monocrystalline modules the efficiency range should be from 17% to 20% (18% can be used as a reference value).
- For polycrystalline modules the efficiency range should be from 14% to 17% (16% can be used as a reference value)
- For amorphous modules the efficiency range should be from 9 to 10%, either of these values can be used as reference for calculations.

The yield of PV modules also depends on the tilt angle of installation and the azimuth angle of orientation[1] (see table below for examples of azimuth angles). Both these variables will influence the **OPVEf** with a **Percentage of Optimum** output.

The optimal inclination for the solar PV modules in Northwest Europe is 30° oriented to South, which is about 10% more efficient than 0° (horizontal). (MONDOL, 2007) (T. Pavlović, 2010)

The **Percentage of Optimum** of annual total PV output normalised with respect to maximum annual total PV output for various surface orientations and inclinations is presented in Table 2 below.

1. Source: The azimuth angle of orientation is the measured angle calculated by perpendicularly projecting a vector from an origin (orientation of PV modules) to a point of interest (in this case South) onto a reference plane.

5.3.5 Efficiency of Inverters

The Solar Photovoltaic Potential of the installation depends also of the **Efficiency of Inverters (InvEf)**, necessary to convert the direct current produced into alternate current injected in the electricity grid.

The average **Efficiency of Inverters** used in solar PV installations varies from 93% to 95% (in this case 94% can be used as a reference value)

Table 2: Percentage of Optimum. Adapted from (MONDOL, 2007)

	AZIMUTH ANGLE	SURFACE TILT ANGLE (DEG)										
		0	10	20	30	40	45	50	60	70	80	90
East	-90	90,1	89,6	87,9	84,9	80,8	78,3	75,5	69,2	61,8	53,9	45,6
	-80	90,1	90,7	89,9	87,7	84	81,7	79,1	72,8	65,5	57,4	48,5
	-70	90,1	91.7	91,8	90,3	87,1	84,9	82,4	76,3	68,9	60,5	51,4
	-60	90,1	92,7	93,6	92,7	89,9	87,9	85,5	79,4	72	63,4	53,9
South East	-50	90,1	93,5	95,1	94,8	92,4	90,6	88,2	82,2	74,8	65,9	56,1
	-40	90,1	94,3	96,5	96,6	94,6	92,8	90,6	84,6	77	68	57,8
	-30	90,1	94,8	97,6	98,1	96,3	94,6	92,4	86,6	78,9	69,6	59
	-20	90,1	95,3	98,4	99,2	97,6	96	93,8	87,9	80,1	70,7	59,8
	-10	90,1	95,5	98,9	99,8	98,4	96,8	94,6	88,8	81	71,3	60,3
South	0	90,1	95,6	99	100	98,6	97,1	94,9	89,1	81,1	71,5	60,4
	10	90,1	95,5	98,8	99,8	98,3	96,7	94,6	88,7	80,9	71,3	60,2
	20	90,1	95,3	98,4	99,1	97,5	95,9	93,8	87,8	80	70,5	59,6
	30	90,1	94,8	97,6	98	96,3	94,6	92,3	86,4	78,7	69,4	58,8
South West	40	90,1	94,3	96,5	96,6	94,5	92,7	90,5	84,5	76,8	67,7	57,5
	50	90,1	93,5	95,1	94,7	92,3	90,5	88,1	82,1	74,5	65,6	55,7
	60	90,1	92,7	93,5	92,6	89,8	87,8	85,3	79,2	71,7	63,1	53,6
	70	90,1	91,7	91,8	90,2	87	84,8	82,2	76	68,7	60,2	51,2
	80	90,1	90,7	89,8	87,6	83,9	81,5	78,9	72,6	65,3	57,2	48,4
West	90	90,1	89,6	87,8	84,8	80,6	78,1	75,3	69	61,8	53,8	45,5

6 EVALUATION OF SOLAR THERMAL POTENTIAL

6.1 Introduction

Incoming radiation from the sun provides direct light and heat, so solar hot water technologies use solar radiation to heat water in a collector. The heated water is then stored and finally distributed through the sanitary and/or heating systems, reducing the dependence on conventional fossil fuel heaters. Due to the specificities of steam uses (out of scope of this document), and the high investment costs of high temperature solar collectors (e.g. Fresnel collectors), this chapter will only focus on the solar potential for hot water demand below 100°C. Solar collectors can be divided into two main categories: flat plate glazed, and evacuated tubes collectors.

