CIC Start Online

Report on

"Optimisation of economic, environmental and energy savings in buildings"

By

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Table of Content

1. Executive summary

This project investigates the feasibility of the use of Low or Zero Carbon Energy Sources (LZCES) in the built environment and the development of an innovative software tool. It can be divided into four main development areas; an investigation into the on-site renewable energy resource, an analysis in the building energy usage profile, a development of a decision-making tool for the rapid identification of the most appropriate LZCES option and a post occupancy monitoring and modelling of a building.

This project details the following considerations of LZCES: passive solar space heating modelling (PSSH); performance of building integrated including solar water collector (SWH); solar photovoltaic (SPV); wind technology (WT); ground source heat pump (GSHP); tri-generation (TriG); biomass (BioH) and rainwater harvesting (RWH).

A collection of manufacturers' data from various LZCES was carried out in order to test the performance of the software tool. Energy, economy and CO2 saving simulations were done on a number of LZCES systems. A final assessment of the number of different options and their impact on the cost, energy and CO2 saving was performed in order to assess the best combination possible.

Future development of the software tool may aim to assess more accurately the output of each technologies, develop a more user-friendly façade and integrate more technologies such as light pipes, earth duct, solar wall, concentrated solar power, energy storage, UTES, waste-to-energy plant, fuel cells and to extend potentially to recycled materials. Other weather data from rest of the world could make the software usable for other project scales and countries.

2. Background information

It is important to look at the ambitions set by the government to encourage sustainable design in the built environment. It allows setting the context in which to develop a LZCES selection tool.

Public and private sector, Non-Governmental Organisations (NGOs) and research establishments have developed strategies and timelines to reduce their environmental impact. Figure 1 details the different drivers available along with their implementation deadlines.

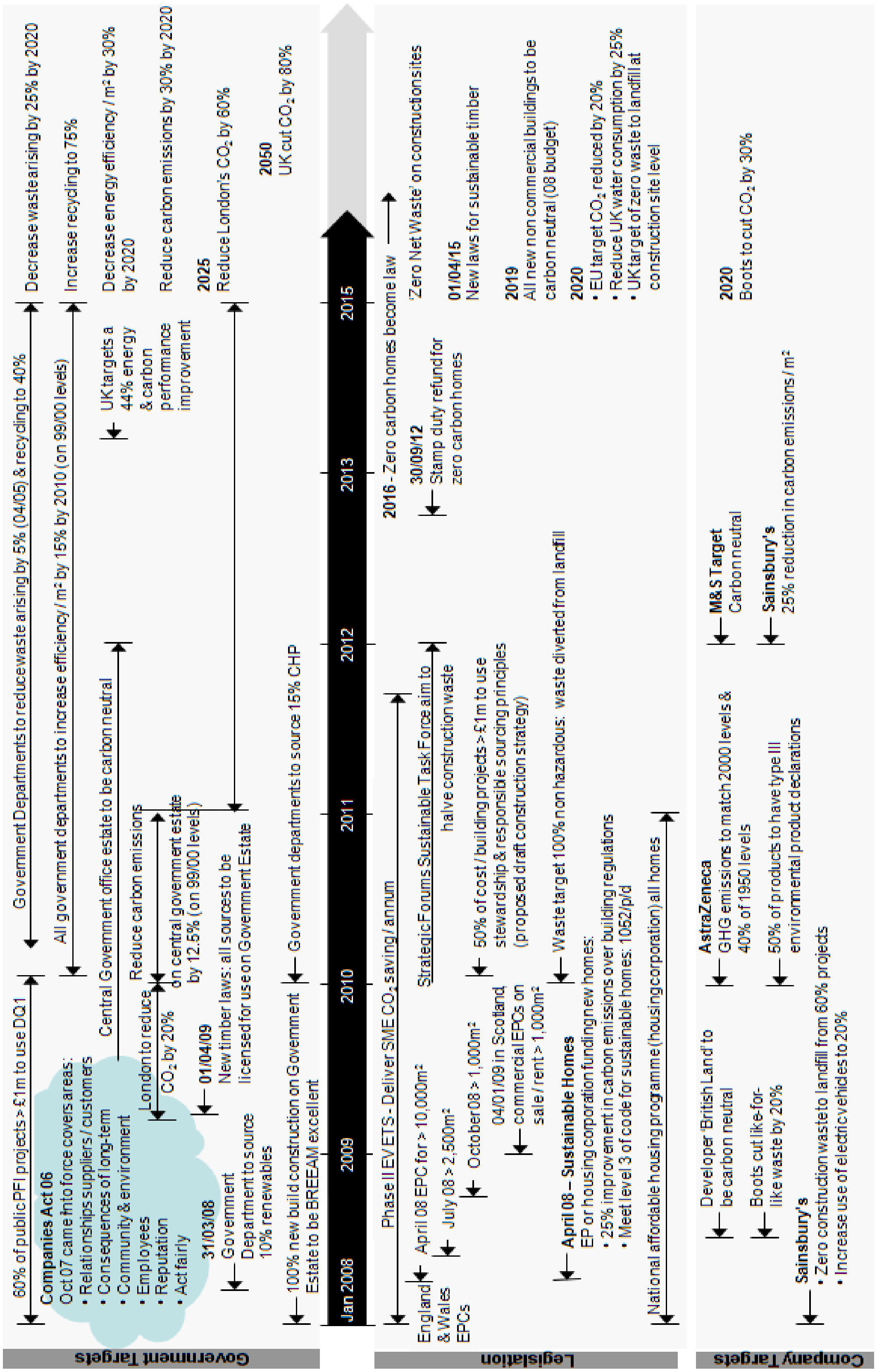


Figure 1: Legislation timeline

More specifically, the DECC is aiming to improve the energy efficiency of 14 million homes in the UK by 2020. This target demonstrates that there is an enormous potential market internally in the UK.

The Scottish and UK governments are committed to reducing CO2 emissions through improving energy efficiency and the deployment of micro-renewables in buildings.

3. Subject description

The need for an energy modelling and decision making tool that aims specifically at buildings outside the residential and commercial sectors was identified as a result of the regular project work undertaken by GEOCAPITA INVESTMENTS LTD. It is clear that there is a lack of data available in energy intensive industrial sectors such as industrial facilities, transportation projects and research and development complexes. In order to collect this data and to turn it into a usable form, the Edinburgh Napier University team has been commissioned to undertake research and to develop a design tool for use by a practicing investment company.

