Open Source as Leverage towards Sustainable Housing

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Abstract: Shelter poses global sustainability challenges, as the population increase accelerates and resources dwindle. It is crucial for initiatives addressing the growing housing demand to incorporate a sustainability perspective. Open source, a form of Internet information-sharing, is being utilised by various housing initiatives worldwide. However, a sustainability perspective is not always included in a robust and holistic way, despite the negative impacts for human needs and ecosystems resulting from many aspects of current housing practices.

The Framework for Strategic Sustainable Development includes basic conditions for a sustainable society and a planning and decision-making methodology to move systematically towards sustainability. It provides a robust method for organizing, evaluating and using tools to aid in handling sustainability challenges effectively. This thesis aims to contribute to the development of affordable, sustainable design solutions, by modelling the incorporation of the FSSD into open source housing initiatives. A case study of a housing project under development in Ghana is used. Despite the complexity of the system under study, the research concludes that bringing a strategic sustainable development perspective to open source approaches can act as leverage for housing to move towards sustainability. Within this context, guidance is provided for approaching open source housing to contribute to SSD.
Keywords: Sustainability, open source housing, Ghana, backcasting, pilot housing project, OS House, FSSD
Statement of Contribution

This research was carried out collaboratively with three team members contributing their respective strengths, talents, passions and perspectives to the process.

The topic evolved from an initiative by Netherlands-based organisation, Enviu, a network of innovators in sustainability. After launching an open source housing project, Enviu required further contextual information for the design competition of a pilot project to be implemented and tested in Ghana in 2010. Our common enthusiasm for the potential of designing innovative solutions in less economically developed regions, using stakeholder contribution and open source approaches for sustainable development, brought us together to develop this thesis.

The team researched and contacted relevant key experts for our interviews and steering committee. The researchers created the conceptual framework together, then divided the work as Charlotte and Stephanie performed fieldwork in Cape Coast, Ghana, performing interviews, conducting surveys, and gathering contextual materials both online and in the field. Meanwhile, Tuna developed concepts around guidance within the larger context of open source potential. While Stephanie returned earlier than Charlotte to Sweden to write and infuse some of the key findings into the thesis, Charlotte continued interviewing locals and collating newly discovered data. Overall, dialogue ensued and Charlotte and Stephanie wrote while Tuna provided conceptual input and diagrams.

While the entire thesis process was not without seemingly insurmountable challenges at times, we agree that the experience of researching and writing collaboratively allowed for new insight and learning opportunities to arise.

Charlotte Barrow, Tuna Ozcuhadar, Stephanie Peterka
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Charlotte Barrow, Tuna Ozcuhadar, Stephanie Peterka
Executive Summary

Introduction

Shelter is an essential component of human existence and satisfies basic human needs. The way civilizations address shelter has major impacts for social and ecological systems. As the global human population expands and rural to urban migration increases, creating mobile cultures, the combination of concentrated pollution and natural resource consumption is resulting in systematic degradation of the entire system. However, advances in technology are simultaneously creating new opportunities to address the increasing problems.

The world today is deeply interlinked, with information travelling across and between continents instantly via the Internet and other communication technologies. As previously isolated places adopt the means to access this information - creating new market desires - potential arises to learn, share knowledge, and innovate solutions. In many places, challenges to meeting human needs are being overcome through Internet resource sharing in various forms. The collaborative potential of the web can thus be harnessed strategically to leverage areas, such as housing, towards sustainability. This presents opportunities for systemic change, and a reversal of the current unsustainable trajectory. This paper examines the potential for the open source format of information sharing to link housing problems with housing solutions, sustainably.

The Framework for Strategic Sustainable Development (FSSD) provides a way for planning for sustainability, systematically and rigorously, which includes: a) basic scientific principles that define sustainability; b) backcasting from a vision of success; c) a structured framework to organize information and make decisions strategically; d) a systems perspective; e) prioritizing actions to arrive at a successful outcome; and f) a toolkit for transitioning towards sustainability.

Purpose

The research aims to contribute to global sustainability via the housing sector. Objectives include testing the feasibility and efficacy of coupling strategic sustainable development (SSD) and open source housing approaches, and offering guidance for designers in achieving this.
Research Questions

Two research questions were posed:

1. How can a Strategic Sustainable Development (SSD) approach be integrated into open source housing initiatives to make them leverages towards sustainability?

2. What are some current barriers and opportunities for open source housing to contribute to Strategic Sustainable Development (SSD); and how can these barriers be overcome and opportunities utilized?

Overarching Research Perspective

The authors propose that using the Framework for Strategic Sustainable Development (FSSD) can strengthen and structure open source housing initiatives by implementing sustainability as a super ordinate goal or overarching vision, thus assisting in the solidification of common ground between designers, sustainability practitioners, and inhabitants. This boosts any current visions of open source housing, widening the scope into a more long-term strategy via design and realisation of sustainable housing. The systems perspective inherent in the FSSD approach aids in analysing the current reality more effectively, while enabling solutions to be discovered with a more strategic, holistic end goal. Specifically, the FSSD definition of sustainability employs 4 basic Sustainability Principles (SPs) as a way to define the concept and goal of sustainability, and to guide actions towards achieving this goal. These principles, coupled with three prioritization questions, can guide the design process using creative tension arising from constraints; and provide open source contributors with a strategic framework for decision-making.

To frame the research questions using a strategic approach, the study used the technique of backcasting. This enabled the role of open source in a future sustainable society to be explored, followed by an in-depth examination of the current situation in regards to sustainability in the target area. Barriers and opportunities for sustainability and open source were uncovered, with the assistance of the case study. This was followed with guidance for strategically harnessing open source potential for sustainability in housing.
Case Study in Ghana

The case study was developed in collaboration with Open Source House (OS House), which aspires to generate affordable housing design solutions in less economically developed countries, by providing an online open source platform for sustainable architecture. Cape Coast, Ghana was chosen as the pilot location for this project, with the “emerging middle class” (lower middle class) as the target group, as defined by earnings of between 5,500 - 10,500 Euros per year.

Aims of the OS House project include a reduction in the following:

- negative environmental impacts of the current dominant housing model, by providing a prefabricated, modular and locally-appropriate model with design freely accessible online, and
- challenges of affordability for the emerging middle class in building a house, by enabling free access to building designs; members of this class often struggle to meet their housing needs.

Detailed Research Phases

The research involved three phases. In Phase I, a literature review was undertaken in the following areas: sustainability; environmental impacts of housing; social and environmental challenges of less economically developed countries; and open source philosophy and applications. This provided an overview of the current sustainability reality of housing and the future potential for the growth of OS House. During this phase, tools were identified for meeting the research requirements of the next phase.

In Phase II, fieldwork was conducted in the target region of Cape Coast, Ghana. The primary research question was answered by inference from a case study, via interviews and a survey sample. Interviewees included experts in the building, government and environmental sectors, as well as target group house owners, while survey recipients included members of the target group that had either built their own house or aspired to do so. The case study included the use of a Template for Sustainable Product Development (TSPD), which acts as a structural tool for enabling strategic, sustainable product design by determining market needs and desires and enterprise potential, as well as sustainability “hot spots”. Within the TSPD,
a Strategic Lifecycle Assessment (SLCA) was performed, revealing environmental impacts of the dominant housing materials in the target region. Potential for OS House and for open source housing schemes in general was tested using a strengths, weaknesses, opportunities and threats (SWOT) analysis, compiling information from Phase I and II findings to answer the secondary research question.

In Phase III data was analysed and information was collated from the first two phases. This entailed presentation of results to peers and advisors; a testing of previous assumptions related to the research findings; and the creation of guidance for using a SSD approach in open source housing projects.

Results and Discussion

The results of the case study and literature review enabled inference about the larger context of open source housing potential concerning sustainability, informing the guidance. The case study results indicated the target group’s interpretation of how their needs for shelter were being met or not met by the current housing reality, sustainability awareness, as well as their desires for housing in the future. Interviews highlighted the current building industry’s impacts on material availability, costs and reasons for decision-making.

The study focused on materials as an area of major impact in the current reality assessment. The most frequently used material, concrete, was compared to other available options for environmental and social impacts. Identified environmental impacts included land degradation by cement and concrete factories; heavy toxins and waste products emitted during the production of cement, a major component of concrete; aggregate production (rock, sand or gravel added to cement to form concrete), accounting for land-use and exploitation of natural resources; transportation and concurrent carbon emissions of cement imported from other countries; and the extra energy required to cool houses made of concrete, which retain more heat than other available materials.

The concrete industry was found to have a semi-monopoly over the building material industry in the region, enabling inflation of prices and causing reductions in the ability of locals to meet their housing needs. This also prevents the development of alternative material industries. The
historically traditional building material in the region, clay, was examined and revealed fewer negative environmental impacts than concrete. It was realized however that while results indicated this material to be preferable for the OS House pilot house, local materials also present sustainability violations if not managed properly, and drastic changes to the current industry could have negative impacts for workers. Therefore, the complexity of the social and environmental factors of the materials industry make further research in this area necessary to ensure sustainability of housing into the future.

Conclusions

Sustainability must become part of a vision for housing globally, in order to meet the challenges of long-term environmental management. Basic principles can provide creative constraints for arriving at sustainability, enabling housing designs to be adapted via open source to each unique location, depending on the needs and desires of the people and local ecological systems.

There is sufficient theoretical support for using a SSD approach to enhance open source housing in transitioning towards sustainability. Through the research, it was confirmed that the core concepts of SSD, including a systems perspective, the principles of sustainability, backcasting, prioritization and selection of tools, etc. can synergistically inform open source housing and fill in gaps in both process (design and planning) and outcome (realisation).

The application of the guidance to the open source housing design process is recommended, enabling experience gained to improve guidance further, in a feedback loop where innovation can occur continuously.
**Glossary**

**backcasting** – a planning procedure by which a successful planning outcome is imagined in the future, followed by the question: “what do we need to do today to reach the successful outcome?” (Robert et al, 2005).

**EIA** – see *environmental impact assessment*.

**Emerging middle class** – the case study target group, defined by incomes of roughly 5,500 – 10,000 Euros per year.

**environmental impact assessment** – used to gauge potential environmental impacts of a planned project.

**Environmental Protection Agency** – branch of government dealing specifically with environmental issues.

**EPA** – see *Environmental Protection Agency*.

**FF** – see *fossil fuels*.

**Framework for Strategic Sustainable Development** – a method for planning strategically for sustainability within systems.

**FSSD** – see *Framework for Strategic Sustainable Development*.

**fossil fuels** – certain combustible fuels formed over millennia from various life forms.

**GHGs** – see *greenhouse gases*.

**greenhouse gases** – emissions released when burning *fossil fuels*; a main contributor to climate change.

**HCD** – see *human-centred design*.

**human-centred design** – an approach prioritising human needs/usability.

**LCA** – see *Life Cycle Assessment*.

**LEDC** – see *less economically-developed countries*. 
LEDR – see less economically-developed countries.

**less economically-developed countries** – countries where a significant portion of inhabitants are unable to meet their basic needs. LEDC and LEDR are used interchangeably in this paper, but LEDR more accurately reflects the economic diversity that exists within “developing” countries.

**Life Cycle Assessment** – a tool for evaluating impacts of materials and products from the “cradle” (resource extraction), through transport, production, and use, to the “grave” (fate after end-use).

**market desire** – the niche for a given product (goods and/or services) in the market economy; contributes to shaping the design of future products as consumers support design decisions with their purchasing decisions.

**Natural Step, the** – an international non-governmental organisation (NGO) that has promoted and supported the development of a framework for sustainable development incorporating backcasting from *Sustainability Principles*, in collaboration with scientists internationally.