- **Flat Plate Glazed collectors** consist of a black absorber surface and attached piping contained in an insulated enclosure, covered with a special glass or polycarbonate designed to extract the maximum amount of thermal energy from the sun. The piping is often copper, or another corrosion-resistant material. Warranties on these collectors average about 10 years, but well-built collectors may last 20 or 30 years.
- **Evacuated Tubes solar collectors** consist of several rows of glass tubes that contain a slim collector surface with attached pipes and are connected to a main pipe. The air has been removed from the tubes to eliminate the heat losses from convection and conduction.

These collectors can be divided in two sub-categories:

- **Direct Flow collectors** – these collectors consist of several glass tubes that contain a flat or curved aluminium fin attached to an absorber pipe made from glass or metal (usually copper). The aluminium fin is covered by a coating that inhibits radiative heat loss and captures solar radiation. Water is the heat transfer fluid and circulates through all the pipes.
- **Heat Pipe collectors** – these collectors consist of a heat pipe made of metal (copper), which is linked to an absorber plate, inside a vacuum-sealed tube. The heat pipe is hollow and the space inside is evacuated, to promote the change of state of the liquid that it contains, that can be purified water with specific additives or alcohol. The vacuum allows the liquid to boil at lower temperatures than at normal atmospheric pressure. When the radiation reaches the absorber, the liquid that is inside the heat tube will turn to vapour and rise to the top of the pipe. The flowing water through the manifold gets heated, at this point the fluid of the heat pipe will condensate and flow back down the tube, so that the process can be repeated.

6.2 Potential barriers to solar thermal use

The use of solar thermal potential may face some hurdles regarding technical, legal or other aspects, which are presented in Table 3. These issues need to be assessed at an early stage to confirm the feasibility of solar thermal systems in a given location.

Table 3: Possible obstacles to solar thermal use in business sites

TECHNICAL	LEGAL	OTHER
Available area too small for installation	National/Municipal legal restrictions (e.g. architectural considerations)	High costs / long time of return of invests
Important shading effects	Long duration to obtain the necessary authorisations	Surface conflict with PV system
Building's hot water temperature level not adapted to solar thermal	No feed-in tariffs / no subsidies for investments	-

6.3 Simplified Energy Potential Calculation Methodology

6.3.1 General Equation

To evaluate the Solar Thermal Potential of a given location the following equation can be used: (6-1)

$$E = AvSol \times A \times OColEf$$

6.3.2 Average Solar Radiation and Area of Collectors

The **Average Solar Radiation (AvSol)** and the **Area of Collectors (A)** can be obtained as explained in chapters 5.3.2 and 5.3.3.

The simple and general expressions presented here give only an estimate of the annual solar energy output. It should also be noted that the method presented here is not valid for air collectors

6.3.3 Overall Collectors Efficiency

The **Overall Collectors Efficiency (OColEf)** depends on the type of collector and also the usage it is given, so the values in the following table can be used as reference. These values are related to the local atmospheric conditions of the places in which the tests/evaluations were carried out for the reference studies.The temperatures differences presented in Table 4 reflect the difference between the fluid temperature entering the collector and the ambient temperature (outside) this difference will be lower when the produced heat is for lower temperature usages and higher when the opposite occurs. Solar collectors have their maximum efficiency when both temperatures are the same.The value used for the **OColEf** to be used in the equation (6-1) should be related to the type of collector to be installed and to the kind of usage that will be given to the resultant heat.

The end results of **Solar Thermal Potential** for the flat rate collectors can be compared to a reference value of 525 kWh/m2/year. This is the value accepted as the minimum for a solar thermal panel installed in Germany (based on a defined calculation routine for low temperature domestic hot water demand profile and a solar fraction of 40%) in order to obtain funding from the Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle – BAFA) (BAFA, 2011). Evacuated tubes collectors are normally above this value.