Innovative features of the research are:

- The tool is specifically intended for project scenarios regularly encountered in design, allowing the early assessment of on site energy available for a building in the context of its location.
- To develop a decision making tool for the rapid identification of the most appropriate and cost effective way of achieving lowest carbon emissions for a specified building.

The developed software allows the selection of low and zero carbon energy sources (LZCES) in buildings (residential and commercial). It allows defining the optimum combination of LZCES in the building with the 3 variables to be analysed being: Energy – Environment- Economy (Financial costs)

A competitor analysis revealed that the software tool proposed for development has not got any competitors as it is a unique purpose built software which combines technical and financial analysis and with application not only in UK but worldwide.

4. Objectives and research method used

The objectives of the project are to evaluate energy demand versus the energy resource and analyse each building under the three E's performance criteria. The feasibility study addresses all possible combinations of LZCES focusing on three aspects – 3 Es - of the: energy generation, emissions reductions and economics (i.e. financial feasibility). It provides all possible combinations of energy efficiency improvements and renewable energy retrofit for the building.

The research method provides a renewable energy economic modelling, selection of the optimum combination of the systems based on experimental methodology as well as computational modelling. The application is initially in the UK but is also available worldwide. The project is based on existing research carried out at Edinburgh Napier University and is aimed to extend this to:

- all types of residential, commercial and public buildings
- apply the software to all possible combinations of energy efficiency and renewable energy retrofit following the 3 E's assessment.

The Figure 2 shows the cost and impact on energy demand of each LZCES. This analysis enables to priorities each LZCES.

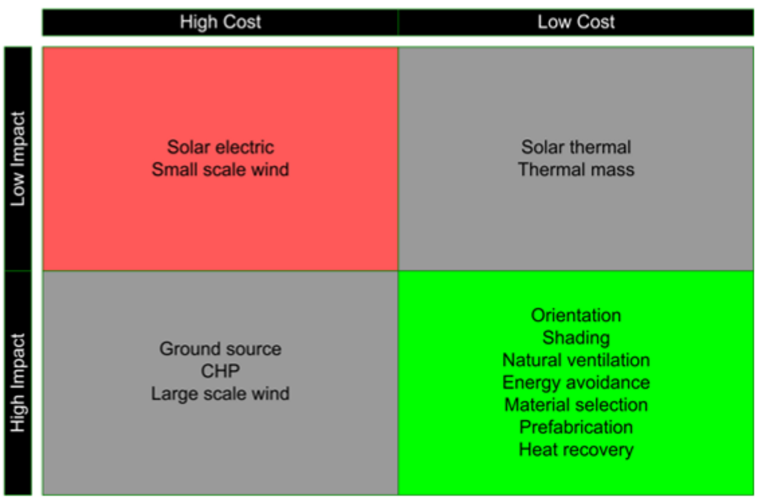


Figure 2: Impact and cost priority table

The figure 3 explains the research method and philosophy of the software.

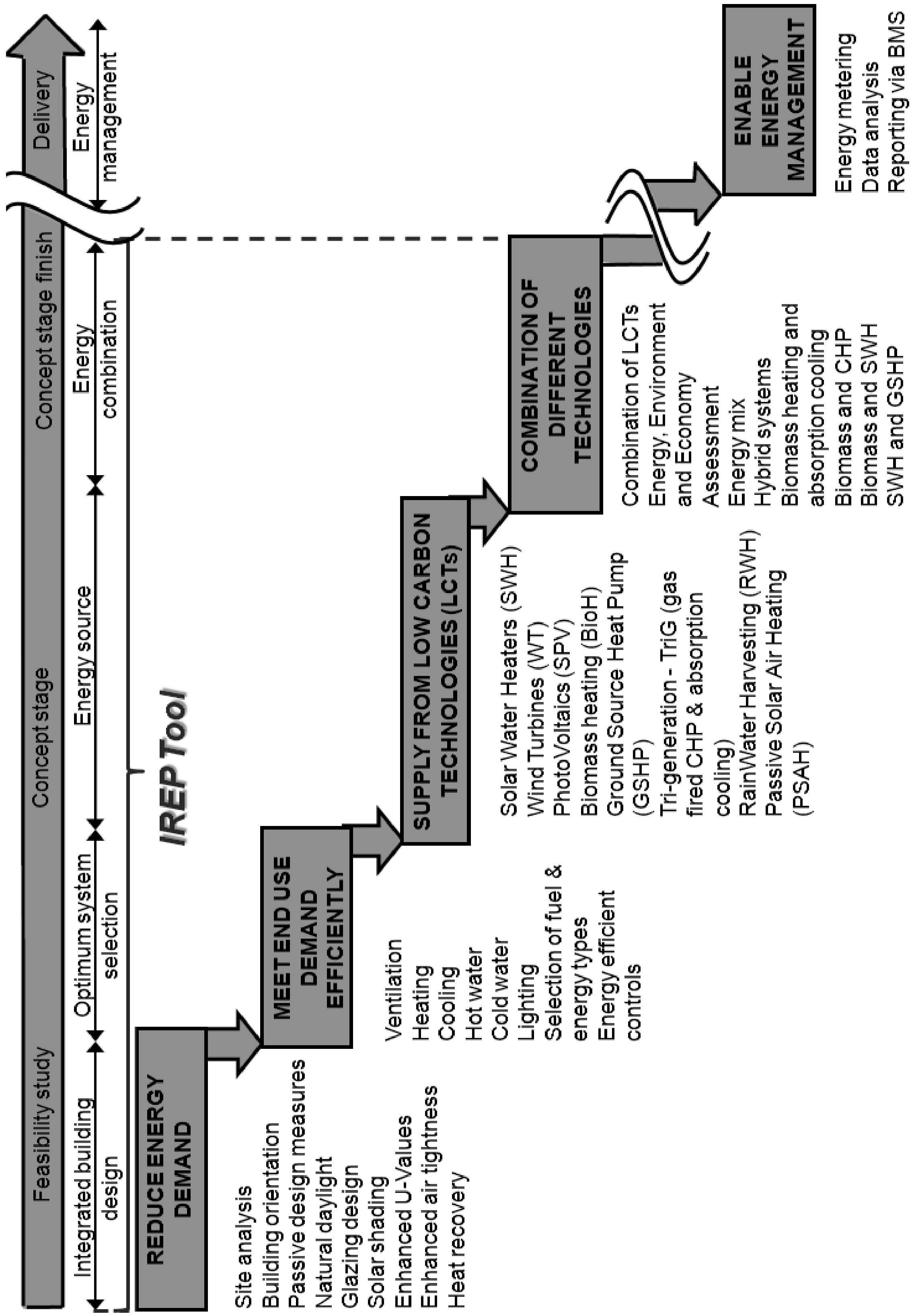


Figure 3: The research method

5. Simulations / tests / experiments

The initial basic research work focused on the validation of the performance of low and zero carbon technologies, their simulation in different UK sites and the impact of their combination on the building carbon emission, energy generation and cost. The development of the decision making tool resulted in using matrix to enable the selection of the best combination of renewable technologies. Using weather and manufacturers' data, the tool is capable of simulating technologies anywhere in the country.