**open source** – the creative practice of free information sharing; the ability of multiple people to contribute to an information system.

**precautionary principle** – if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is *not* harmful falls on those who advocate taking the action.

**SLCA** – see *Strategic Life Cycle Assessment*.

**Strategic Life Cycle Assessment** – a tool based on the 4 *Sustainability Principles* set against the life cycle stages of a product; both an assessment and a communication tool, which identifies the major issues in relation to a product or process in a qualitative manner, highlighting key aspects to be explored in greater, quantified detail as necessary.

**strengths, weaknesses, opportunities and threats analysis** – categorises information about a project or system.

**sustainability** – a condition achieved by not violating the four *System Conditions* as defined by *The Natural Step*. 
Sustainability Principles – see System Conditions.

SWOT – see strengths, weaknesses, opportunities and threats analysis.

System Conditions – four generic and non-overlapping principles used to define sustainability from a scientific, whole-systems perspective. These principles act as system constraints in defining the basic conditions that must be met in order to achieve sustainability. The four conditions describe a society in which nature is not subject to…

1. … systematic increase in concentrations of substances extracted from the earth’s crust;
2. … systematic increase in concentrations of substances produced by society;
3. … systematic physical degradation of natural systems;

and in which people are not subject to…

4. conditions which systematically undermine their ability to meet their basic needs.

Template for Sustainable Product Design – based on the Framework for Strategic Sustainable Development, an approach which: bridges the competence gap between sustainability experts and product experts; facilitates communication between management and the product development level in a company; serves as a benchmark for the analysis of existing products’ sustainability performance; and/or provides planning support for a specific new product concept.

TSPD – see Template for Sustainable Product Design.

Vernacular architecture – methods of construction using local traditions to address local needs; vernacular architecture tends to evolve over time to reflect the environmental, cultural and historical context in which it exists.

Westernism – the duplication of styles, tastes, modes of living etc. that have arisen in industrialized countries, most prominently USA and western Europe, in less economically developed countries; often spurred by admiration of the assumed material wealth associated with these regions.
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1 Introduction

1.1 The Sustainability Challenge

There is increasing consensus that the world is on an unsustainable trajectory. As the global human population expands, increasing pollution and natural resource consumption is resulting in declining ecological systems and often, the inability to meet human needs. This is evidenced through contaminated water tables, loss of biodiversity, declining natural resource reserves, rising toxicity levels, the climate change phenomenon, increasing gaps between the rich and poor, etc. The systems currently in place for resource extraction and use function in such a way that environmental degradation is systematically, or cumulatively, increasing in four key areas: extraction of scarce materials from the Earth’s crust; pollution; physical degradation of ecosystems; and the inability of humans to meet their needs through the world around them. The combination of increasing population spurting systematically increasing environmental problems, while the ability of the Earth to recover decreases with time, has been termed the “funnel” reality (Robèrt et al, 2004).

As more previously non-industrialized or less economically-developed regions (LEDR) adopt many of these unsustainable systems and patterns of resource consumption, a lack of infrastructure is often a major problem in managing resources and waste sustainably, particularly in cities, where the pressure of human habitation on ecosystems is often most significant. In turn, this contributes to the inability of human populations to meet basic needs as resources dwindle along with the capacity of the ecosphere to process the concentrated pollution and waste.

Worldwide concern over these mounting problems was a major driver in the 1983 formation of the Brundtland Commission, assembled by the United Nations. In 1987, the Commission put forth a definition of sustainable development:

“Humanity has the ability to make development sustainable-to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987).
This definition, however, is abstract and lacks clear boundaries for action. Within complex systems such as the interconnected human societies within the ecosphere\(^1\), a clearly defined, shared understanding of sustainability must be used to diagnose problems and to inform solutions.

A scientific consensus process was initiated to address such issues it has resulted in a Framework for Strategic Sustainable Development (FSSD) (Holmberg and Robèrt 2000, Robèrt 2000, Robèrt et al. 2002). This framework structures planning in complex along five distinct but interconnected levels:

1. **The System**: individuals, organizations, systems, countries, etc. in society in the ecosphere;
2. **Success** in the system: future desired outcome, delineated by compliance with four Sustainability Principles (SPs);
3. **Strategic Guidelines** to arrive at success in the system: backcasting from success, prioritizing guidelines;
4. **Actions** aligned with strategic guidelines to arrive at success in the system: steps taken to integrate and implement improvements in housing;
5. **Tools**: to help prioritise and monitor strategic actions to arrive at success in the system.

### 1.1.1 The Urgency of Addressing Housing

While many systems and actions globally are contributing to the current unsustainable reality, there are particular sectors with disproportionately negative impacts. These must be addressed immediately in order to quickly move towards more sustainable societies. One such area of enormous environmental impacts and threatened human needs is housing. According to the World Wide Fund for Nature, “The way we heat and power our homes has a massive impact on the environment – not just locally, but globally. Our homes account for 22% of our ecological footprint and up to 30% of our carbon emissions” (accessed February, 2010).

Increasing rural-to-urban migration, rapid population growth and large-

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\(^1\) Cole (1958) coined the term “ecosphere” to define the totality of living organisms and the inorganic environment that sustains them (Huggett, 1999).
scale demands for housing pose global challenges for ecosystems and human needs. It is predicted that from now on, the world population will be urban in its majority (United Nations: World Urbanization Prospects, 2007). These trends, particularly prevalent in many less economically-developed countries, acutely pressure housing demands and basic infrastructure requirements such as water, electricity and waste disposal. In many cases, houses are constructed before infrastructure is in place, resulting in unplanned sprawl, improper waste management, flooding, and conversion of green areas. Often there is no provision of roads, water, electricity or drainage systems. Human needs are compromised in these circumstances by the lack of reliable access to basic services.

Ghana is no exception to these trends. Currently the country is experiencing a shortage of housing, and is struggling to meet the rising demand in many urban areas. In 2009, the Ministry of Water Resources, Works and Housing suggested that the housing deficit is in excess of 500,000 housing units, whilst supply figures for new units vary between 25,000 and 40,000 units per annum as against the annual requirement of 140,000 units. The national annual housing supply to demand ratio for new housing is about 35%, leaving 65% of the demand unmet. The approximate national housing requirement for the next ten years is one million units. Furthermore, the urban population in Ghana is expected to double by 2020 (2009). This indicates the urgent need for sustainable housing solutions that can be tested quickly and implemented widely.

1.1.2 Addressing Housing Strategically and Systematically

The problem of unsustainable housing is embedded in complex systems of supply and demand for materials and other resources, stakeholder interests, and human needs and desires for shelter, comfort, identity, expression, etc. These wider social and ecological systems, with numerous causal relationships and feedbacks among components, require a whole-systems approach when examining problems and suggesting solutions. A systems perspective is integrated into the strategic sustainable development (SSD) approach taken in this paper, and is highlighted as a key point for designing solutions and understanding problems.

Maintaining a whole-systems perspective avoids the disadvantages of the reductionist approach of attempting to comprehend complexity by reducing
it into parts. When focusing solely on the parts of a system, root causes of problems can easily be overlooked as interactions between parts and the whole picture are ignored. This also poses dangers when creating solutions, as unexpected consequences for another part in the system can occur.

1.2 Open Source Potential for Sustainability

“Open source” is a form of information-sharing that enables data to be freely accessed and altered. The most famous example may be the Internet site Wikipedia, where users can freely access the open source platform to enter word definitions and edit entries by others. As a methodology, open source harnesses the power of distributed peer review and transparency of process; and in theory enables the continuous testing and improvement of ideas, including design models.

Open source has been widely applied, from healthcare to computer software (for example, Linux operating system), and has frequently proven to create a space for successful ideas and solutions. There is an emphasis on involvement, transparency, cooperation and free sharing. Online open source communities are connecting previously remote parts of the world, fostering new cultures of shared interests. The diversity of perspective, experience, and skills of these networks has potential to solve global problems precisely because it provides opportunity for global collaboration.

Due to the magnitude of ecological and social impacts attributed to the housing sector, open source housing solutions which can be adapted to specific local contexts, including climate and available materials, have the greatest potential to leverage the housing sector and ultimately society towards sustainability. Addressing housing in an open source manner has demonstrated progressive design thinking, and coupling this with a robust sustainability framework could prove an excellent solution to the problem of unsustainable housing.

1.2.1 The Open Source Design Process

Initial brainstorming sessions emphasise open exchange, broad participation, and rapid prototyping of ideas. During open exchange, ideas are built upon and inspire new concepts. Broad participation is key; a skilled collaborator is one who encourages others to generate ideas. This process allows for designs to be improved in the first stage, where often the
most potential exists for sustainability to be designed in. Once a design is complete, its sustainability attributes are largely fixed. Rapid prototyping gets a product from concept to market quickly, and also enables designers to view the product in the early stages. This open environment is dependent upon free exchange of ideas with open access to information, so a solution can be improved by diverse input and sharing of expertise.

1.2.2 Human-Centred Design

A central point of designing sustainable housing solutions in an open source manner is employing design thinking with or for the people in need from a needs-based perspective. Human-centred design (HCD) is an example of this type of thinking. HCD is a process and set of techniques used to create new solutions, including products, services, environments, organisations, and modes of interaction. The HCD process begins by examining the needs, dreams and behaviours of the people being affected by the solutions (IDEO, 2009). According to the HCD toolkit, it is crucial to meet people in their respective working and socializing environments, as this immersion enables experiential as well as intellectual understanding of needs.

1.2.3 Combined Housing Expertise

When populations have existed in locales over time, knowledge of building materials, methods, and techniques are often contained within the local knowledge base to meet needs in ways that are relevant to the local context. This ‘vernacular’ knowledge can strongly benefit housing designs, particularly from an environmental perspective, as it is based on the local climate and available materials. The open source strategy can encourage adaptation to local contexts by enabling and advancing the use of local building materials, techniques, knowledge of environmental conditions, and craftsmanship. Additionally, the platform enables people in other locations and disciplines to contribute knowledge, ideas and case studies of their design experiences.

Combined with this, advances in environmental awareness and technology have enabled progressive developments in the formalised field of architecture, resulting in exportable expertise that can enhance vernacular concepts. For example, modular housing, emerging globally, creates opportunities to reduce ecological footprints in production, compared to traditional on-site construction. Waste is reduced as construction efficiency
increases, and units can be exchangeable and flexible during both the use and end-of-life phases in the lifecycle of the house.

Open source provides an opportunity to combine these different types of expertise, allowing contributions from geographically-separated sources and contributing to a strategic design system, where elements and ideas can continually metamorphose.

### 1.2.4 Current Open Source Housing Initiatives

One example of open source and architecture is Architecture for Humanity, a non-profit design services firm founded in 1999 by Cameron Sinclair and Kate Stohr. Sinclair stated the mission is “…to promote architectural and design solutions to global, social and humanitarian crises… We believe that where resources and expertise are scarce; innovative, sustainable and collaborative design can make a difference” (2006). The Open Architecture Network was developed to create an online platform to share case studies and ideas experienced through Architecture for Humanity. The website offers open source architectural plans, toolkits, and manuals. Celebrating its tenth year, the Network continues to grow and currently boasts 15,000 registered users and 50,000 unique monthly visits. This represents huge growth in potential for the architecture realm to access the areas of greatest need. Through Architecture for Humanity, several successful projects have been carried out and are available as case studies on the Open Architecture Network. See **Figure 1** for a map of aspects of the Network’s operations.
Figure 1 Interpretation of Open Architecture Network, based on speech by Cameron Sinclair, 2009

There are a slew of contemporary examples on the Open Architecture Network. One example from 2000, which continues to flourish today, is La Voute Nubienne, a response to a growing need in Burkina Faso for clean water, shelter, power, education, and healthcare. Population growth, linked with increasing desertification and regression of forested areas, has inhibited traditional building techniques in the area. La Voute Nubienne has re-introduced into the region an ancient architectural technique with a modern spin: vaulted roofs using basic, readily available local materials and easily-learned building skills. People in the region are now building shelters for themselves using this technique (accessed June 2010).
While projects such as these may be innovative and address human needs and sustainability challenges, a shared, Principle-based definition of sustainability could bolster this and other projects by not only introducing new materials, techniques and relationships but also introducing a holistic long-term perspective, within the constraints of the 4 SPs. To emphasize, in this project, the raw material of earth is used for making mortar and mud bricks, which are dried in the sun. This could eventually cause erosion if not properly managed, considering the growing population. A SSD approach can help identify and address issues like these strategically, when integrated into projects early on.