Table 4: Collectors efficiency relation with the usage type. Based on (Industries, 2010)

TECHNICAL	LEGAL	OTHER
Temperature Difference (Usage)	Collector Type	Efficiency Range
0°C – 25°C (Pool Heating)	Flat Plate	60-70%
	Evacuated Tubes	35-45%
25°C – 45°C (Hot Tub)	Flat Plate	45-60%
	Evacuated Tubes	32-35%
45°C – 60°C (Domestic Hot Water)	Flat Plate	35-40%
	Evacuated Tubes	28-32%
60°C – 65°C (Space Heating)	Flat Plate	28-35%
	Evacuated Tubes	27-28%
65°C – 95°C (Seasonal Heat Storage)	Flat Plate	0-28%
	Evacuated Tubes	22-26%

7 EVALUATION OF WIND POTENTIAL

7.1 Introduction

The solar income of our planet generates bands of high and low-pressure air masses. The result of this is two great regions of high pressure around the poles and a low pressure band at the equator. The warm air rising from equatorial regions spreads to the north and south, and wind is produced from air flowing from high pressure zones to low pressure zones.

Energy can be converted from wind as it moves through the ‘swept area’ of a turbine’s blades. On the downwind side of the turbine the wind moves slower, as some of its kinetic energy has been converted into kinetic energy of the moving turbine blade. The rotational energy is transmitted to an electrical generator producing electricity.

7.2 Potential barriers to wind turbines use

The use of wind turbines may face some hurdles regarding technical, legal or other aspects, which are presented in Table 5. These items need to be assessed in an early stage to confirm the feasibility of wind turbines at a given location.

Table 5: Possible obstacles to wind use in business sites

TECHNICAL	LEGAL	OTHER
Available area too small for installation	National/Municipal legal restrictions to wind electricity generation (e.g. noise)	High costs / long time of return of invests
Wind obstacles (buildings, trees, etc.)	Restrictions regarding areas around wind turbines	Noise and shadow impact
Electrical system outdated / inadequate capacity for additional energy generation system	Legal limits to tall structures in the considered area	Bird protection
Difficulties in finding accurate wind speed data	-	Population / employees position regarding wind turbines

7.3 Simplified Energy Potential Calculation Methodology

7.3.1 General Equation

To get an estimation of the **Annual Energy Output (E)** of a wind turbine in kWh/time the following simplified equation is used (assuming a general air density of 1,23 kg/m3) (SEW, 2012).

$$E = AvWs^3 \times 0.48 \times (T/1000) \times EfWT \times RD^2 \tag{7-1}$$

The value **0.48** in equation (7-1) represents a simplification made from the original equation.

$$E = \frac{1}{2} \times AvWs^3 \times \text{Air Density} \times (T/1000) \times EfWT \times \pi R^2$$

$$R^2 = \frac{1}{2} D^2$$

In this case **0.48** comes from multiplying **1/2** by the air density (**1,23**), by **π** and by **$1/2^2$**

7.3.2 Average Wind Speed

The **Average Wind Speed (AvWs)** (m/s) can be calculated by averaging wind speed and wind direction data for your business site location for one year in hourly values, either from the nearest meteorological station or simulated (explained on page 29).

The most common wind direction must be evaluated for that location and for a given time frame (for example yearly).

It is important to know the common wind direction at the site's location to be sure that there is no obstacle that will be limiting the wind potential.

Note that the results of the **Wind Energy Output Potential** will apply to the time unit defined in the average wind speed term.

7.3.2.1 Simulation of wind speed data

Wind, contrary to solar radiation, is extremely sensitive to topographical conditions and physical obstacles. Wind may vary significantly, both in intensity and direction within a few meters due to the presence and shape of obstacles. The energy theoretically available depends on the cubic power of the wind speed. The calculation for hilly regions is extremely sensitive, so usually specialized software is used to calculate the wind potential based on values measured in meteorological stations and the terrain conditions (like the contour of the terrain and roughness of the surface). One of the most used for this purpose is the WaSP RISO Denmark - UNEP Risoe Centre on Energy, Climate and Sustainable Development form the Technical University of Denmark (DTU, 2012).