This work has investigated the feasibility of the appropriate use of Low or Zero Carbon Energy Sources (LZCES) within the built environment. A number of different assessments were employed including the collection and analysis of LZCES monitoring data. The tool holds ten different simulations and estimations such as energy demand, solar photovoltaic panels, passive solar air, solar water heating, ground source heat pump, wind power, solar photovoltaic, rainwater harvesting, biomass, CHP simulation and a combination simulation.

The Figure 4 shows the different simulations and their impact on the software process.

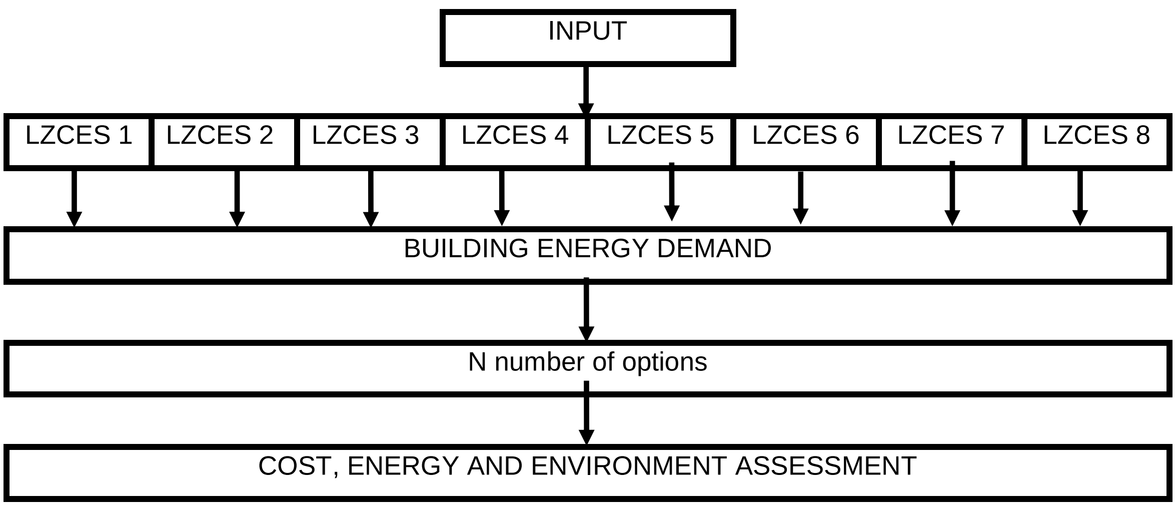


Figure 4: LZCES simulation principle

The software uses a colour code to allow the user to input the data, see Figure 5. The cells collared in blue need to be completed before any analysis.

Figure 5: Legend code for the software

The input table of fuel cost and CO2 emissions need to be completed prior to the analysis, see Figure 6. A table of CO2 emission conversion and cost is integrated in the software if the user does not know them.

INPUT DATA AND PROFILE

Fill the cells that are coloured in blue with bold character

Building Demand	Heating Fuel (kWh)	Cooling Fuel (kWh)	Electricity (kWh)	Water (m³)	biomass fuel (wood pellet / wood chip) (kWh)
SAP efficiency	78%	300%	90%		78%
Economy Cost (pence per unit)	3.5	7	7	150	2.5
Real Cost (pence per unit)	4.5	2.3	7.8	150.0	3.2
TOTAL demand Cost (x £1000)	185.32051	100.33333	179.66667	3	132.3717949
Environment (kg CO2 per unit)	0.194	0.18133333	0.544	1.0336	0.025
TOTAL demand CO2 (Tonne CO2)	801.22	779.73333	1256.64	2.0672	103.25

Figure 6: Input cost and CO2 emission of fuel data

The first analysis is performed on the building without LZCES to have a benchmark position for the investment, from left to right, the user need to input the different energy demand and cost. The output can have a first feel about the cost and CO2 emssions, see Figure 7.

Code*	Low Carbon Technology	Heating Demand (kWh)	Cooling Demand (kWh)	Electrical Demand (kWh)	Water Demand (m³)	Capital Cost (x£1000)	Annual Maintenance Cost (£1000)	Annual Cost Economy (GBP x£1000)	Cost saved Economy FIT/RHI/ECA (GBP x£1000)	Financial payback (year)	Financial payback (year) FIT / RHI / ECA	Environmental Impact (Tonne CO2)	Embodied Energy (kWh)	Energy Return on Investment (year)	Embodied Carbon (Tonne CO2)
hbd	Heating building demand (hbd)	4130000	0	0	0	£ 100	£ 5.00	£ 185.32	NO INCENTIVE	NO PAYBACK	NO PAYBACK	801.22		NO EROI	
cbd	Cooling building demand (cbd)	0	4300000	0	0	£ 450	£ 3.00	£ 100.33	NO INCENTIVE	NO PAYBACK	NO PAYBACK	779.73		NO EROI	
ebd	Electrical building demand (ebd)	0	0	2310000	0	£ 10	£ -	£ 179.67	NO INCENTIVE	NO PAYBACK	NO PAYBACK	1256.64		NO EROI	
wbd	Water building demand (wbd)	0	0	0	2000	£ 10	£ -	£ 3.00	NO INCENTIVE	NO PAYBACK	NO PAYBACK	2.07		NO EROI	

Figure 7: Building without LZCES

Then the second table allows the user to input the data from LZCES considered. Each data is depending on the restriction of the site such as the plant room size, the roof area, the size of the land, the heating, cooling, electrical and water demand, see Figure 8. The data can be imported from external design software and manufacturers quotes.