1.2.5 Copyleft

Ideas such as this, made public and free, can be disseminated widely and quickly. This allows solutions, projects, and toolkits to cross-pollinate, improve and be locally inspired and adapted, perpetuating the feedback loop of knowledge sharing. At the forefront of the “Copyleft” movement, Creative Commons provides free licenses and other legal tools to mark creative work with the creator’s desired freedom, so others can share, remix, use commercially, or any combination thereof (Creative Commons, 2001). Creative Commons supports the structure of a richer public domain, making it easier for people to share and build upon the work of others, consistent with many of the rules of copyright. For example, in the case of Architecture for Humanity, licenses are granted in the designers’ names.

Copyleft can give architects and designers alike the confidence to undertake pro bono work and maintain a sense that their work and creativity aren’t ‘wasted’. It acts as a legal standard, where the full copyright may be retained, meanwhile permitting organisations and individuals to work within an attribution-only framework. Designers can develop a solution for one area and then market to a broader audience. Additionally, designers are permitted to charge people to use the design while simultaneously sharing the same work freely with others who cannot afford to pay. This alternative of “some rights reserved” replaces rigid “all rights reserved” constraints.

1.3 The Open Source House Project

Building upon these ideas with the desire to generate choice for meeting human needs sustainably, the Open Source House project (OS House) was formed. The idea was developed by the Netherlands-based organisation
Enviu and Dutch architect Vincent van der Meulen, to provide an open source platform for sustainable architectural design solutions in targeted regions in less economically developed countries (LEDR). OS House provided an opportunity for this research to examine a contemporary case study that is merging open source housing with a sustainability perspective.

1.3.1 The Emerging Middle Class as Target Group

The OS House pilot project targets Ghanaians in need of affordable and ecological housing. The choice was made not to focus on disaster-stricken areas or people at the bottom of the economic totem pole. There are already important (although still not sufficient) projects attempting to meet these needs, such as initiatives led by Architecture for Humanity and Habitat for Humanity. Instead, the project targets those who have some income available to purchase housing, yet cannot afford the majority of current new options, which according to OS House research is designed for the rich (2009). Targeting this niche market both: a) provides opportunities for income and return on investment, and b) addresses the sustainability issues arising from the large environmental impacts of the emerging middle class (EMC) when compared to the poor. The consumption choices of the EMC, while often underserved, are vital to developing a sustainable housing industry. Branching out to this target group complements work already being done and contributes to a systematic approach to transforming the housing industry.

1.3.2 Design Competition

In January 2010 the project began with a global design competition for a pilot house that is being built and tested in 2010 in Cape Coast, Ghana. The design is primarily chosen by adherence to eight principles prescribed by OS House (see Appendix 1) and is designed for a family of the EMC. Ideally, the approach and online platform will extend to the wider world of housing design, particularly in LEDR. The findings of this research around the current sustainability challenges and potential, as well as barriers and opportunities for an open source model, contributed information to the OS House project, while engaging with the target group in Ghana and communicating with the pilot designers through the OS House platform.
1.4 Purpose, Scope and Limitations

This study attempts to determine how the FSSD and open source strategies can be combined to contribute to SSD in housing. The research strengthens the case for using an open source approach for improvements in sustainability through design; filling in the gaps of the open source housing field by showing how a structured sustainability perspective can be brought to a current housing project. The research aims to contribute to the development of affordable, sustainable design solutions to address housing shortages globally.

The study was limited by restrictions of budget, communication and time. Widespread distribution of the survey, and materials that could have bolstered the Human Centred Design perspective of the paper, such as photography equipment, workshop materials, etc. was prevented by budget limitations. The research period lasted four months, of which three weeks were spent in the case study location. The majority of the case study research could only occur during the time in Ghana due to the lack of remote communication options, where the time was too short to distribute and receive sufficient responses to the survey. The application of study results is also limited by the timeframe; although the research aims to provide input on the direction of the OS House project’s housing designs, the turnaround between submittal of the research and the selection of the design competition winner is too short to allow meaningful incorporation of findings, particularly the guidance.

1.5 Research Questions

1. How can a Strategic Sustainable Development (SSD) approach be integrated into open source housing initiatives to become leverage towards sustainability?

2. What are some current barriers and opportunities for open source housing to contribute to Strategic Sustainable Development (SSD); and how can these barriers be overcome and opportunities utilized?
2 Methods

Methods were chosen to answer the research questions strategically. Three phases were required: Background, Fieldwork, and Collating Results and Developing Guidance. See Table 1 for a temporal portrayal of the three overlapping phases, where the numbers along the horizontal axis correspond to the months January – June, 2010. Research phases are explained in detail in the following pages.

Table 1 Method Design

<table>
<thead>
<tr>
<th>Phase</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Phase II</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Phase III</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

2.1 Phase I: Background Research

2.1.1 Open Source Housing within the Context of the Framework for Strategic Sustainable Development

This thesis relies upon the application of the above-mentioned framework for strategic sustainability planning within complex systems, to analyze open source housing. Known as the Framework for Strategic Sustainable Development (FSSD) and supported by The Natural Step, a non-governmental organisation, the FSSD is used to promote systematic analysis and planning towards sustainability. The Framework aids in restructuring organizations and systems within societies to operate more
sustainably, as defined by the 4 sustainability principles outlined in table 2, below.. It is also known as The Five Level Framework for Planning, as it is demarcated into five hierarchical levels:

1. The ‘System’ level defines the interrelationship of a system, contextualizing the specific issue within its larger spheres of influence. Because planet Earth and all its life forms are contained within the ecosphere, continuation of that life requires examination and protection of the conditions that make the survival of the ecosphere possible. Therefore, the system level seeks to understand the workings of the ecosphere with the careful use of science including thermodynamics and conservation laws, biogeochemical cycles, basic ecology, the primary production of photosynthesis, etc. Within the ecosphere, “society,” or the human-created realm, can be understood by looking at social institutions, networks, characteristics of society’s interdependent pursuit of human needs, and the importance of diversity (Robèrt et al, 2004). See Figure 2 for a depiction of the system studied in this paper.

![Figure 2 Housing System Boundaries](image)

2. The ‘Success’ level defines success within the system from the perspective of compliance with the 4 SPs, the basic requirements for society to achieve sustainability. The 4 SPs were advanced with the following criteria:
a) *science-based*, compliant with a contemporary scientific understanding of the world.

b) *necessary* to achieve sustainability, to avoid over-complication; failure of compliance with any of the four SPs would not allow for sustainability.

c) *sufficient* to achieve sustainability; taken all together, the principles cover every aspect of sustainability, avoiding gaps in thinking.

d) *general* so that people from any discipline can comprehend and use them in all activities, at any scale.

e) *concrete*, guiding action for solutions and for trouble-shooting dilemmas; acts as structure and bolsters planning agendas.

f) *non-overlapping*, or mutually exclusive to allow for structured understanding, analysis and monitoring.

g) preferably designed as *boundary conditions*, to allow for inclusive, creative and disciplined dialogue - creativity within constraints where limitations provide creative tension.

The success identified in the case study in this paper is future open source housing supported by inhabitants’ desires, which can serve to help actualize their basic needs within a sustainable community that is constrained by compliance with the 4 SPs, or system conditions outlining the basic requirements of a sustainable system (see Table 2).
### Table 2 Four Basic Principles for Sustainability (Robèrt et al. 2004)

<table>
<thead>
<tr>
<th>FOUR BASIC PRINCIPLES FOR SUSTAINABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a sustainable society, nature is not subject to systematically increasing…</td>
</tr>
<tr>
<td>I  …concentrations of substances extracted from the Earth’s crust;</td>
</tr>
<tr>
<td>II  …concentrations of substances produced by society;</td>
</tr>
<tr>
<td>III …degradation by physical means;</td>
</tr>
<tr>
<td>And in that society…</td>
</tr>
<tr>
<td>IV …people are not subject to conditions that systematically undermine their capacity to meet their needs.</td>
</tr>
</tbody>
</table>

3. At the ‘Strategic’ level, an approach to choosing steps for arriving at success is used. Backcasting can be employed as a planning tool where a vision of success is created, and strategic moves are undertaken to move towards it (Holmberg and Robèrt 2000). This achieved by creating a vision, followed by the question: “what do we need to do today to reach the successful outcome?” In this case the backcasting concept is used to envision a future sustainable and affordable housing sector. Prioritizing guidelines then allow the project or system to be addressed from a strategic perspective in moving toward this vision of success, in the form of three key questions. The questions enquire whether the action provides:

a) …a step in the right direction to move toward sustainability?

b) …a flexible platform from which future actions for sustainability can be adapted as circumstances change?

c) …a return on investment, which is not restricted to financial returns, but can include social, intellectual and/or other forms?

4. The ‘Action’ level includes all concrete actions taken strategically to move towards success. Actions are specific to the individual project and
are strategically selected by ‘backcasting’, or imagining a future ideal scenario from the perspective of success constrained by the four SPs, then prioritising measures to arrive at this vision. Actions taken to achieve sustainable housing in Cape Coast, for example, must as a whole represent logical progression towards achieving the goal of success. This goes for any open source housing project anywhere on any scale.

5. At the ‘Tools’ level, tools and methods are selected to provide strategic, systematic support to the project. Planning for sustainability by backcasting is supported by the ABCD tool. The “A” step regards awareness of the current reality of the system. In the “B” step, participants analyse their current situation from a sustainability perspective. The “C” step includes visioning and brainstorming of actions that could potentially bridge the gap between today (B) and the future success vision (C). In the “D” step, actions are prioritised according to the three questions mentioned in the Strategic Level above, and a plan is created to arrive at the vision.

During this phase, planning and sustainability measurement tools for products (in reference to a house as a product) were selected for examining the case study system: shelter needs within Cape Coast society within the ecosphere. An open source platform was examined from the perspective of the FSSD, as a main strategic tool or method for achieving success in this project and beyond, as a sample case for open source housing approaches.

### 2.1.2 Backcasting from Sustainable Housing

A common vision can guide sustainable development within a system. The 4 SPs inform a common vision by providing “creative constraints”. This allows the vision to act as a compass for decision-making, moving housing projects towards sustainability from their onset. A vision for housing might run thus: “in a sustainable society the housing sector will meet the 4 SPs, which will be integral to all related activities, systems, and life cycles. This will entail housing not only to be affordable for inhabitants, but also to contribute to sustainable development and resilience of communities.” Open source provides a space to combine a variety of perspectives of needs, desires, social and environmental contexts, etc. related to a specific housing project, bolstering creation of a holistic, system-oriented vision.