For wind speed data simulation, in case of remote locations where there are no measurements from meteorological stations, there is software available to model the wind speeds, such as, for example, Meteonorm software (Meteonorm). In general it is difficult to evaluate the potential of a site without a meteorological station at that location.

Wind potential in urban areas can be very difficult to assess. The wind measures should be made in situ if the distance to the meteorological station is more than a few kilometres and the site is surrounded by other buildings, trees or steep terrains. Data must be recorded for at least one year to calculate an annually representative wind speed frequency distribution.

> A general potential study can be made using the wind velocity and direction measures from the nearest weather station, but it should be taken into account that this can only provide a rough seasonal or annual estimation of the site’s potential.

7.3.3 Time Frame

The **Time Frame (T)** (in hours) should be defined in the same time frame as the one used data for **Average Wind Speed (AvWs)**. Common T values are presented in Table 6.

Table 6: Common T values

	TIME FRAME (T) IN HOURS
Year	8760
Month	730
Week	168
Day	24

7.3.4 Efficiency of Wind Turbines and Rotor Diameter

In the specification sheets provided by turbine suppliers the characteristics of turbines and the parameters of **EfWT** and **Rotor Diameter (RD)** (m) can be extracted to be used in the equation (7-1). The most suited turbine for the site's wind velocities must therefore be chosen beforehand.

> A wind turbine can extract no more than approximately 60% of the energy from the wind, so the maximum value for the **Efficiency of Wind Turbine (EfWT)** should be 0,6 (SORENSEN, 2004).

For each wind turbine the optimal wind speed at which this value of efficiency can be achieved, or almost achieved, is called the nominal speed. The chosen wind turbines to install will have higher efficiencies if their nominal speed is within the average values of wind speeds for the site's location.

7.3.5 General Data for Small Wind Turbines

Wind turbines that can be suited to business sites will usually have a rated power higher than a few kW and lower than 1 MW.

The main characteristics of this segment of turbines are presented below:

Operational data

Cut-in wind speed[2]:	3 to 4 m/s
Nominal wind speed:	9 to 16 m/s
Cut-out wind speed[3] :	25 to 30 m/s
Rotor Diameter:	20 to 55 m
Rated Power:	100 to 800 kW
Swept area:	870 to 2,100 m^2

2 Cut-in wind speed: is the minimum wind speed at which the wind turbine will generate usable power.

3 Cut-out wind speed: is the wind speed above which the wind turbine ceases to produce useful power, this is a safety feature which protects the wind turbine from damage.

8 GEOTHERMAL ENERGY

8.1 Introduction

Energy harvested from ground, commonly called geothermal energy, is suitable for many different type of uses but are commonly divided into two categories, high (>150 °C) and low (<150 °C) enthalpy according to their energy content. High enthalpy resources are suitable for electrical generation with conventional cycles (e.g. steam turbine), low enthalpy resources are employed for heating and sometimes for electricity generation using a binary fluids cycle.

In this chapter the focus will be mainly on thermal uses from low enthalpy geothermal energy, and in particular, for energy efficiency reasons, low temperature space heating. The existing systems for these purposes are usually composed of two main components, the collector pipes and the heat pump.

The collector pipes are usually buried in the ground and have a fluid running through, which absorbs underground heat. Typically, ground temperatures are warmer than the air above during the winter and cooler in the summer. Depending on the considered latitude, the ground temperatures, in the first 6 meters, can range from 7°C to 21°C. The temperature beneath the upper 6 meters of Earth's crust remains nearly constant over the year and lies between 10 and 16°C. Below 10 meters the temperature increases with the depth (LTD., 2012). Therefore, geothermal energy can be used for both heating and cooling, depending of the energy system installed.

As heating systems need hot water temperatures around between 35 and 80°C the temperature level obtained from the collector must therefore be increased, usually with the help of a heat pump.

Heat pumps work like inverted refrigerators: they increase the temperature level of the absorbed heat using electrical energy. Depending of the type and considered temperature levels, heat pumps can be said to use one unit of electricity to produce four units of heat.