Code*	Low Carbon Technology	Generated Heating (kWh)	Generated Cooling (kWh)	Generated Electricity (kWh)	Collected Water (m³)	Added Capital Cost (x£1000)	Added annual Maintenance Cost (£1000)	Cost saved Economy (GBP x£1000)	Cost saved Economy FIT/RHI/ECA (GBP x£1000)	Financial payback (year)	Financial payback (year) FIT / RHI / ECA	Reduced Environmental Impact (Tonne CO2)	Embodied Energy (kWh)	Energy Return on Investment (year)	Embodied Carbon (Tonne CO2)
a	Solar Passive Air Heating (SPAH)	0	0	0	0	£ -	£ -	£ -	£ -	0	0	0.00	0	#DIV/0!	0
b	Biomass Heating (BioH)	4130000	0	0	0	£ 840	£ -	-£ 41.30	-£ 107.38	20	8	-697.97	76982	0	41878.3
g	Ground Souce Heat Pump (GSHP)	2050000	2150000	0	0	£ 1,450	£ 5.00	-£ 65.19	-£ 251.07	24	6	-1586.03	145775	0	79301.5
p	Solar Photovoltaic (SPV)	0	0	200000	0	£ 840	£ -	-£ 14.00	-£ 72.60	60	12	-108.80	800	0	435.2
r	Rain Water Harvesting (RWH)	0	0	0	2000	£ 28	£ -	-£ 3.00	-£ 3.00	9	0	-2.07	19	#DIV/0!	10.336
s	Solar Water Heater (SWH)	34000	0	0	0	£ 95	£ 0.65	-£ 1.19	-£ 6.97	176	15	-6.60	36	0	19.788
t	Tri Generation (TriG)	4130000	4300000	2310000	0	£ 4,450	£ 42.00	-£ 90.00	£ -	93		-822.90	302538	0	164580.4
w	Wind Turbine (WT)	0	0	1000	0	£ -	£ -	-£ 0.00	£ -	0	0	0.00	283640	284	154300

Figure 8: LZCES integrated building

6. Results: Decision making process

This part describes the results of the research and the process of combining different technologies to obtain the most effective solution depending on cost savings, energy generated and CO2 emissions reduction. The tool has for aim to allow the consultant and its client to find the most appropriate choice very rapidly at the early stage of the design, therefore allowing it to estimate a fee more accurately and estimate the time, cost of man hours.

Seeking to evaluate energy systems according to the concept of sustainability, the so-called 3E (Energy, Economy, Environment) criteria have been proposed. The concept evaluates and optimises technical systems from the point of view of energy, economy and environment, see Figure 9.

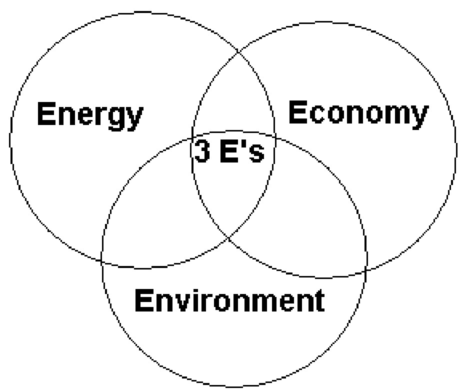


Figure 9: Three E's Assessment principle

Each section is detailed as different definitions explained in Table 1.

Table 1: Three E's assessment definition

Energy	Economy	Environment
Energy generated, building demand reduction	Funding available, Feed-in-Tariff, capital cost, running cost, NPV, PI, IRR, MIRR, XNPV, XIRR	Reduction of CO_2 emission in building design,

Combination assessment analysis

Looking at the number of combinations, designers generally do not have time to do an analysis combining LZCES. Table 2 shows an assessment on the number of combinations possible with a fifty different LZCES and different group sizes. In order to face this dilemma and help the designers, the analysis enables to combine rapidly the different options available.

Table 2: Number of combination with 50 LZCES

Names and types of technologies	Number of tech "n"	C	Group size "k"	Number of Combinations
SWH 1	50	C	1	50
SWH 2	50	C	2	1225
SWH 3	50	C	3	19600
SWH 4	50	C	4	230300
SWH 5	50	C	5	2118760
SWH 6	50	C	6	15890700
SWH 7	50	C	7	99884400
SWH 8	50	C	8	536878650
SWH 9	50	C	9	2505433700
SWH 10	50	C	10	10272278170
SAH passive 1	50	C	11	37353738800
SAH passive 2	50	C	12	1.214E+11
SAH passive 3	50	C	13	3.54861E+11
SAH passive 4	50	C	14	9.37846E+11
SAH passive 5	50	C	15	2.25083E+12
SAH passive 6	50	C	16	4.92369E+12
SAH passive 7	50	C	17	9.84738E+12
SAH passive 8	50	C	18	1.80535E+13
SAH passive 9	50	C	19	3.04059E+13
SAH passive 10	50	C	20	4.71292E+13
Solar PV 1	50	C	21	6.73274E+13
Solar PV 2	50	C	22	8.87498E+13
Solar PV 3	50	C	23	1.08043E+14
Solar PV 4	50	C	24	1.21549E+14
Solar PV 5	50	C	25	1.26411E+14
Solar PV 6	50	C	26	1.21549E+14
Solar PV 7	50	C	27	1.08043E+14
Solar PV 8	50	C	28	8.87498E+13
Solar PV 9	50	C	29	6.73274E+13
Solar PV 10	50	C	30	4.71292E+13
GSHP 1	50	C	31	3.04059E+13
GSHP 2	50	C	32	1.80535E+13
GSHP 3	50	C	33	9.84738E+12
GSHP 4	50	C	34	4.92369E+12
GSHP 5	50	C	35	2.25083E+12
GSHP 6	50	C	36	9.37846E+11
GSHP 7	50	C	37	3.54861E+11
GSHP 8	50	C	38	1.214E+11
GSHP 9	50	C	39	37353738800
GSHP 10	50	C	40	10272278170
Tri generation 1	50	C	41	2505433700
Tri generation 2	50	C	42	536878650
Tri generation 3	50	C	43	99884400
Tri generation 4	50	C	44	15890700
Tri generation 5	50	C	45	2118760
Tri generation 6	50	C	46	230300
Tri generation 7	50	C	47	19600
Tri generation 8	50	C	48	1225
Tri generation 9	50	C	49	50
Tri generation 10	50	C	50	1

Combination analysis using Pascal's triangle

In this part the combination model is explained. It utilises the Pascal's triangle principle. Other methods such as Monte Carlo are used extensively in the finance industry to look at investments scenarios statistics. It was quickly found that it takes too long. The Pascal's triangle is the other method that has been used, see Figure 10.