Constructing a vision can be done in numerous ways, including using scenarios, principles, or both. In SSD it is argued that backcasting from a vision based on principles (i.e. rules or guidelines of the “game”) is more
flexible and thus more desirable than using scenarios (i.e. imagined futures, based on today’s reality), and inspires creativity. There are a few issues to consider with using scenarios only: firstly, it is difficult to achieve consensus that a particular scenario will be reality in the future; secondly, there may be technological advancements that could later make the scenario obsolete; and thirdly it is difficult to know if an envisioned scenario is actually sustainable, without the use of principles (Robèrt et al. 2004).

2.1.3 Literature Review

Relevant materials were reviewed in each of the following areas: sustainability, environmental impacts of housing, economically–developing countries, Ghanaian culture, politics and the construction industry, and open source philosophy and applications. The compilation of literature from various topics allowed a thorough overview of both the current reality of housing in Cape Coast, and of the future potential for OS House success in the region. It involved identification of tools to use in the research. It also enabled examination of the ways open source initiatives have previously utilised or ignored sustainability perspectives related to housing. The following information sources were utilised: Libris (provided by the National Library of Sweden), ebrary®, BTH Library Catalogue, and Google Scholar. Archival research was also conducted at The Institute for Housing and Urban Development Studies in the Netherlands.

2.2 Phase II: Fieldwork and Case Study

The OS House case study, which is attempting to use open source for leverage towards sustainability in housing, was used to examine the current sustainability of housing in a LEDC and informed barriers and opportunities for future sustainable housing. Two of the authors travelled to Cape Coast, Ghana to assess the situation with a SSD perspective, using various tools as outlined below.

2.2.1 Template for Sustainable Product Development

The Template for Sustainable Product Development (TSPD) was used to examine the current reality of sustainability within the target area, highlighting current and future sustainability challenges, gaps and potential opportunities for sustainable development. The TSPD is intended as a conversational tool to increase communication between sustainability
experts such as researchers and other potential stakeholders, and the product developers, in this case OS House, during the development phase of a product, to prevent unsustainable choices which, once built into a product, can be difficult to undo (Ny et al, 2008).

The TSPD structured case study data by incorporating three separate “templates” or categorized aspects of the product development process. “Need”, “Concept” and “Extended Enterprise” were examined from “current practices” and “future desired visions” perspectives, highlighting areas for consideration during development of a sustainable product.

Need

“Need” examines how needs and desires for a given product category (in this case, housing) are formulated, referring both to people’s individual needs and to the desires created by dominant market trends, looking at the current reality and the potential evolution of future market desires. In this study, a needs assessment was incorporated into a survey to discover the target group’s understanding of the ways current housing practices contribute to meeting their housing needs for choice, affordability, and access.

Concept

The “Concept” template addresses how needs and desires are met by current manifestations of the product in question, and what contributions to un-sustainability result. It also considers what steps could be taken to create a sustainable product in the future.

“Strategic Life Cycle Assessment” or SLCA (Ny et al. 2006) is an important tool sometimes used within the concept template. SLCA is based on the Life Cycle Assessment (LCA) engineering tool, where a product’s ‘life cycle’ is traced from the ‘cradle’ (raw material extraction) through production and use, to the ‘grave’ (disposal or end use). SLCA differs from LCA in that it attempts to illuminate the relationship between comprehensive sustainability factors and life-cycle thinking, employing a full sustainability perspective including social and economic aspects of impacts and avoiding the sole focus on known damaging impacts (Ny, 2006). It explores areas obscured in the traditional LCA by integrating a backcasting approach.
The SLCA was used to gain an overview of environmental and social sustainability aspects of dominant housing materials. The SLCA reveals systematic violations of sustainability principles, by examining the life cycle of the materials from a whole-systems perspective and not focusing solely on “down-stream” or resultant impacts. This perspective is important in analyzing the life cycle of materials and providing suggestions for systematic solutions.

*Extended Enterprise*

Finally, the “Extended Enterprise” template underlines what potential exists for the house to influence societal changes toward sustainability, through communication and by building business potential within stakeholder relationships. Looking at stakeholder (including supply chain) blocks to sustainable development within the product category, it imagines future stakeholder cooperation in sustainable product development (SPD) and looks for the steps to arrive there.

**2.2.2 Interviews**

Structured and semi-structured interviews assisted in understanding of the overall housing situation, including opportunities for SSD in the region, as well as providing the majority of the information for the SLCA contained in the Concept category of the TSPD. Expert interviews provided technical information for assessing the ecological impacts of housing, as well as providing insight into previous relevant research.

In addition, engaging in effective dialogue was an integral part of the fieldwork in Cape Coast, as this enabled a deeper understanding of the behaviour and housing decision making by the target group. The researchers engaged with the emerging middle class through personal contact and informal interviews, in order to make space for a comfortable and personable atmosphere in which to explore the housing domain fully and realize barriers and opportunities for open source housing. This approach enabled more effective understanding of stakeholder networks by illuminating personal understandings of the role of housing in meeting needs in the target region, providing context for the Extended Enterprise category of the TSPD. Interviews occurred between February and April, 2010. See Table 3 for a list of interviewees, their positions and locations.
Table 3 Interviews Conducted in Rotterdam & Ghana

<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ari van Amerongen, Student Architect</td>
<td>Rotterdam, Netherlands</td>
</tr>
<tr>
<td>2</td>
<td>Felix Addo, Environmental Protection Agency</td>
<td>Accra, Ghana</td>
</tr>
<tr>
<td>3</td>
<td>Frederick Tettey-Lowor, Safi Sana</td>
<td>Accra</td>
</tr>
<tr>
<td>4</td>
<td>David Kombat, Statistics Ghana</td>
<td>Accra</td>
</tr>
<tr>
<td>5</td>
<td>Joseph Boateng, Institute for Development Studies</td>
<td>Cape Coast University</td>
</tr>
<tr>
<td>6</td>
<td>Justice Amoah, District Assembly</td>
<td>Cape Coast, Ghana</td>
</tr>
<tr>
<td>7</td>
<td>EMC member; Engineer, designed &amp; built own home</td>
<td>Cape Coast</td>
</tr>
<tr>
<td>8</td>
<td>EMC member; Batik Maker, built own home</td>
<td>Cape Coast</td>
</tr>
<tr>
<td>9</td>
<td>Edmund Appiah, Architect and Teacher</td>
<td>Cape Coast</td>
</tr>
<tr>
<td>10</td>
<td>Samson Nibi, Architect and OS House Developer</td>
<td>Rotterdam</td>
</tr>
</tbody>
</table>

2.2.3 Survey

A survey was distributed to the target group, via officials at a secondary school, a university, and a government office block or District Assembly (see Appendix III). Of the 40 surveys distributed, 19 were completed and returned. The TSPD Needs category was addressed mainly through the survey responses, with research from the literature review and expert interviews with OS House affiliates contributing to formulation of the survey questions. The survey consisted of 24 questions gauging respondents’ views in 4 topic areas:

a) Current housing reality;

b) Desired future reality of housing;

c) Current potential for OS House; and

d) Identified barriers to utilization of OS House model in the region.
2.3 Phase III: Collating Data and Developing Guidance

In Phase III data was analysed and information was collated from the first two phases, to clearly answer the research questions while further developing both the structural overview of the paper and the guidance for open source housing designers.

2.3.1 SWOT Analysis

A strengths, weaknesses, opportunities and threats (SWOT) analysis was conducted using a compilation of data gathered during the first two research phases. These four categories set out to provide a quick overview of key aspects of the case study pilot project, as a way to organise information about the project’s current potential in the region and its efficacy in facilitating the movement of housing in Cape Coast towards sustainability. It was also intended to act as guidance for the project and the organisation as a whole as it develops new projects in other LEDC. Furthermore, the SWOT findings were intended to categorise findings related to the overall potential of open source to contribute to sustainable housing.

2.3.2 Guidance

To fulfil the purpose of this study, which is to suggest a way in which a SSD perspective can be integrated into open source initiatives to assist in moving housing towards sustainability, a structured assessment of open source housing design was conducted and then linked with the FSSD. The guidance was created last, as researchers were able to compile all information gathered during the first two phases and glean insight for future open source sustainable housing designers. The generic guidance is a proposed set of overall suggestions that can be tailored by individuals or organisations to specific cases and applications.
3 Results

3.1 Case Study

3.1.1 Survey Results

The overall sample was 32% female and 68% male. The salary range was from 73.55 to 787.94 Euros (142 to 1,500 Ghana cedis) per month with an average of 259.85 Euros per month, with five undisclosed salary rates\(^2\).

Of the overall survey sample, 100% selected “yes” to the question “If housing designs were made freely available on the Internet for you to use, along with the construction documents, would you make use of them if you were building your own house?” Reasons given were related to the expected professionalism of the information (2 responses); the learning value and/or potential to use it as a plan for building their own house/design (2 responses); a belief in the “trustworthy, accurate and precise” nature of information found on the ‘net (1 response); saving time on finding materials (1 response); and expected cost savings (5 responses) of which expected savings were related to the cost of designing by an architect, draftsman or building engineer (3 responses) and the cost of documentation (1 response).

Within the survey sample, 42% of respondents had built a house. While 20% of these did not live in the house they had built, 100% of house owners had been involved in building their house. The length of time taken to build houses within the sample ranged from 1 year to 8 years. The average length of time taken to build was 3.88 years. Table 4 shows the age of respondents that had built a house, and materials chosen. Table 5 represents respondents that had not built a house and the amount of time spent on the Internet per week, giving insight into potential usage of open source housing designs.

\(^2\) Salaries were collected in Ghana cedis, converted to Euro using xe.com. Salary amounts and averages are rounded to the nearest tens decimal point.
Table 4  Background data of Survey Respondents that had built a house

<table>
<thead>
<tr>
<th>Age</th>
<th>20-30: 0</th>
<th>30-40: 50%</th>
<th>40-50: 25%</th>
<th>50-60: 12.5%</th>
<th>60+ 12.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Wood/bamboo: 3</td>
<td>Metal sheets/slate/asbestos: 4</td>
<td>Stone: 5</td>
<td>Cement/sandcrete: 7</td>
<td>Cardboard: 1</td>
</tr>
<tr>
<td></td>
<td>Vinyl tiles: 1</td>
<td>Ceramic/ marble/tiles: 4</td>
<td>Terrazo: 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Those who had built their own house professed salaries ranging from 140 to 830 per month with the average being 415 Euros per month. According to their job self-identification, these respondents consisted of 2 Administrative Officers, 1 Batiker (batik material printmaker), 1 Civil Servant, 1 Field Service Engineer, 1 Librarian/Businessman, 1 Senior Library Assistant, 2 Quantity Surveyors, and 7 Teachers. 3 respondents did not disclose their job titles.

Table 5 Background data of Survey Respondents that had not built a house

<table>
<thead>
<tr>
<th>Age</th>
<th>20 – 30: 45%</th>
<th>30 – 40: 27%</th>
<th>40 – 50: 27%</th>
<th>50+ : 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet use in hours per week</td>
<td>No time: 0</td>
<td>1or less: 27%</td>
<td>1–3: 36%</td>
<td>3-5: 36%</td>
</tr>
</tbody>
</table>

The respondents who had not built a house comprised 68% of the sample survey. Their salaries ranged from 80 to 220 Euros per month, with an average of 170. Job titles included 2 Administrative Officers, 1 Civil Servant, 1 “NSS”, 1 Quantity Surveyor NSS, 1 Senior Library Assistant, 4 Teachers and 1 undisclosed.
3.1.2 Interview Results

Interviews revealed similar results to those expected in the area of potential sustainability improvements by material choice. The findings which were repeated in more than one interview are included in Table 6.