The efficiency of heat pumps is strongly dependant on the temperature of the geothermal source and of the heating demand. These equipments have the highest efficiency when the difference between both temperature levels is the lowest possible. Therefore, a heat pump should preferably be used for low temperature heating demands, e.g. floor heating systems that work around 35°C.

8.2 Potential barriers to geothermal use

The use of geothermal potential may face some hurdles regarding technical, legal or other aspects, which are presented in Table 7. These issues need to be assessed at an early stage to confirm the feasibility of developing a geothermal heat pump project for a given location.

Table 7: Possible obstacles to geothermal use in business sites

TECHNICAL	LEGAL	OTHER
Area available too small for drilling boreholes	National/Municipal legal restrictions to drilling depth	High costs / long time of return of invests
Drilling limited due to soil/rock type or groundwater reservoirs.	Area Development Plans limiting the potential area.	No studies regarding geology of the area
Existing underground infrastructures blocking drilling	-	-

8.3 Collector Types

There are four main types of collectors. Three of these - horizontal, vertical, and pond/lake - are closed-loop systems, the other is an open-loop option, where the fluid only circulates once in the pipe before being rejected to the environment. All of these systems can be applied in residential or industrial/commercial buildings, but the most commonly used are the closed loop systems. In this document open loop systems are not considered because these systems make direct use of groundwater. Groundwater, when existing, may have many other uses besides being used for space heating. Also the risk of water contamination by the heating system (circulation of glycol in the pipes) should be avoided.

Horizontal

Horizontal systems have the collector's piping system in trenches at least 1 meter deep and spread out over a large surface. This solution is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available.

Pond/Lake

If the site has a pond or a lake, this can be one of the cheapest collector solutions. This is another form of horizontal collector, but instead of having the piping in trenches, it is installed in a pond or a lake, where it extracts the heat from water. The heat source needs to be within 100m from the building to reduce thermal losses.

Vertical

Due to the large surface required for horizontal loop systems, large buildings often use vertical collector systems. In soils too shallow for trenching the vertical loops are also a good option. Holes are bored 18 to 60 meters down, and about 5 to 6 meters distant from each other. Two pipes are connected at the bottom of each hole with a U-bend to form a loop, therefore forming a closed circuit. The vertical loops are connected with a horizontal pipe which is connected to the heat pump in the building.

None of the presented systems has adverse impacts on the landscape as long as the vertical boreholes and trenches are properly covered and compressed, and the pipes are properly sealed.

8.4 Simplified Energy Potential Calculation Methodology

In business sites the available area to drill the boreholes can be a major limiting factor. Also, contrary to solar or wind power, it is not the objective to produce low enthalpy geothermal energy continuously. Instead, its use shall cover space heat demands. The approach chosen for this chapter is therefore to assess the thermal power according to the surface available and the type of collector. This thermal power can then be compared to that of the actual heat demand, thus determining the contribution of geothermal to the overall heating needs.

> The dimensioning methodology, for this renewable energy source, is divided into horizontal, pond/lake and vertical collector systems due to the different aspects to consider.

8.4.1 Horizontal Systems

In horizontal systems the piping is placed inside trenches. Some dimensioning rules need to be considered in order to achieve the best performances in such a system (Ground Loop, 2012). The trenches should be 1.0 to 1.8 m wide, normally another 1.0 to 1.8 m deep, and a maximum of 6 pipes should be placed per trench with at least 0.3 m of separation between pipes. Another rule to consider is to leave a space of 3 to 4 m between trenches.

8.4.1.1 Total Piping Length

In order to calculate the **Total Length (TL)** possible to install in a certain **Area (A)** the following equation should be used.

$$TL = A \times 1{,}13 \qquad (8\text{-}1)$$

This is used in cases where the pipes are buried in straight lines. In cases where the available area is small one should consider coiling the pipe into circles to maximize the use of trenches or to install a vertical collector.

The value 1,13 in equation (8-1) represents a simplification made from the original equation.

$$TL = \frac{W \times 0{,}34}{0{,}3} \times L$$

For this equation one would need to know the Length (L) and Width (W) of the Area, where 0.34 stands for the 34% of available width of terrain to install piping if one considers the rule of having 3 to 4 m of space between trenches. The value 0.3 stands for the 30 cm of space in between pipes.