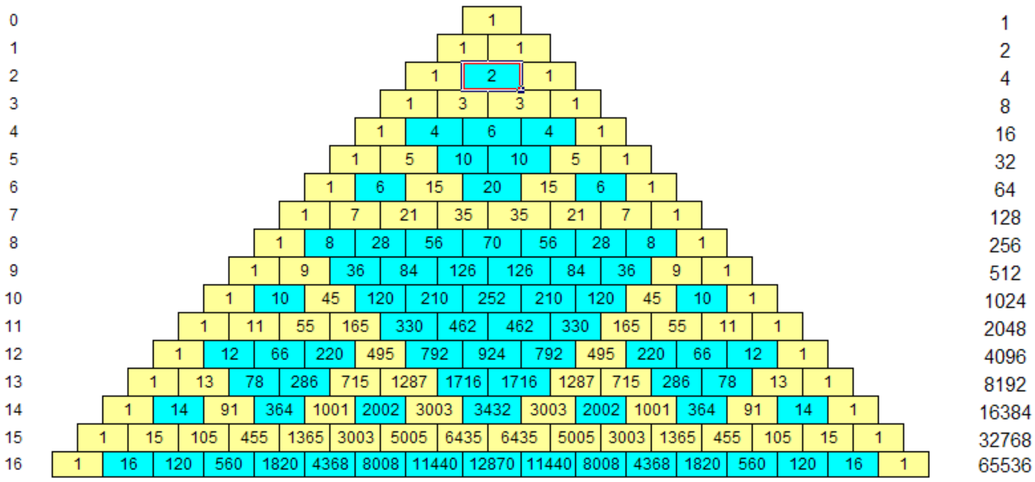


Figure 10: Pascal's triangle (first seventeen rows)

The number of combinations can simply be found by looking up the appropriate entry in the triangle. Table 3 shows another combination layout.

Table 1 Table of nCr

n \ r	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1												
1	1	1											
2	1	2	1										
3	1	3	3	1									
4	1	4	6	4	1								
5	1	5	10	10	5	1							
6	1	6	15	20	15	6	1						
7	1	7	21	35	35	21	7	1					
8	1	8	28	56	70	56	28	8	1				
9	1	9	36	84	126	126	84	36	9	1			
10	1	10	45	120	210	252	210	120	45	10	1		

For example, suppose a building owner wants to consider 10 LZCES and wants to know how many ways there are of selecting 8 at a time. The answer is entry 8 in row 10 (with the first row and the first entry in a row numbered 0): 45. That is, the solution of choosing 8 out of 10 LZCES is 45 combinations.

Another example of different scenario can be seen in the Table 4. The example details the input of three solar and wind technologies with a group of two.

Table 2 Scenario calculation basis of the tool

Solar option		Wind option
X		A
Y		B
Z		C

The three best options can be selected from the final list such as lowest cost, lowest environmental impact or highest energy generation possible. The final choice would then be done by the engineer, see Table 5.

Table 3 Result scenario examples

Best scenario	Selection criteria	Result
X and A	Lowest cost	£15,000
X and B	Lowest environmental impact	1000kg CO_2
Y and A	Highest energy generation	1500kWh

One of the most important facts is to implement the cheapest cost and a payback LZCES option.

Data input

Once the first screen is filled, the data is transferred automatically on the second and the combination analysis can be performed. Then, the user needs to select the LZCES that are likely to be implemented as part of the project along with the group size. The group size needs to be selected depending on the budget. It is important that it stays as small as possible to limit the number of options to a maximum. The input form of software – combination is shown in Figure 11.

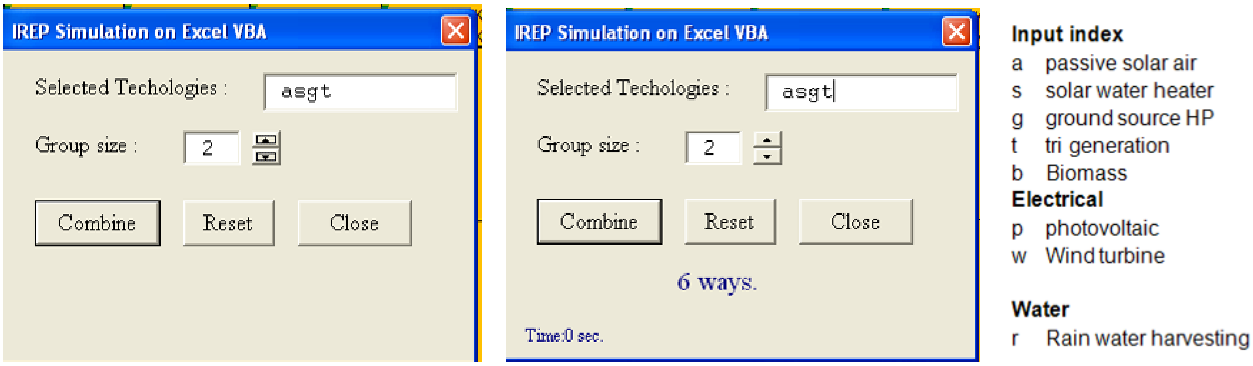


Figure 11: From left to right, input / output combination form showing 6 ways in less than 1second

Ordering the results

Once the analysis is performed, the different combinations can be ordered to facilitate the selection of the optimum option. This is done via MS Excel VBA ordering program.

