Proceedings of 2nd Conference: ***People and Buildings*** held at Graduate Centre,
London Metropolitan University, London, UK, 18th September 2012.
Network for Comfort and Energy Use in Buildings: http://www.nceub.org.uk

Autonomous housing and refurbishment
Is it feasible to make an existing urban house autonomous?

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Abstract

The aim of this study is to examine the feasibility of transforming an existing semi-detached Edwardian house in an urban environment into an autonomous state (energy, water and waste). The selected case study is located in central Headington, Oxford and follows a typical household energy consumption pattern.

Nowadays, it is difficult to keep up with the rising cost of fossil fuels and the present excess life style, therefore there is an increasing necessity to continuously reduce the energy consumption in order to achieve eventually an autonomous state.UK government has set several targets for the refurbishment of existing houses and the implementation of renewable technologies. This research combined these targets and applied them to an average UK Edwardian house.

Through a modelling based research, the study focused on the feasibility of implementing appropriate types of low carbon technologies, limitations and efficiency depending on the site (domestic or community scale). Moreover the possibility to increase thermal comfort and satisfaction of the occupants by means of these strategies.

The conclusion illustrated that it is feasible to create an autonomous dwelling or community; however this depends mainly on the resident's contribution and commitment to the autonomous concept.

Keywords: Autonomous, Refurbishment, Passive, Low-carbon strategies

1 Introduction

Our fossil fuel based life style is continuously requiring a greater exploitation of land for fossil fuel extraction, leading to increasing properties and everyday life expenses. (Iain Johnston, 2005) This is contradictory to the sustainable lifestyle.

UK has a target to reduce its total CO2 emissions 80% from 1990 levels by 2050 and the emissions from houses by 29% from 2008 levels (HM Government, 2009) (Energy Saving Trust d, 2010). Code for Sustainable Homes (CSH) which was released in December 2006 and became mandatory in 2010 rates the overall sustainability performance. The last CSH is code 6 and is called net zero carbon house code because it certifies the enhancements of new buildings regarding low carbon emissions, energy and water consumption as well as waste.

UK has also set a target for all new houses to be Zero Carbon by 2016 however 75% of them are already built. (Energy Saving Trust, 2010). One potential solution to this issue is the eco refurbishment of the existing buildings. To achieve this target by 2050, a total of 13.000 houses must be refurbished every day. National Refurbishment Centre. (2010) Throughout the years, an increasing amount of people have debated over the subject of which option, demolition and rebuilt or refurbishment, is more sustainable with the latter being chosen as the most beneficial for producing less carbon emissions through each embodied energy. (Power A., 2008)

Heat and Energy Saving suggests that all existing dwelling should by 2030 have a 'whole house' package which consists of the insulation of the building's fabric by 2015 thus 'cost-effective energy saving measures, plus renewable heat and electricity measures'. (Department of Energy and Climate Change, 2009)

Therefore creating an existing house autonomous is significant for the upgrade of the 'whole house' package proposal, by including an upgraded insulation of the building's fabric and a holistic approach of passive solar design.

Autonomous building is one that can operate and function independently from public services and utilities with little or no utility bills and can achieve energy, water sufficiency by using renewable technology, water sufficiency by using rainwater harvesting and waste sufficiency by using for instance a bio-digester or composting toilet. (Brenda Vale et al, 2000)

The ultimate purpose is to create an autonomous house that has a high-quality and comfortable living environment. As suggested by the definition of autonomous house, from a macroscopic viewpoint, autonomous house design involves the three areas of sustainable environment, architectural design and energy applications. (Brenda Vale et al, 2000), (Shang-Yuan Chen et al 2009)

2. Aim: The aim of this research is to discover the possibility and ways of making an existing urban house autonomous.

Characteristic of Case Study

The case study is an Edwardian 3 bedroom, 2-storey semi-detached house.
It is located in an urban environment, in the heart of Headington, in Oxford town in UK.
Occupation Profile: It is occupied by a family that consists of 2 adults and 2 children under 10 years old.