8.4.1.2 Heat Pump Power

The maximum **Heat Pump Power (HPP)**, for a given area, can be estimated using the following equation:

$$HPP\ (kW) = TL\ (m) \div PL\ (m) \qquad (8\text{-}2)$$

In horizontal systems, generally, 35 to 50 m of **Piping Length (PL)** is required per kW of heat pump capacity (NRC, 2009). For equation (8-2) the average Piping Length (45m) can be assumed.

8.4.2 Pond/Lake Systems

Concerning pond/lake systems, it is difficult to define a regular type of installation, as each case is different. Even though the dimensioning of a geothermal pond system is very similar to the horizontal systems, the difference is that in this case the pipes will be coiled into circles and submerged in at least 2 meters of water (to avoid freezing).

8.4.2.1 Total Piping Length

For this type of collector the pipes normally use coils of about 90 to 150 m each (Geothermal, 2010), an average value of 120 can be used for calculation. Each of these coils will occupy an average area of 2 m2. In order to have free space between the coils, each submerged coil must be separated from the others by at least the same area it occupies.

Therefore, half of the available area of the pond could be used to place the coiled piping. Given these assumptions, the **Total Length (TL)** of piping can be calculated by the following equation:

$$TL = \frac{PA\ 4}{4} \times 120 \tag{8-3}$$

For calculating the maximum power that can be extracted with such systems one needs to have an estimation of the **Pond Area (PA)** that has more than 2 meters of water depth.

8.4.2.2 Heat Pump Power

For pond collectors, around 26 m of **Piping Length (PL)** are needed for each kW of heat pump capacity (Jourdan, 2011). The maximum **Heat Pump Power (HPP)**, for a given area of pond, can be estimated using the following equation:

$$HPP = TL \div PL \tag{8-4}$$

8.4.3 Vertical systems

In vertical systems, knowing the Available Area will help determining the maximum number of boreholes that can be drilled. The boreholes should be placed at a Distance D of at least 5 to 6 meters from each other.

8.4.3.1 Number of Boreholes

The **Number of Boreholes (NB)** will depend on the **Distance (D)** between them and the **Available Area (A)** (m2):

$$NB = \frac{A}{\pi \times \left(\frac{D}{2}\right)^2} \tag{8-5}$$

8.4.3.2 Total Piping Length

The following equation determines the **Total Length (TL)** of piping needed according to the **Number of Boreholes** and the **Maximum Depth (MD)** of drilling. These values are multiplied by 2 because the piping needs to go up and down the total depth of the borehole.

$$TL = 2 \times NB \times MD \tag{8-6}$$

In these systems piping is inserted into boreholes that are usually 150 mm in diameter, to a depth of 18 to 60 m depending on soil conditions and the size of the system. A depth of 38m may be used for a first approximation.
The **Total Length** of piping is dependant of the **Maximum Depth** of drilling, and this depth depends on the soil conditions, rock type or sediment type. The soil type and conditions must be checked to evaluate how deep the boreholes can be drilled.

8.4.3.3 Heat Pump Power

In vertical systems usually, about 23 to 31 m of **Piping Length (PL)** is needed for every kW of heat pump capacity (NRC, 2009). For the equation (8-7) the average Piping Length of 27m can be assumed.

The maximum **Heat Pump Power (HPP)** can be estimated using the following equation:

$$HPP = TL \div PL \tag{8-7}$$

After analysing these different collector types it can be concluded that for each meter of piping installed, vertical and pond/lake collectors can achieve around 40% more efficiency in heat transfer than the horizontal collectors.

8.5 Heat Pump Coefficient of Performance

The Coefficient of Performance (COP) of a heat pump is the ratio of heating power (or energy) to electrical power (or energy). The COP is used to compare heat pumps according to their energy efficiency, a high value indicating that the equipment has a high efficiency.