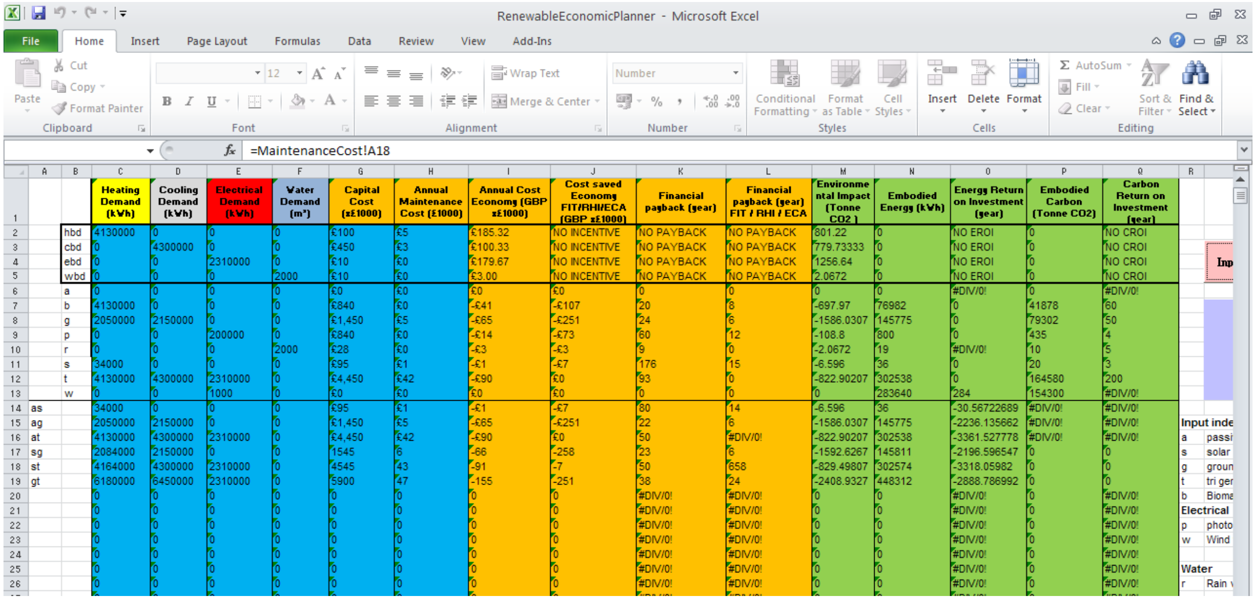
Combination – 3 E's Analysis

Using the methodology described in the previous part, the user can enter the data and find the different options possible to incorporate the technologies in the project.

Before using this tool, the user must make sure that the technologies have been reviewed as the energy efficiency of the building needs to be optimum before incorporating LZCES. Then, looking at the different values taken from the energy output of the technologies for the specific site, the data is entered into tables. These tables are then compiled into the simulation.

Different options for improvement of the building energy generation can be seen as different combinations of technologies.

By use of the 3'Es assessment, different combinations can be modelled via Microsoft Excel Visual Basic for Application (VBA) program. The different options can be simulated automatically and the best options found. Figure 12 shows an example of a selected four LZCES and a group size of two. The first four rows show the energy demand, the other eight rows show the individual LZCES imported from the other tab. The six combination results of the simulation can be seen from row 14 to row 19. The software allows flexibility to add any other restriction very rapidly.



=MaintenanceCost!A18

Row	A	B	Heating Demand (kWh)	Cooling Demand (kWh)	Electrical Demand (kWh)	Water Demand (m³)	Capital Cost (x£1000)	Annual Maintenance Cost (£1000)	Annual Cost Economy (GBP x£1000)
2		hbd	4130000	0	0	0	£100	£5	£185.32
3		cbd	0	4300000	0	0	£450	£3	£100.33
4		ebd	0	0	2310000	0	£10	£0	£179.67
5		wbd	0	0	0	2000	£10	£0	£3.00
6		a	0	0	0	0	£0	£0	£0
7		b	4130000	0	0	0	£840	£0	-£41
8		g	2050000	2150000	0	0	£1,450	£5	-£65
9		p	0	0	200000	0	£840	£0	-£14
10		r	0	0	0	2000	£28	£0	-£3
11		s	34000	0	0	0	£95	£1	-£1
12		t	4130000	4300000	2310000	0	£4,450	£42	-£90
13		w	0	0	1000	0	£0	£0	£0
14	as		34000	0	0	0	£95	£1	-£1
15	ag		2050000	2150000	0	0	£1,450	£5	-£65
16	at		4130000	4300000	2310000	0	£4,450	£42	-£90
17	sg		2084000	2150000	0	0	1545	6	-66
18	st		4164000	4300000	2310000	0	4545	43	-91
19	gt		6180000	6450000	2310000	0	5900	47	-155
20			0	0	0	0	0	0	0
21			0	0	0	0	0	0	0
22			0	0	0	0	0	0	0
23			0	0	0	0	0	0	0
24			0	0	0	0	0	0	0
25			0	0	0	0	0	0	0
26			0	0	0	0	0	0	0

Row	Cost saved Economy FIT/RHI/ECA (GBP x£1000)	Financial payback (year)	Financial payback (year) FIT / RHI / ECA	Environmental Impact (Tonne CO2)	Embodied Energy (kWh)	Energy Return on Investment (year)	Embodied Carbon (Tonne CO2)	Carbon Return on Investment (year)
2	NO INCENTIVE	NO PAYBACK	NO PAYBACK	801.22	0	NO EROI	0	NO CROI
3	NO INCENTIVE	NO PAYBACK	NO PAYBACK	779.73333	0	NO EROI	0	NO CROI
4	NO INCENTIVE	NO PAYBACK	NO PAYBACK	1256.64	0	NO EROI	0	NO CROI
5	NO INCENTIVE	NO PAYBACK	NO PAYBACK	2.0672	0	NO EROI	0	NO CROI
6	£0	0	0	0	0	#DIV/0!	0	#DIV/0!
7	-£107	20	8	-697.97	76982	0	41878	60
8	-£251	24	6	-1586.0307	145775	0	79302	50
9	-£73	60	12	-108.8	800	0	435	4
10	-£3	9	0	-2.0672	19	#DIV/0!	10	5
11	-£7	176	15	-6.596	36	0	20	3
12	£0	93	0	-822.90207	302538	0	164580	200
13	£0	0	0	0	283640	284	154300	#DIV/0!
14	-£7	80	14	-6.596	36	-30.56722689	#DIV/0!	#DIV/0!
15	-£251	22	6	-1586.0307	145775	-2236.135662	#DIV/0!	#DIV/0!
16	£0	50	#DIV/0!	-822.90207	302538	-3361.527778	#DIV/0!	#DIV/0!
17	-258	23	6	-1592.6267	145811	-2196.596547	0	0
18	-7	50	658	-829.49807	302574	-3318.05982	0	0
19	-251	38	24	-2408.9327	448312	-2888.786992	0	0
20	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
21	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
22	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
23	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
24	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
25	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!
26	0	#DIV/0!	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!

Figure 12: Combination scenarios with four LZCES and a group of two

All LZCES can be model to estimate the amount of electrical, thermal energy can be produced. The outputs of the different scenarios can be displayed into a monthly averaged graph to see if the demand profile matches the produced one.