Table 6 Interview Findings

<table>
<thead>
<tr>
<th>INTERVIEWS</th>
<th>FINDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>Major hot spots for housing sustainability in region: urban planning, including waste and resource management; lack of regulation for private builders</td>
</tr>
<tr>
<td>4, 6, 7, 8, 9, 10</td>
<td>Housing affordability heavily affected by costs of materials and of designing the house</td>
</tr>
<tr>
<td>7, 8, 10</td>
<td>Material choices limited by semi-monopoly of HeidelbergCement over building materials industry in the region</td>
</tr>
<tr>
<td>7, 8</td>
<td>House builders often forced by lack of available/affordable options to use illegal and/or unsustainable materials despite awareness of the impacts and/or illegality</td>
</tr>
<tr>
<td>7, 10</td>
<td>House builders feel social pressure to buy into the use of concrete</td>
</tr>
<tr>
<td>1, 2, 5, 8, 10</td>
<td>Basic human needs must be met before infrastructure supporting ecological management can be implemented</td>
</tr>
</tbody>
</table>

3.1.3 Template for Sustainable Product Development

The results of the interviews and surveys are summarized in the following templates. Answers to questions posed in the TSPD were built on knowledge gained from the literature review regarding open source housing initiatives; the interviews and survey; and fieldwork experience. It was shared with OS House for feedback and to aid in judging the design competition for this and/or future pilot houses, alongside the eight Eco-principles (see Appendix I).
Current Reality of Needs/Desires Template

Current Reality of Market Desires

What current market desires are houses intended for and what are some of the needs they can satisfy (see Appendix IV)?

- Shelter (Subsistence)
- Prestige (Identity, Participation)
- Modernism (Participation, Understanding, Identity, Freedom)
- Social security (Protection, Identity)
- Respect (Identity, Creation)
- Space, privacy (Idleness, Affection, Freedom, Understanding)
- Accomplishment (Identity, Affection, Participation)
- Responsibility, reliability, duty (Participation, Understanding, Identity)
- Investment (Protection, Freedom, Subsistence)

What are some current sustainability challenges related to these market desires?

- Housing may support buy-in to unsustainable trends, e.g. non-local materials; materials that are unsustainably harvested and/or managed; building styles and techniques that are unsuitable to the particular climate, culture, resource availability, and/or socio-economic reality
- Housing demonstrates inefficient use of materials, resulting in a high volume of waste production during and after construction. While some materials are locally-sourced, they are not being sustainably harvested or managed, resulting in erosion, pollution, climate change, loss of biodiversity, increasing levels of toxicity and physical degradation of land
- The cement monopoly and subsequent material choice limitations and high cost of building are inhibitors to meeting human needs (Subsistence, Creation, Identity, Freedom, etc.)
Future Needs/Desires Template

Potential Future Market Desires

What market desires are likely to evolve in the future as responses to the sustainability challenges?

- To be informed and educated about sustainability and housing impacts
- To have wide choice for building materials, and full life cycle information readily available to enable informed decisions
- To build resilient communities in the face of sustainability challenges such as climate change and energy, water and other resource shortages
- Demand for local, sustainable markets
- Demand for sustainable use of renewable resources & sustainable infrastructure
- To have a clean environment where basic human needs aren’t inhibited, in harmony with preservation of local ecological systems

Could related human needs be actualized in a new way through open source housing methods within constraints of the 4 SPs?

- Yes. Participation could enable home builders to engage with a global community of designers and engage members of the local community in the building process, building upon the need for Understanding, enhancing knowledge of systems, sustainability, design and the local environmental impacts of housing decisions
- Creativity could enable inhabitants to co-create new designs and adapt to the local environment, versus relying upon a contractor with a fixed set of designs, which could be stagnant and not outfitted with a sustainability perspective
- Identity could be enhanced, as open source offers potential to provide sustainable designs to inhabitants, creating more choice and accessibility

Are there any market trends that point in this direction?

- Proliferation and success of open source and sustainable housing projects, as evidenced by the work of Architecture 4 Humanity, etc.
- Increased investment in projects in LEDC around sustainability
- Increased connectivity to the Internet and ICT in general with initiatives such as 50 x 15 (outlined later in paper)
- HeidelbergCement, Ghana’s cement processor, has committed to moderate C02 reductions and GRI G3 reporting (Global Reporting Initiative), and states environmental care as a main business pillar
**Current Conceptual Design of House**

How are market desires/needs being met? From a full life cycle perspective, how is the housing model from a sustainability standpoint currently? What current flows and management routines are linked and critical to the chosen housing model/concept from a full life cycle and sustainability perspective?

**Critical flows:**

*From the lithosphere to the ecosphere:*

- Fossil fuels (FF) for transporting materials, with attending greenhouse gas emissions (GHGs)
- For concrete: machinery for mining limestone, shale, clay, sand & iron ore requires FF input. These are extracted from the Earth’s crust and the elements combined: calcium, silica, aluminium and iron
- FF and electricity are consumed to support production in concrete factories, contributing to GHGs (e.g. sulfur dioxide) and increased scarcity of materials in nature (e.g. lead)

*From the technosphere (society) to the ecosphere:*

- Waste from suppliers and construction phase created before, during and after building of houses, contributing to emissions and landfills

**Management routines:**

- Monopoly over supply industry; cement is more available than other material options and this means prices can fluctuate widely
- House builders are not always aware of origin of materials and may unknowingly support, for example, illegal gathering of beach sand which contributes to beach erosion
- House building often precedes sufficient infrastructure, and without environmental impact assessments
- On-site construction produces a lot of waste
- Aside from materials, because of the frequent lack of indoor plumbing or sewage systems, liquid and solid waste from inhabitants is disposed outside in ditches and streams that often are connected to the same streams that urban farmers use to irrigate crops sold at local markets
Future Product Concept Template

Conceptual Design of Future House

Could flows and management routines related to the current product be developed to help society comply with the 4 SPs? What improvements can be made to current house life cycles to reduce violations to the SPs?

Critical flows:
- More efficient use of materials (ensuring materials are sustainably managed, exchangeable, recyclable, culturally and socio-economically appropriate, energy-efficient, locally & sustainably harvested)
- Substitute harmful for benign and non-persistent substances, for example producing cement from industry waste by-products versus raw materials extracted from the Earth’s crust
- Decouple services provided from unsustainable flows of materials and energy, ex. use locally-sourced and sustainably-produced materials

Management routines:
- Introduce knowledge-sharing across entire lifecycle of the material so end-users are aware of the sourcing and production of materials
- Institutionalise best practices by offering government taxes and subsidies to encourage responsible resource management
- Break monopoly on materials, further develop alternate material sources
- Invest in new technologies & equipment to improve energy efficiency at manufacturing facilities
- Recycle concrete as base materials for roads, concrete slabs, and sidewalks, in place of virgin materials
- Promote modular housing in an effort to reduce the ecological footprint during manufacturing, compared with on-site construction
- Promote housing which integrates sanitary waste disposal systems & sustainable technologies such as solar power, rain water collection, grey water filtration systems, composting systems, etc.
- Support more ecologically-certified material suppliers such as the Forest Stewardship Council

Could new open source housing concepts more easily aid society in complying with the basic 4 SPs while meeting current and/or future market desires/needs?

- Promote pilot houses based on designs that incorporate sustainability in local communities encouraging engagement with local leaders who are involved with the projects to facilitate acceptance, understanding, education, awareness and participation
- Leverage the position of the housing sector to drive societal sustainability,
potentially beginning with SP 4 (relating to human needs) as leverage

- Housing involves an entire supply chain of products and services, so open source housing concepts could allow for the 4 SPs to be widely spread and infiltrate all activities involved in housing, affecting all stakeholders, and spread throughout the housing sector into other industries
- Share and promote SSD on open source housing platforms to become an educational space for dialogue to ensue and ideas to be generated around sustainability
- Ideas about sustainable housing from economically developed regions could merge with ideas from LEDR, stimulating innovation cross-pollination
- Promote designs that are feasible and regard the surrounding systems of the house, for example food production, local waterways, rain water catchment systems, culture, etc.

Current Stakeholder Template

Current Stakeholder Communication/Cooperation

Who are the societal stakeholders involved? What current preferences and conditions of society at large are opposing the introduction of more sustainable concepts?

Stakeholders

- House inhabitants and builders; Community members
- OS House; Contributors to OS House
- Government
- Land/housing developers; Building material producers and suppliers
- Architects, draftsmen, engineers, contractors

Societal conditions/preferences:

- Housing exists within an unsustainable society
- Housing is often constructed haphazardly; construction preceding infrastructure. Sites, materials and building techniques are not properly assessed from an ecological standpoint
- Housing can support the buy-in to unsustainable market trends (modernism and consumption)
- Association of building sustainably with high prices and a limited understanding of the socio-ecological impacts of housing, what sustainability actually is, and how housing can become sustainable
- Lack of support from politics and public authorities to make sustainable concepts more feasible to implement
- An ingrown set of unsustainable habits showing resistance to change, including societal pressure to conform to current standards
Is open source housing accepting or changing these preferences and conditions?

- Aiming to change conditions via pilot projects, demonstrating benefits to socio-ecological systems, of designing and building more sustainably and efficiently; and aim to demonstrate the feasibility, attempting to change preconceptions society may hold that run contrary to sustainability being feasible and affordable
- Aiming to change process of design and realization, with many projects aiming to involve the community and increase Understanding, Creativity and Participation in the entire process, enabling more informed and sustainable decision-making, reversing the current conditions
- Most open source housing projects aim to bring costs down

What current value-chain cooperation is agreed-upon to assure a full life-cycle responsibility (what gaps could be identified)?

- The Building and Road Research Institute is making efforts to introduce alternative and affordable material choices to the housing market, by researching and promoting local materials, where the full life cycle is being discussed in terms of impacts and affordability
- Lack of systems perspective and strategy in the housing sector, resulting in a lack of full life-cycle responsibility for the manufacturing and supply companies

Future Stakeholder Template

**Likely future Stakeholder Communication/Cooperation**

What future stakeholder preferences and conditions would be favourable for the development of more sustainable houses?

-Preference to live in sustainable houses, in terms of materials, process, impacts, safety and longevity
-Subsidies for sustainable housing projects and materials
-Governmental initiatives supporting sustainable/open source projects
-A supply chain exists that supports sustainable housing developments
-Cultural enthusiasm and support for sustainable ventures, supported by community initiatives and conversations around sustainability
-Taxes & fines for unsustainable housing projects & use of these funds to support sustainable initiatives
-Programmes that educate public about environmental impacts of housing decisions & importance this has for human needs and societies
How can an open source housing project like OS House communicate externally to facilitate such change?

- Demonstrate sustainability initiatives on platform & housing site
- Adopt 4 SPs & encourage designers & stakeholders to comply
- Choose suppliers based on sustainability of materials & services
- Demonstrate via pilot houses the economic, legal and physical feasibility coupled with the personal, financial and communal benefits
- Maintain a presence, ensuring it doesn’t depreciate or become obsolete, as exchangeability and proliferation occurs over time with local awareness, acceptance and involvement

What future strategic alliances would be favourable for a full life cycle responsibility? How could such cooperation be developed?