When comparing the efficiency of various heat pump models, 3 parameters need to be taken into account: the evaporation temperature (the temperature on the collector's side), the condensation temperature (the temperature delivered on the heating distribution side) and the efficiency at part-load. Heat pumps' efficiency indeed decreases when they are not operating at nominal power, which happens most of the time. Usually manufacturer data is provided at nominal power, so future load behaviour must be considered when choosing the equipment, given that this can strongly deteriorate the COP. Also, the efficiency of the system increases for smaller temperature differences between the collector's side and the heating system's side. Therefore, the use of heat pumps for heating purposes should always be critically assessed when the hot water temperature is above 35-40°C.

9 FURTHER STEPS

A detailed analysis of the renewable energy potential must be conducted before a final decision on implementation is taken. Aspects like the determination of the best location for the technologies, as well as accurate energy outputs from each single area of terrain might be covered by the use of specific tools and software. For projects dealing with intermittent renewable energy sources, it is important to have detailed data, preferably in intervals of 15 minutes or one hour, on the energy production potential.

A list of specific tools and software for more detailed energy assessment is given below. Further reading regarding energy audits, renewable energy installations and smart grids is also provided.

Table 8: List of books concerning energy audits, renewable energies and smart grids.

TITLE	AUTHOR
Renewable Energy	Bent Sørensen
Handbook of Energy Audits	Albert Thumann,William J. Younger,Terry Niehus
A Practical Guide to Renewable Energy: Power Systems and their Installation	Christopher Kitcher
Planning and Installing Photovoltaic Systems – A guide for installers, architects and engineers	Deutsche Gesellschaft
für Sonnenenergie	
Wind Power: Renewable Energy for Home, Farm, and Business	Paul Gipe
Geothermal Heat Pumps: A Guide for Planning and Installing	Karl Ochsner
Smart Grid: Fundamentals of Design and Analysis	James Momoh

Table 9: List of specific tools and software

TOOL	RENEWABLES CONSIDERED	COST	LINK
Homer	Solar PV and Thermal, Wind, Ocean currents, Waves, Biomass, Hydro,	Free 2 weeks trial period. 99$ for each 6 months	http://www.homerenergy.com/
EnergyPlan	Solar PV and Thermal, Wind, Ocean Currents, Waves, Biomass heating, Hydro, Geothermal power and ground-source heating	Free	http://energy.plan.aau.dk/
RETScreen	Solar PV, Wind, Ocean currents, Waves, Biomass heating, Hydro, Solar thermal, Tidal, Geothermal power and ground-source heating	Free	http://www.retscreen.net/

10 CONCLUSIONS

This document addresses the main steps in order to become an energy positive business site. Business sites wanting to implement C2C principles should, according to the second principle of using the sun as energy source, rely on renewable energies to cover their energy demands with the objective of becoming net energy exporters making use of the existing technologies and contributing to the transition towards C2C implementation.

The integration of renewable energies in business sites should follow a clearly defined strategy for both greenfield and brownfield developments. This involves maximizing the amount of renewable energy produced on the site and implementing energy efficiency and energy saving measures that will make it easier to meet the site's energy demands through renewable energy. Evaluating the renewable energy potentials and the opportunities available will assist the site's efforts to become energy positive. The evaluation of opportunities also needs to be seen as a continuous process over time, since the evolution of the business sites regarding the number of buildings, occupancy and energy demands is also changing over time.

Exploiting the existing synergies arising from the installation of renewable energy technologies in buildings and matching these with the design and uses planned for the buildings will allow the improvement of design, comfort, usability and reduction of costs.

It can also be concluded that having a clearly defined energy strategy will allow business sites to minimise the potential barriers and overcome the remaining ones.

This document provides an overview of the site's potential in renewable energies as well as a rough estimation of the power provided by each technology. The energy production calculated using the equations presented in this tool for each type of renewable energy should make use of data from reliable sources to ensure the most accurate results. The usage of more advanced tools is encouraged for dimensioning and installing a complete system.

There are many opportunities in business sites in terms of energy, so in that sense this document presents a vision on how to make the best use of these opportunities, either from the existing synergies between buildings, harvesting energy potentials, distributing energy possibilities and becoming energy positive. Business site managers should, with this document's help, be able to at least conduct some estimations of their energy potential and plan their various steps to become energy positive using renewable sources.

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Funding

C2C BIZZ has received European Regional Development Funding through INTERREG IV B.