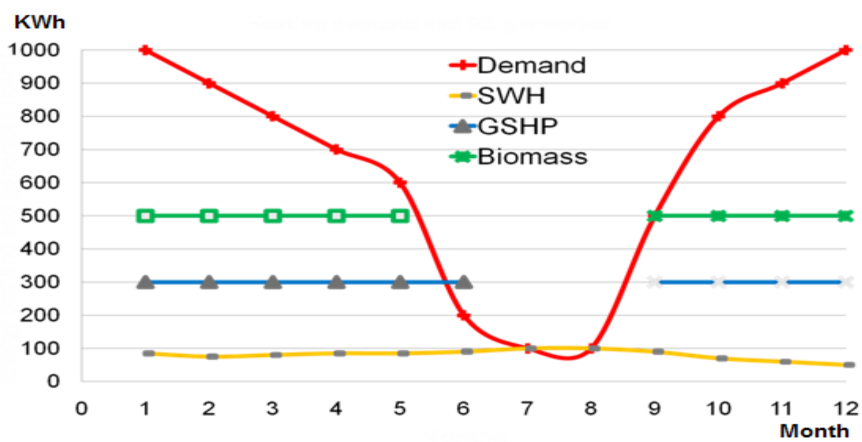


Figure 13: Monthly average heating demand and LZCES heating generated

Figure 13 shows a building heating demand profile example along with the amount of heating generated by three LZCES. This graphical analysis enables to see more easily the heating demand matching the heating generated.

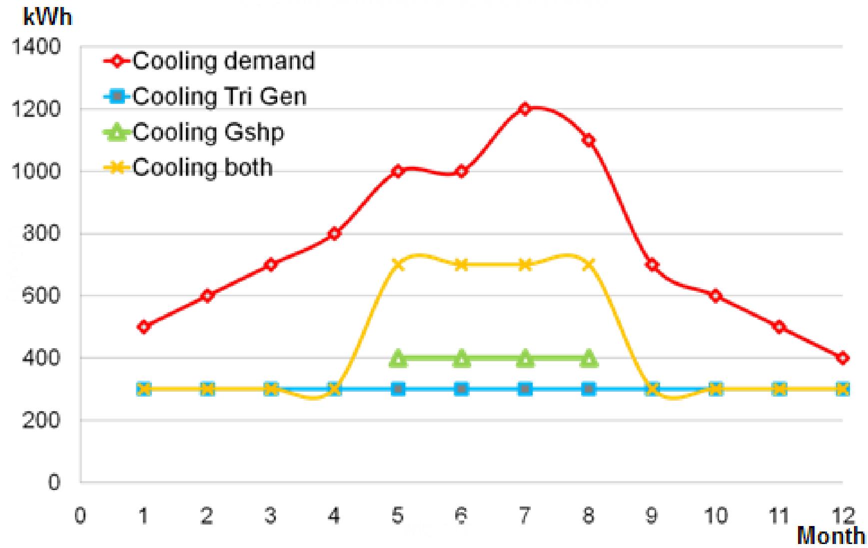


Figure 14 Monthly average cooling demand and LZCES cooling generated

Figure 14 shows a building cooling demand profile example along with the amount of cooling generated by two LZCES. This graphical analysis enables to see more easily the impact of integrating TriG and GSHP on the cooling demand.

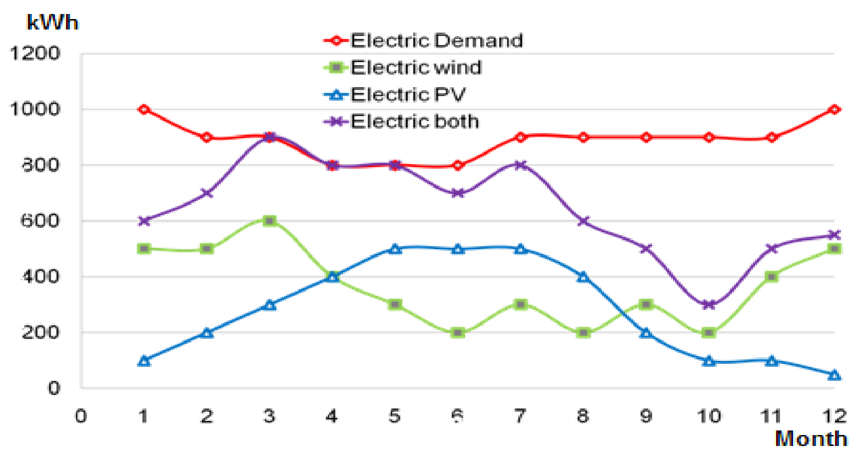


Figure 15 Monthly average electrical demand and LZCES electricity generated

Figure 15 shows a building electrical demand profile example along with the amount of electricity generated by two LZCES. This graphical analysis enables to see more easily the impact of installing PV and WT on the electrical demand.

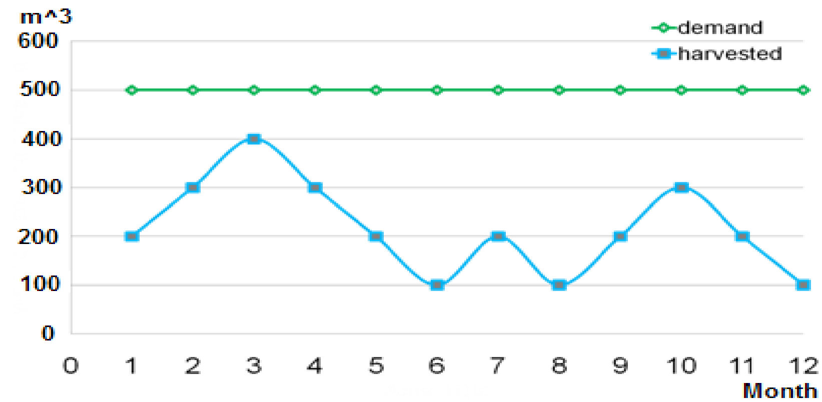


Figure 16 Monthly average water demand and rainwater harvested

Figure 16 shows a water demand profile example along with the amount of water generated by RWH. This graphical analysis enables to see more easily the RWH impact on the demand profile.

Referring to the four previous figures, the results can also be displayed on hourly average over a month, see Figure 17.