Phases for achieving the autonomous concept in an urban existing house

3.1 Phase 1: In order to achieve the autonomous concept, a desktop research on the theoretical aspects of the passive strategies, renewable technologies and an analysis of the potential limitations of an existing urban house are required. Moreover, through a detailed theoretical analysis of the available technologies for water and waste treatment was able to provide with the appropriate information that will be examined by hand calculation. Passive strategies depend on the bioregional of the case study such as location.

Table 1 (M.Santamouris, 2007), (Chiras D, 2002)

Passive strategies	Daylight and Passive heating: Optimum orientation of high performance operable windows and optimum wall to window ratio depending on the orientation of the building, however in summer external shutters are required to avoid overheating
	Natural Ventilation: Cross ventilation and Night Cooling: uses high thermal mass of the building

Orientation-Tilt	30-40 º ,South is the optimum orientation in order to maximise solar gains
Potential Renewable Technologies	Solar thermal+ PV+ Ground Source Heat Pump (GSHP) Solar thermal+PV+Biomass boiler Solar thermal+Combined Heat and Power (CHP)

3.2 Phase 2: Subsequently, an active primary research for the analysis of the condition assessment of the case study and a detailed literature review of the construction of the type of house of the case study in order to create a clear understanding. Furthermore, an examination of the solar, water, ground and wind potentials based on the bioregion of the case study is required in order to reassure the exploitation of possible renewable resource that will be proposed to be used by the renewable technologies.

Table 2

Limitations

Photovoltaic /solar thermal	Limited available area on orientation required and Capital cost
Ground Source Heat Pump(GSHP)	The soil suitability is a limitation because the thermal conductivity of the ground may have an impact on the depth and type of ground loop. The cost is high; however the low maintenance cost and the fact that it provides both coolth and heat, makes it a viable option. Fuelled by electricity that in an autonomous house this should be also calculated in the electricity generation from the PV's.
Wind Turbines	Wind turbine output is in an urban environment due to obstacles
Rainwater-harvesting	There may not be enough available roof space or space to place the water storage tanks Oxford has the lowest annual rainfall by 60mm in comparison to other areas of UK such as West Scotland by 226mm.
Solar thermal	Extra electricity required in order for the pump of the solar thermal to function so it should be calculated in an early stage.
Biomass CHP	Available space required for either boiler and wood chips or pellets.
Justification for the selection	Photovoltaics: The efficiency is high 13-17% -The area per kWp is low 6-8m^2 Solar thermal: retain their efficiency and minimize the heat losses in a variety of external temperatures due to the insulated covering that surrounds them CHP: Production of both electricity and heat. -Electrical efficiency is 6% and heating 70% Heat Pumps: Beneficial for all the seasons-it provides heat and coolth
Proposals	Photovoltaics: Façade coverage if there is not roof space available Solar Thermal: Use of evacuated tubes in Oxford due to local climate and cloudy environment Government should publish and promote the benefits and available grants CHP: There are no domestic biomass CHP used and sold in UK Use of wood pellets chips, on the assumption that the trees will remain growing instead of those consumed -Biomass Boiler: Create local wood suppliers. -GSHP: Horizontal system is the desirable one in urban areas.

3.3 Phase 3: The development of a model in IES program, based on the geometry, characteristics and implemented interventions on the case study's envelope will provide with sufficient information and justifications for the results. According to these, the suitability of the implemented passive strategies will be decided and the energy consumption will be indicated.

Note: The electricity and gas consumption was dramatically reduced. Before the implementation of the autonomous conception, the former was fluctuating between 1800-3400 kWh/m2/yr and the latter 6000 kWh/m2/yr depending on the occupant's demands. After the electricity was 1801 and the biomass consumption for space heating is 2500kWh/m2/yr and DHW is 1641kWh/m2/yr.