- Building strategic alliances with competitors (other housing projects) in an effort to push common suppliers towards sustainability
- Aligning with local craftsmen and environmental heroes who demonstrate willingness to be leaders to shift towards a sustainable society within the community
- Developing relationships between communities & sustainability causes to educate the public during building process about interrelated systems
- Aligning initiatives with other sustainable housing projects
- Aligning with educational programmes/institutes to share knowledge, empowering communities by enabling access

3.1.4 Strategic Lifecycle Assessment

Whilst in Cape Coast, the current reality was found to be vastly complex and cannot be attributed to a single problem. However, both the literature review and the fieldwork revealed materials to be a major hot spot and this was the area focussed on for the SLCAs. Within the EMC, it was difficult to discover one dominant housing model to analyse, as the mix of materials ranges greatly in variety and proportion. However, four materials were prevalent and easily discernable as dominant, where “sandcrete” or concrete formed from cement mixed with sand and sometimes rock is the most prevalent, followed by clay and clay bricks. See Figure 3 for a photo of sandcrete blocks, formed by hand, drying in the sun. The results of the in-depth overview of the dominant housing materials in Cape Coast: cement, clay, rock and sand, are summarized below (see Tables 7 - 10). Because the most significant and unsustainable material was found to be concrete, the cement SLCA was more clearly weighed against the 4 SPs.
**Figure 3** Sandcrete block production, Cape Coast, Ghana

**Table 7 SLCA of Cement**

<table>
<thead>
<tr>
<th></th>
<th>Extraction</th>
<th>Production</th>
<th>Transport</th>
<th>Use</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>Fossil fuels</td>
<td>Fossil fuels, electricity</td>
<td>Fossil fuels</td>
<td>Electricity</td>
<td>Destabilized mine area</td>
</tr>
<tr>
<td>SP2</td>
<td>GHGs, particulates</td>
<td>GHGs, toxic slurry, form oil</td>
<td>GHGs</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP3</td>
<td>Land clearance, water quality, runoff, dust</td>
<td>Land clearance for plants</td>
<td>Roads constructed; traffic increase</td>
<td>Land clearance, construction waste, water tables</td>
<td>Cement is slow to break down</td>
</tr>
<tr>
<td>SP4</td>
<td>Health &amp; safety, air &amp; water quality; noise</td>
<td>Safety: accidents, toxins, noise</td>
<td>GHGs, climate change</td>
<td>Industry monopoly</td>
<td>Cityscape, waste</td>
</tr>
</tbody>
</table>
Environmental and Social Impacts of Cement

Sustainability Principle 1 (SP1) highlights the use of scarce materials extracted from the earth’s crust. In the case of cement (also known as Portland cement), fossil fuels, which take billions of years to evolve from fossils, are extracted from the earth’s crust for the machinery used to extract components of cement, including limestone, shale, clay, sand and iron ore; process these materials into cement through heating, grinding, blending and drying; log the timber used for packaging materials; and transport cement from production facilities to areas of secondary production and to construction sites. Because cement absorbs heat, cement houses in hot countries can require more electricity for cooling than other materials. This electricity can take the form of natural gas and/or coal.

SP 2 shows the use of harmful substances produced by society. For cement, this includes greenhouse gas emissions (GHGs), particularly carbon dioxide (CO₂) released during fossil fuel use, which results in climate change and associated problems. Pollutants include particulates and gaseous emissions, toxic slurry, and form oil, affecting washing and mixing water.

SP 3 indicates the physical degradation of nature. Areas of vegetation and animal habitat are cleared for mining cement components, for creating roads to and from mining sites, and for production plants to house the world’s largest piece of moving industrial equipment – the cement kiln. In addition, large-scale mines cause dust clouds, as well as storm water runoff which results in erosion and changes to water tables and water quality. Forests are felled for the production of paper packaging materials. Construction waste including excess and rejected cement winds up in landfills. Climate change results in erosion, desertification, rising sea, etc.

Finally, SP 4 describes threats to meeting human needs. Cement involves the use of heavy machinery which can endanger the health and safety of workers through accidents, exposure to toxins, adverse effects on air and water quality, and through the impacts of climate change. In addition, cityscapes are affected by abandoned buildings that decay slowly. Finally, the semi-monopoly of the foreign-owned cement company, HeidelbergCement, drives up costs house materials and inhibits the robust development of alternate, locally-owned material industries.
Cement is mostly imported into the country but two manufacturing plants exist in the region, and the industry is currently undergoing expansion, as a new cement factory is slated to open in the Central Region of Ghana.

*Table 8 SLCA of Beach & Lagoon Sand, Cape Coast Region*

<table>
<thead>
<tr>
<th>Sand</th>
<th>Extraction</th>
<th>Production</th>
<th>Transport</th>
<th>Use</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>—</td>
<td>Fossil fuels</td>
<td>Fossil fuels</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP2</td>
<td>—</td>
<td>GHGs, dust particles/toxins when mixed w/cement</td>
<td>GHGs</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP3</td>
<td>Erosion, water tables disrupted, aquatic life threatened</td>
<td>Roads</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP4</td>
<td>Income loss for tourism, illegality, poor water quality</td>
<td>Health and safety</td>
<td>GHGs, climate change when mixed w/cement</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Table 9 SLCA of Rock, Cape Coast Region

<table>
<thead>
<tr>
<th>Rock</th>
<th>Extraction</th>
<th>Production</th>
<th>Transport</th>
<th>Use</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>Fossil fuels</td>
<td>Fossil fuels</td>
<td>Fossil fuels</td>
<td>—</td>
<td>Destabilized quarries</td>
</tr>
<tr>
<td>SP2</td>
<td>GHGs</td>
<td>GHGs, toxins</td>
<td>GHGs</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP3</td>
<td>Land clearance for quarries and access</td>
<td>—</td>
<td>Roads</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP4</td>
<td>Health and safety, taxing labor</td>
<td>Health and safety</td>
<td>GHGs, climate change</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Environmental and Social Impacts of Sand and Rock

Although sand and rock have minimal environmental impacts when viewed individually, they are not used in isolation for housing. Most frequently, they are combined with cement to form concrete, sometimes called “sandcrete”. Many of the impacts included in the cement SLCA are therefore also relevant to sand and rock.

Sandcrete buildings carry the risk of erosion and collapse if mixed with salty sand, or if they are not properly covered to prevent ocean spray from eroding the iron rebar usually used for infrastructure support. A plaster of clay is sometimes used to prevent this, and sand gathered from the ocean is whenever possible left out in the rain to be washed clean of salt, to prevent erosion.
Sandcrete blocks can be created by hand or by machine, and are dried in the sun. Sand is transported by truck to local sandcrete block production sites, either from the beach or from a nearby lagoon. Sand gathering from the beach has resulted in bare rock exposure, causing erosion and negatively complimenting rising sea levels. This could also have negative impacts on the local beach tourism industry. The EPA and local District Assembly implemented a ban on beach sand gathering to reduce impacts. However, illegal beach-sand gathering still occurs. Sand removal from lagoons poses environmental problems as well, resulting in lowered water levels, as well as damaging habitat for biological life in the lagoon system, along with bank erosion, and groundwater disruption. According to focus family interviews, while house builders may be aware of the negative impacts of sand gathered from beach or other locations, they will likely choose to purchase it anyway if it is the most available option. Sandcrete block formation is tedious manual labour and is not highly paid.

Land must be cleared to access rock, currently mined on a much smaller scale than cement. Rock processing quarries are located just outside town in previously wild areas which have been cleared. Both sand and rock are gathered and processed in the region and therefore do not represent large contributions to sustainability violations via transportation and resulting fossil fuel emissions. Rock extraction and production requires slightly more fossil fuel input than sand however, as it cannot be gathered by hand and is more often processed into usable-sized pieces by machine. However, it can also be processed by hand. While machine-processed rock is more desired for its uniformity of size, hand-hewn rock is cheaper and employs dozens of workers (mainly female). The workers processing the rock by hand are by majority women. The work is low-paid, tedious, strenuous and sometimes physically painful.
### Table 10 SLCA of Clay, Cape Coast Region

<table>
<thead>
<tr>
<th>Clay</th>
<th>Extraction</th>
<th>Production</th>
<th>Transport</th>
<th>Use</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>Fossil fuels</td>
<td>Fossil fuels</td>
<td>Fossil fuels</td>
<td>—</td>
<td>Excavation sites destabilized</td>
</tr>
<tr>
<td>SP2</td>
<td>GHGs</td>
<td>Dust particles, slurry</td>
<td>GHGs</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP3</td>
<td>Erosion, land clearance, habitat disruption</td>
<td>Land clearance for brick plants</td>
<td>Roads</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SP4</td>
<td>Erosion</td>
<td>Taxing labor</td>
<td>GHGs, climate change</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Environmental and Social Impacts of Sand and Rock**

Clay has historically been an important material in the region. It is not found on the coast but a few hundred kilometers inland. Again, it is extracted using machinery, outside human settlement areas, degrading natural systems. Erosion occurs when clay is harvested excessively, particularly on hillsides. Transportation impacts are less than imported cement, but are somewhat more than the rock-quarrying distances. It is now used far less widely in the urban setting of Cape Coast, although it is still in frequent use in surrounding rural areas.

While clay was the dominant material in the past, it was more expensive than other materials in the Cape Coast area due to its scarcity in the region.
It is now however seen as a weaker material and is less expensive than cement, due to its vulnerability to water erosion if not covered before heavy rains, and its association with old-fashioned ways of living. Buildings made of clay in urban areas are usually plastered with a cement mixture to protect from weathering. This also gives the illusion of more modern building façades.

There are two distinct ways of using clay in building. The first involves mixing the clay with water and layering it onto the sides of buildings; the second involves forming it into bricks which are baked before being plastered together. When baked into bricks, wood fuel inputs are also required. Clay bricks are however very expensive and not frequently used.

Another material option is mixing cement with clay to produce “landcrete”. This is less common than sandcrete but still in use in the Cape Coast area. Mixing with cement enables the clay to withstand weathering. However, it is also seen as more resistant than cement to ocean spray and salt erosion.

### 3.1.5 Politics and Shelter Needs in Ghana

In 1973, the Environmental Protection Council (EPC) was created; the first governing body in Africa to focus specifically on issues of environmental management. Over the years as environmental issues surfaced in the media, the EPC focused on developing an Environmental Impact Assessment (EIA) system in Ghana. In 1989 a National Environmental Action Plan (NEAP) was established in order to assess all new projects affecting the environment. Finally, in 1994 the Parliament passed Act 490, legally establishing and renaming the EPC as the Environmental Protection Agency (EPA), with additional powers to ensure environmentally-sound development in the country (Appiah-Opoku, 2000).

This greatly impacts housing, as new building projects occurring on a large scale must pass minimum environmental requirements in the form of an Environmental Impact Assessment (EIA) to receive a building permit. Smaller-scale projects can use the simpler Strategic Environmental Assessment (SEA). However, at the individual building level, permits are granted based on the architectural plan. According to interviewees, once a permit has been granted, the plot owner can do as (s)he likes with the land.
Based on interviews conducted with the EPA it was discovered that jurisdiction is mostly relegated to public projects or large-scale developments. Small-scale developments such as individual housing permits are the domain of local district assemblies. Currently there are approximately 170 districts in Ghana. This decentralization began in 1989 to combat corruption among officials.

Past governmental initiatives for affordable housing have failed to reach low-income target groups or meet housing requirements in a sufficient manner. The private sector lacks incentives to develop affordable housing, as financing is often a problem for private developers with banks demanding high interest rates on loans. Government-subsidized housing developments constructed by private industries have been minimal compared to the dwellings built by the informal sector, as this incremental housing process outpaces formal construction enormously. However, according to the Cooperative Housing Foundation, now referred to solely as CHF International, “there is sufficient evidence to suggest that communities are able to become sufficiently organized to drive settlement upgrading in partnership with government and the private sector” (CHF, 2004).