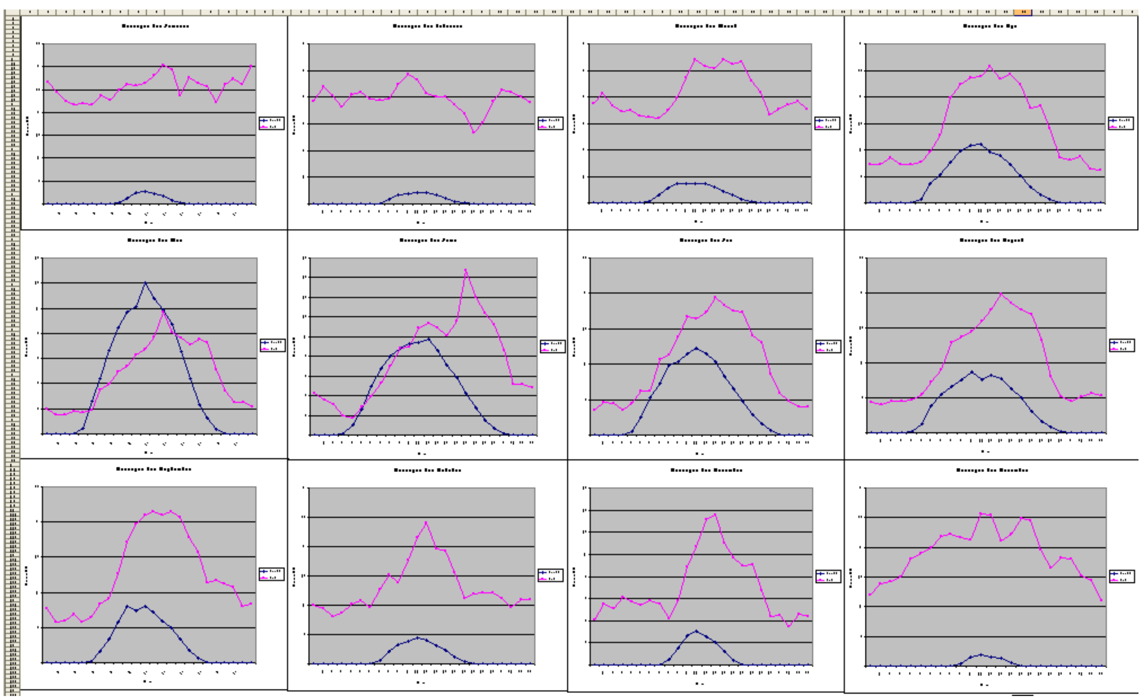


Figure 17 Average hourly renewable electricity generated for each month

This software is to be very useful for building simulation because it allows the simulation of available energy to harvest. The use of the software tool significantly reduces the cost, increases the precision of pre-feasibility studies and contributes to the formulation of more fully informed decisions prior to project implementation.

7. Findings

This part describes the findings of the research.

Innovation: The software tool developed is a new prototype which enhances the efficiencies of the LZCES through its use as a decision-making tool at the early stage of a project. It lowers the capital costs and allows the investor to be more confident about the expected performances of the LZCES resulting in facilitating the selection.

Methodology and feasibility: Simulation provided detailed information of the software behaviour in different combination mode.

New predicting tool: The innovative modelling tool developed can analyse the amount of sun, wind and rain of the LZCES resources for any location in the UK and therefore predict the LZCES performance. Software simulation parameters can be changed by the user for their own research resulting in evolving the program.

Design improvement and costs: Improvements to the software simulation were suggested. It can be improved by having better access to costs and performance of LZCES.

Viable prototype: The software tool showed a high commercial potential due to its environmental and monetary benefits resulting in a viable commercialisation of the prototype. Improvements to the software simulation were also suggested for future development through the carbon footprint, financial and technological performances.

Viable simulation: The software prototype demonstrated potential for LZCES integration into commonly used heating, cooling and electrical installations which enhances sustainable solutions. This type of simulation could be used within classical mechanical design.

Market value: The software tool has a real market value. To date, there is no commercial decision-making tool in the LZCES building integration market resulting in a niche product. The software tool can have a high market value when integrated into modern design methods for building construction.

8. Conclusions

The use of the software tool significantly reduces the cost, increases the precision of pre-feasibility studies and contributes to the formulation of more fully-informed decisions prior to project implementation.

Even with the conservative approach followed in the impact assessment, the authors conclude that the software can have a significant impact on all indicators since the software and related tools are available on MS Excel. The software can make a significant contribution to sustainable development in the UK and throughout the world.

This can be achieved by increasing and improving access to clean energy technologies, building awareness and capacity, and helping to identify opportunities that facilitate the implementation of energy projects that save people money, while reducing greenhouse gas emissions.

The specific benefits of the software are:

- the provision of a fast technology option-selection for a reduction in energy and carbon emissions
- the selection of the optimum combination of LZCES
- the saving of time and costs in design through early identification of technology
- the offering of a better information base for clients to make informed decisions

The innovative features of the software are:

- to provide an opportunity for projects to identify LZCES at the beginning of developments and work with technology providers
- to provide a critical assessment of how close building projects are to true ‘zero carbon emissions‘ status
- to apply the tool to current and future building projects enabling continuous improvements using achieved data
- to incorporate site specific conditions into the selection decision (e.g. climatic)
- to provide a LZCE option-selection for use from project feasibility onwards

9. References

BWEA, 2009. Wind resource map. Accessed online from http://www.bwea.com/images/misc/noabl_c.gif [Accessed on 09th Sep 2011].

CHPA, February 2010. The Combined Heat and Power Association. Accessed online from: www.chpa.co.uk [Accessed on 09th Sep 2011]

European Photovoltaic Industry Association, 2008. Report solar generation V-2008. Accessed online from: http://www.epia.org/fileadmin/EPIA_docs/documents/EPIA_SG_V_ENGLISH_FULL_Sept2008.pdf

European Wind Energy Association, 2007. Stats 2007. Accessed online from http://www.ewea.org/fileadmin/ewea_documents/documents/statistics/gwec/08-02_PR_Global_Statistics_2007.pdf [Accessed on 09th Sep 2011].

London Renewable Toolkit, 2006, Integrating renewable energy into new developments, Toolkit for planners, developers and consultants

Proven Energy Ltd, 2010. Technical specifications sheet for WT600, WT 2500, WT 6000 and WT 15000.

PVGIS, 2008. Photovoltaic Geographical Information System. Accessed online from http://re.jrc.ec.europa.eu/pvgis/index.htm [Accessed on 09th Sep 2011].

PVSYST 4.33., 2008. Software for photovoltaic Systems. Accessed online from. http://www.pvsyst.com/index.php [Accessed on 09th Sep 2011].

REA, 2010. Renewable Energy Association Website. Accessed online from http://www.r-e-a.net [Accessed on 09th Sep 2011].

RETScreen International, January 2010. RETScreen International Clean Energy Project Analysis Software Accessed online from www.retscreen.net [Accessed on 09th Sep 2011].

Scottish Renewable, 2010. The Scottish Renewable Association. Accessed online from http://www.scottishrenewables.com [Accessed on 09th Sep 2011].

World Wind Energy Association, 2008. Statistical report. Accessed online from http://www.wwindea.org/home/index.php?option=com_content&task=blogcategory&id=21&Itemid=43 [Accessed on 09th Sep 2011].