3.4 Phase 4: The results of face 3 can be implemented through an extensive analysis of a refurbishment based on the optimum options. In the case study, Code 6 was set as a target for the energy performance of the semi-detached case study (46kWh/ m2/yr) due to the fact that it included not only the energy but also water and waste targets.

4. Optimum requirements for autonomous house

Table 3 Optimum requirements (Kingspan Insulation, 2009)

Grid	Connection to the Local Grid in order to export the surplus generated electricity.
Energy	Initially reduction of the electrical and heating consumption through the refurbishment, passive strategies, A++ rated lighting and appliances.
Water	Reduction of water consumption depending on the technologies and occupants patterns, through dual flash WC, flow restrictors in shower heads, grey water recycling flushing, rainwater harvesting for washing irrigation and meters to increase the occupants water consumption alertness. Two different types of storage tanks should be provided for the potable water and non-potable water.
Waste	Composting or bio-digester is two ways of waste treatment. An existing building with no basement may face issues regarding the availability of space of the composting toilet. However a biodigester is located in every garden and can function for more than one house depending on each size.

3.5 Phase 5: Consequently, a quantitative analysis of the optimum combination of the renewable technologies results to the optimum energy generation and the detection of potential limitations. This analysis includes 2 scales, a small which consists of one house and a large scale which consists of 80 houses. The aim of this analysis is the proposal of the optimum combination of renewables for each scale.

Small and large scale specifications

Table 4 (M.Hutchins, 2012) (Encraft, 2012)

Options	GSHP	Biomass	Biomass CHP	Solar thermal	PV
Efficiency	Horizontal 90%	Biomass domestic small scale 80-90%	6%electricity output70%heating output	Evacuated tubes are more efficient than flat plate	Monocrystalline 13-17%
CO_2 savings	60 kgCO2	3795 kgCO2	6518 kgCO2	1920.966kgCO2	1134.72kgCO2

Capital cost	£5000	-	£5000	Maximum £5000	£6000
Demand met	90%DHW and SH and 10% by solar thermal	100%SP & DHW	100% SH elect. Demand surplus of heat & elect.	100% DHW and 50% of SH demand, by 60% roof area	100% electricity by 40% of rooftop generating 15%surplus

Large Scale

Table 5 (M.Hutchins, 2012) (Encraft, 2012)

Options	GSHP	Biomass	Biomass CHP	Solar thermal	PV
Efficiency	90%	80-90%	20%electricity 50%heating output	Evacuated tubes are more efficient than flat plate	Mono-crystalline 13-17%
CO_2 savings	237417 gCO2	240000kgCO2	651900kgCO2	243591.0kgCO2	184278.5kgCO2
Capital cost	£9,000-17,000	-	About £ 600,000	£320.000	£695.330
Demand met	90%DHW &10% SH by PV's & solar thermal	100%of DWH and SH demand	100%cover of SH+ electricity	45%of SH and DHW demand by 50% of the roof	100% elect. by 60% of rooftop generating 143%

The optimum solution proposed for the small scale, in the case study, is the combination of ground source heat pump, solar thermal and PV's. This solution was selected because heat pump is able to provide sufficient space heating and cooling and almost cover the whole DHW demand while the additional DHW will be supplemented with the solar thermal .Furthermore, it has been proven that PV's can generate more electricity than the electricity demand of the house which results to the conclusion that they should be connected to the grid in order to generate the surplus electricity.

On the other hand, the optimum solution that was proposed for the large scale was the CHP due to the fact that it can provide heat and electricity in a conventional cost.

4 Future researches:

One of the key proposals of the dissertation, is that the government, apart from the promotion of the upgrade of the existing house in order to meet the CO2 emissions target, could promote and support the autonomy of the buildings in order to assist to this target and create responsible people, dedicated to achieve the target of reducing the C02 emissions and protect the environment.

The framework that was indicated in this paper, will contribute to move towards to an autonomous conception target, in a small or large scale, which may hopefully result to a diverse range of approach for a sustainable way of thinking and living.

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