Another issue in Ghana which must be considered in the realisation phase of open source is the process of land tenure. The land ownership system is governed by a complex combination of customary, statutory, and common law. In Ghana the laws and rules create a confused state of land tenure with overlapping regulatory frameworks and clouded titles (CHF, 2004). The World Bank estimated in 2004 that registering formal ownership or a lease over a piece of unencumbered land in Ghana is the third longest registration process in the world. Because of the confusion surrounding land tenure, including the desire to avoid permit costs, it is not uncommon to see abandoned housing structures that are partially built, halted by building inspectors who have painted in red on the building: STOP WORK, PRODUCE BUILDING PERMIT (see Figure 4).
3.1.6 Potential for EMC Housing in Cape Coast to Move towards Sustainability – SWOT Analysis

Information collected during fieldwork in Ghana was organised into a SWOT analysis, presented below. The findings reveal insight into the pilot project and relate to the overall potential of open source to contribute to sustainable housing, most specifically in LEDC.
Table 11 Strengths, Weaknesses, Opportunities and Threats Analysis

**Strengths**

- OS House platform provides space for openness, transparency, involvement, co-operation and democratization to flourish among designers and local stakeholders.

- OS House’s eight eco-principles (see Appendix I) provide creative constraints for designers, demanding locally-relevant designs. Some principles are design-oriented and specific to building, forming a shared vision for designers of a locally-appropriate modular style.

- Ideas and designs will remain available on the OS House platform after the competition ends. Designers can learn from and improve housing designs, refining ideas in collaboration with others and adapting to other projects where relevant.

- Using a modular structure for the pilot house encourages exchangeability and adaptation, aligned with current Ghanaian housing culture. Due to cost restrictions, or for other reasons such as accommodating growing family units, it is common to make additions and changes to dwellings over time.

- The OS House model enables inhabitants to avoid the extra costs of hiring a professional to design their house.

- The OS House model aims to bring new housing ideas into the region, increasing opportunities to actualize basic human needs such as creativity and identity.

- The encouragement of sustainable architectural designs initiates the dialogue and awareness around sustainability for the designers and in the region for the inhabitants.

**Weaknesses**

- Although Internet access is available, it is currently not frequently used by the target group. The majority of survey respondents spent 1 hour or less per week on the net. Internet access and computing capacity in
the Cape Coast region is currently unreliable with frequent disruptions to connectivity.

- The OS House site is only available in English, which can be limiting for members of the target group. While English is Ghana’s official language, many people speak native dialects primarily.

- The OS House pilot project relies on the selection and introduction of a design decided by a panel of judges and not the target group.

- The guidance from this research project could not be fully incorporated into the pilot house, as the design competition ran concurrently with the research.

- OS House lacks a clear definition of sustainability. While “sustainable designs” may be the professed goal, the concept of sustainability can be interpreted differently by different designers.

- Adherence with the Eco-Principles does not ensure sustainability and in some cases may actually preclude it. For example, the first principle of OS House requires that design be “embedded in the local cultural context... can be produced locally... and strives to minimize the need for import and transportation”. This can only be sustainable if the available local materials comply with sustainability principles. The local lack of sustainable sourcing and management techniques is currently resulting in environmental degradation.

**Opportunities**

- Professed openness within the target group towards new housing ideas, since the current housing situation is drastically underserved in terms of sufficient affordable housing options.

- The regularly increasing cost of concrete is enabled by the local supply monopoly. Locally sourced and sustainably managed materials embedded in the design (in adherence with the first principle of OS House) could provide attractive cost savings to house builders.

- Among the surveyed sample, there was a positive indication of concern about availability of material resources into the future. This public
awareness presents an opportunity to transition towards more sustainably managed materials, particularly if the move is supported by government structures such as the EPA.

- A market desire for modernity and Westernism is an opportunity for open source technology and sustainable housing, like modular houses, to be seen as progressive, modern, responsible and trendy.

- The online database can work as an educational tool for sharing and generating ideas about sustainability in housing. Local stakeholders or others in less economically developed regions can be exposed to design possibilities for new sustainable housing projects, encouraging user innovation.

- Locals share knowledge and are influenced by one another’s building choices. This strong desire to meet social expectations for housing decisions could result in widespread use of the OS House model.

- If influential designs that encourage the use of locally, sustainably harvested and managed materials are available and demonstrated successfully within the community, there is potential to generate a populous shift toward sustainability.

- Africa holds 1 billion people, of which only 54 million are connected to the Internet. However, the 50 x 15 Foundation is working to provide affordable Internet access and computing capacity to 50 percent of the world’s population by 2015. Currently, 50x15 is committed to training and connecting communities throughout Africa. Architecture for Humanity has already partnered with 50 x15 on various projects including one in South Africa, boosting Internet access and usage (50 x 15).

- The product-service system (PSS) of the house represents numerous stakeholder relationships and opportunities for revenue flow. The local economy could thus be stimulated by sustainable housing.

### Threats

- Lack of awareness of long-term impacts means sustainability is not prioritised in decision-making for housing.
Concrete is by far the most readily available material on the market; HeidelbergCement has a semi-monopoly over the building materials industry. This presents barriers to the development of more sustainably-produced and managed local materials.

Houses currently are comprised of a mixture of different materials. For example, it is not uncommon to see concrete, wood, zinc sheets and clay in one structure. However, the shift to a total use of concrete is rapidly occurring, replacing the infrastructure and vernacular skills needed for alternative, more sustainable forms of building.

A threat identified by local home builders is the pressure to conform to one’s neighbours’ house standards, preventing the consideration of other materials and/or styles. The style of the selected pilot house may not be seen as desirable and this could prevent widespread adoption.

3.2 Guidance

In analysing, consolidating and comprehending the information gleaned from the first two phases of research, the authors attempted to map out the relationship between open source housing design and SSD. The FSSD was then used to explore open source housing within a sustainable society in the ecosphere.

3.2.1 Open Source, Innovation and Sustainability

The open source process begins with the use of Information and Communication Technologies (ICTs) such as the Internet; domains where collaborative networks are created and developed. On these platforms, open source projects are initiated between collaborative networks, where the aforementioned Creative Commons licence allows ideas to spread and develop, inspiring creativity, leading to knowledge building, and stimulating further innovation. User-Centred Design and Continuous Product Development are often integral in open source platforms, bolstering the methods with which designers can cooperate on projects. User-Centred Design allows the needs of the end-user to be given extensive attention at every stage of the design process, similar to HCD. Continuous Product Development refers to the constant, proactive process of discovering market changes and seizing opportunities to develop new
products, fuelling open source platform feedback loops in a progressive and evolutionary manner.

These ingredients create massive potential to incorporate sustainability and contribute to continued development of sustainable Product Service Systems (PSS), a mix of products and services. If success is defined as sustainable housing however, it is not occurring automatically on these platforms, because of a lack of a shared, holistic and Principle-based definition of sustainability. The following figure demonstrates components of open source housing design and the leap required for sustainability to become a reality in every housing project (see Figure 5).

Figure 5 Open Source as Leverage towards Sustainable Housing
3.2.2 Guidance for Open Source Housing Designers

This guidance combines FSSD with open source in an attempt to provide a more strategic system of open source design for sustainability. It is targeted towards designers, as this is arguably the point where sustainability attributes can most effectively be addressed. Design must become the solution to many housing sustainability challenges, instead of the main problem, and it is hoped this guidance will assist in the transition. This guidance was influenced by Bitterman, Lopez and Wright’s work on conflict resolution, where the framework was similarly integrated (2007). Specific actions and tools can be applied when and where necessary, complementing the FSSD; however, this guidance is not a prescription of actions and tools for every circumstance, as that would impose limitations and reduce flexibility for the project.

1. System Level: The system that is planned for

- Holistic understanding of the relationships between ecological and social systems, including thermodynamics and conservation laws, biogeochemical cycles, basic ecology, photosynthesis, institutions, networks, society's interdependent pursuit of human needs, the importance of diversity, etc.
- Holistic understanding of key structures, institutions and relationships of housing in the global socio-ecological system. These include the housing space (historical, political, economic, institutional and physical spaces)
- Design of open source housing project X within society within the ecosphere

2. Success Level: The Vision (Core Purpose & Core Values, Strategic Goals within Sustainability Principles) for Success in the System

- Adherence to the ‘System Conditions” for global socio-ecological sustainability
- Design of open source housing project X in compliance with its vision within constraints set by principles for global socio-ecological sustainability

3. Strategic Guidelines Level: Guiding principles for the process of moving strategically towards the vision of Success in the System. The ‘strategy’ itself is created by prioritizing the Actions (level 4) according to the
Strategic Guidelines and creating a step-by-step plan with a realistic timeline.

1) Backcasting from a co-created vision of success envisioned by each open source housing project

2) Introducing SSD strategies as early as possible

3) Obtaining a systems perspective to understand the housing need, and identify and address root causes and drivers of current situation for inhabitants

4) Incorporating a human needs perspective

5) Collaborating with ‘others’: ensuring meaningful participation, cooperation and inclusion

6) Communicating effectively through design

7) Building capacity and resilience: strengthening the social fabric

8) Prioritizing Actions according to the following principles (as a minimum):
   • Right direction (towards the vision)
   • Flexible platforms
   • Good return on investments (financially, socially, etc.)

9) Other principles as desired, such as urgency

10) Adhering to the Precautionary Principle

11) Involving legal means (e.g. building codes, environmental codes, impact assessment reports, green rating systems, etc.)

4. Actions Level: Concrete actions and capacity-building measures. The list of Actions, prioritized according to the Strategic Guidelines, creates the ‘strategy’

The following examples of possible actions are presented according to the associated strategic principle listed in level 3 above:
1) *Backcasting:*
   a) Participate in an online ‘ABCD’ workshop, as described in Section 2.2 to set goals and plan how to achieve them

2) *Early Introduction of SSD:*
   a) Begin education relating sustainability issues to human needs and begin implementing these ideas into design of houses as soon as possible

3) *Systems Perspective:*
   a) Map the housing site
   b) Identify and address root causes and drivers of the current housing situation or lack of housing situation
   c) Promote a culture of sharing, collaboration and innovation

4) *Human Needs Perspective:*
   a) Address basic human needs (e.g. analyse design decisions according to sustainability principle IV – does this action undermine anyone’s capacity to meet their needs?)
   b) Use inclusive, participatory, people-centred approaches to design

5) *Collaborating with ‘others’:*
   a) Use sustainability goals to unify designers; find common ground and build relationships
   b) Build relationships with building material designers and other stakeholders in the supply chain with an SSD approach, increasing economic market of sustainable products and services
   c) Work with local communities during the design process to allow for meaningful participation, a basic human need

6) *Communicating effectively through design:*
   a) Be transparent with decision-making; this allows people to understand, implement, adapt, and learn from designs and correct mistakes if necessary, thereby advancing the design
   b) Communicate sustainability through design so it is logical for people to adapt (e.g. be explicit about climatological aspects of the design such as direction facing)
   c) Be transparent, participative and inclusive during the design phase, as this allows for errors to be recognized early on in the process and ‘designed out’ to allow for the safest and most effective design
7) **Building capacity and resilience; strengthening the social fabric:**

   a) Create adaptable and efficient designs that enable vernacular skill building and pride in sense of place
   b) Involve communities to heal themselves in the aftermath of disaster, increase skill sets and opportunities and/or be more prepared in the event of a disaster
   c) Design DIY, user-friendly, culturally and socio-economically relevant designs, promoting education and cultural wealth

5. **Tools Level:** Tools that support the Actions and Strategy to achieve Success in the System. Included are tools for monitoring, measuring, assessing, analyzing, etc.

   ✓ Human needs assessments
   ✓ Culturally appropriate material for understanding systems surrounding housing site (e.g. traditions of the region, habits, food production, etc.)
   ✓ ABCD analysis/workshop
   ✓ International agreements (e.g. the Millennium Development Goals)
   ✓ ICT, computer, software, hardware, AUTO CAD, Internet, Intranet, open space platforms/forums (technological infrastructure)
   ✓ Case studies
   ✓ Green rating systems
   ✓ Process indicators
   ✓ Eco-design tools, life-cycle assessments, other tools as appropriate
4 Discussion

4.1 How can a SSD approach be integrated into open source housing initiatives to make them leverages towards sustainability?

4.1.1 Satisfying Shelter Needs Sustainably

In determining the scope of this research, the objective was to highlight both barriers and opportunities, as well as tools, for open source housing to contribute to SSD. The complex and overarching barrier of people’s inability to meet their housing needs has social and environmental circumstances specific to each locale. However, this research has shown that within and beyond the case study, the FSSD and open source philosophies can be combined to assist in creating a shared language and mental model for stakeholders, who are currently not communicating efficiently. The components of the open source design and realisation process, namely participation, collaboration, cooperation, and transparency, already demonstrate a step in the right direction to contribute to SSD.

Open source housing was selected for this research because of its potential for innovating around sustainability challenges rapidly, on a large scale; solving housing problems with new ways of thinking and collaborating. Aims include satisfying needs in a more locale-appropriate and needs-sufficient way than current housing practices. Current practices have demonstrated fragmented and reductionist approaches, as the entire system in which housing is embedded lacks a cohesive sustainability strategy. As the case study demonstrated, the target group is using environmentally-inappropriate materials, and struggling with choice and affordability.

Affordability is a main aim of open source housing and an area of focus for OS House. For example, the 8 Eco-principles encourage designers to utilize local materials and technology, minimizing production, transportation and construction costs of the building process for the target group. Case study findings indicated this could support alternative industries, if interest and action were engaged, decreasing the power of the current cement monopoly and its impacts on inhabitants and the ecosystem.
4.1.2 How and Why SSD?

As aforementioned, the main contribution of this research is in exploring a practical application of the FSSD in open source housing. Even though sustainability has been an aspect of some open source housing initiatives, the authors have not encountered evidence of the holistic use of a SSD approach in this area, where a robust sustainability strategy has been incorporated into the structure of the project system. The features of the FSSD, such as: backcasting, the framework as a decision-making and planning tool, and the vision for the future make it complementary to current and future open source housing strategies by providing a clear strategic framework for planning.

Central to SSD, backcasting is useful for the complex domain of housing within open source; aiding in planning and designing solutions within complexity. In addition, it can help when the current reality is part of the problem, as with housing and sustainability challenges. Backcasting can aid in shifting mindsets from the present towards a goal or vision that is further-reaching, not projected from the current reality but from a desirable future situation. This frees the solution-creating process from the constraints of current unsustainable patterns of decision-making and behaviour. Creating an inspiring and ambitious vision can be the first step for open source housing projects wishing to implement a SSD perspective.

The structure of the FSSD as a planning and decision-making tool is useful for mapping the current situation, as was used in this thesis to select tools to map the current housing dilemma and to frame open source solutions. Looking at open source housing through the lens of SSD allows for root problems to surface. Open source housing is similar to sustainability in that both require an individual and societal change of behaviour and perspective, as a departure from the current state. Using the FSSD to create a Principle-based vision for the future provides potential to seed this shift in open source housing.

Thus, the case study served as an example of using the FSSD to implement a SSD approach into an open source project, by using the five-level framework within the ABCD process to create a vision, choose tools, and structure research following a “stepwise” approach to examining the current reality and future potential for housing; while following basic principles in the definition of an end goal (sustainability).
4.2 Critical Response

Overall, results indicate that open source housing contains many of the necessary components of a successful process to be leverage towards sustainable housing. However, much of this remains theoretical and therefore, the guidance should be tested practically. It is not certain that the guidance will be well-received as the authors are unsure of the future of the Internet, the desire of open source housing designers for sustainability, or the time it will take to understand and incorporate the guidance into design challenges. The urgency for housing could inhibit rapid or full adoption of the guidance and it is uncertain whether or not understanding of the scientific underpinnings will be sufficient, or how to encourage participation from the diverse perspectives on open source platforms.

In addition, open source housing initiatives revealed that while open source allows for a way to innovate solutions around sustainability challenges with the creation of new online collaborative networks on open source platforms, this innovation does not necessarily lead to sustainable solutions. The authors believe that guidance can assist in strategically bridging the gap currently present, resulting in sustainable housing design.

It is imagined by the authors that the guidance created will be primarily applied to open source housing design challenges online which aim to unite designers on one project and thereby, expose them to the Principle-based definition of sustainability. It is believed this guidance can help address and overcome challenges faced when designing sustainable housing. The attempt is to provide a more strategic framework for designing sustainably via open source, providing a vision from which to backcast, and to structure the design process, allowing for creativity to flourish within sustainability constraints. It is argued by the authors that this integration could provide leverage for open source to contribute to SSD in a more robust fashion.

However, while this paper benefited from full awareness of the many facets of the FSSD, projects wishing to undertake a similar approach may need a deeper understanding of the tools available and processes required, which it was beyond the scope of this paper to provide. Therefore, it is hoped that the overall process and conceptual framework can be taken as a model for similar initiatives, which must then both adopt practices and adapt them to their own circumstances.
4.3 What are some current barriers and opportunities for open source housing to contribute to SSD; and how can these barriers be overcome and opportunities utilised?

4.3.1 Key Barriers and Opportunities

As outlined in the SWOT analysis, many barriers and opportunities exist for the implementation of sustainable, open source housing. The authors used the case study as a sample of an open source housing project in a LEDC to identify some key points in further detail, which are discussed below. While it is acknowledged that every project will have locale-based barriers and opportunities that can be utilised and overcome, there are universal barriers and opportunities in contributing to SSD. The strengths of the results are that the researchers were able to be in the field among the target group in the location where the pilot house project will begin and the information was collected experientially and intellectually.

To summarize, the main barrier is a lack of a shared, holistic and Principled-based definition of sustainability for open source housing designers. This can be overcome with the integration of the guidance into design challenges, spreading vastly and widely over collaborative networks, creating a shared vision for sustainable housing and contributing to SSD.

A key opportunity for open source housing to contribute to SSD is the success on which open source relies. In order for open source to exist, openness, transparency, involvement and cooperation must be present, and this organisational framework of aspects support socially sustainable processes. Additionally, this open environment can encourage and inspire discussion, knowledge-sharing, understanding and innovation around sustainability, pushing awareness, action and movement towards a sustainable society vastly and rapidly. In utilising this opportunity, sustainability can become part of the organisational framework in open source housing design, for example, through the guidance, enhancing the likelihood of making a contribution to SSD through sustainable housing.
4.3.2 Sustainable Development and Human Needs

It was recognized that while environmental awareness is present within the target group, other concerns are considered dominant, such as satisfying basic Subsistence needs like shelter and food. This is common in many LEDC, where OS House plans to continue the project. While this class generally does not struggle in meeting their basic needs as much as other lower economically earning classes do, it was believed by some interviewees that basic human needs must on the whole be satisfied before infrastructure supporting ecological management can be implemented. This agrees with the idea that human needs must be met in order to address ecological sustainable development and vice versa; societal and ecological systems are indivisible.

The pursuit of ecological sustainability is an essential part of the global effort to reduce poverty and other barriers to human needs because environmental degradation is inextricably and causally linked to problems of poverty, hunger, gender inequality, and health (United Nations Development Programme, 2005). However, many governments do not recognize the importance for human development in addressing ecological issues. Until this is understood, resources may be prioritized for short-term relief of human development problems at the expense of longer-term investment in sustainable development.

4.3.3 Political Barriers and Opportunities for Sustainable Housing in Ghana

Even though the government’s environmental branch, the EPA, has been in place for a few decades, environmental destruction is still occurring, endangering the sustainability of ecological and social systems in Ghana. Many LEDC like Ghana are adopting EIA procedures that have more in common with Western models than the socio-economic and institutional conditions in developing countries (Appiah-Opoku, 2000). Therefore, essential parts of this process are lacking, such as comprehensive knowledge about impacts and assessment, resulting in weak, reductionist-oriented assessments and thus, continued degradation of systems.

Decentralization of environmental and other forms of governance has the potential to enable local legislation to more accurately reflect and foment the flourishing of local building practices, drawing on sustainably managed
resources and focusing on local community-based projects. However, the current reality does not reflect this notion. Socioeconomic aspects of housing in Cape Coast are multi-faceted. Current infrastructure planning does not combat the environmental problems of sprawling development with insufficient infrastructure planning including waste management and water availability. In addition, policies which in practice allow freedom of decision-making for plot owners once the permit has been granted can contribute to poor planning on the individual household scale for waste management and other environmental problems.

Finally, the cement monopoly presided over by HeidelbergCement does not allow for alternative, locally-owned and controlled material industries which are more socially and environmentally friendly, to develop. This restricts the resilience of the market and subjects local house builders to potential exploitation through prices for materials. Government policies need to reflect the necessity for a diverse industry which includes environmentally-sound building material options.

4.3.4 Use of Local Materials

While local material use is encouraged to avoid the reduced transportation and energy, these resources must be more sustainably managed or they will not represent improvements to the overall sustainability of housing. Local production is preferable to importing material as it not only reduces transportation impacts but provides stimulation to the local economy. However, as one example of the dominant material, concrete, the heavy impacts inherent in production, combined with the extra heating costs required for buildings made of heat-retaining concrete, signify that it is preferable to instead use more natural and traditional materials. Government subsidies could be redirected to stimulate the creation of a more diversified materials industry with less of a focus on concrete.

4.3.5 Opportunities for Open Source for SSD in LEDC

The opportunity and ability to freely share and adapt open source content such as housing designs presents potential for LEDC to build capacity. A levelling in terms of access to information between geographic areas is occurring with initiatives such as 50 x 15, aiming to make Internet infrastructure more firmly in place in LEDC. Open source reduces costs for access and participation compared to other forms of training and knowledge acquisition, such as formal schooling in architecture or other
related disciplines. The adaptability of the content is also beneficial, in that it can be improved, transformed and applied as needed to meet an individual, community or society’s need. The results can be measured in terms of collaborative innovation, local capacity building and system strengthening, key ingredients for global sustainability.

The opportunities for contributing to SSD is that collaborative, distributed networks can engage in cooperatively creating value. For example, common global themes such as sustainability can become focal points for advancing progress. Open source platforms can provide a fertile space for education and awareness around sustainable development to occur and proliferate widely and rapidly, where time is of the essence in addressing sustainability issues. In LEDC, where ecological and social problems are rampant, local users can be exposed to new ideas, engage in the dialogue around sustainability, begin to have more choice and contribute solutions both locally and globally. Many of the most successful solutions today were generated by community-driven needs-based ideas, the community being integrally involved. The idea is to harness the resources of indigenous or vernacular knowledge to enhance the global network’s intelligence and leverage the open source network’s intelligence into LEDC. Collective knowledge can be considered a resource of the commons and ideas and practices for sustainable development should be shared freely and openly – open source enables this to occur. As problems vary in between and within economically developed and less-developed regions, users in LEDC can take the lead in adapting and generating solutions to local needs. The application beyond theory involves community groups along with public and private sectors.

There exists economic potential for users as well, such as developing local skills “for free”, creating local businesses and enabling active participation in the global information society. The systems that can be built around free open source content are likely infinite and relevant to sustainable development where sustainability is part of a shared vision.

A main hurdle in adopting open source technology for many economically developed countries, with solid technological infrastructure in place is one of changing habits, such as with computer interfaces. Most open source platforms vary from traditional ones currently in place and in LEDC where it is common that many individuals have never used a computer, and adapted to old technological systems, this presents an opportunity adapt to
new systems. Old systems can be bypassed, users ‘leapfrogging’ directly to newer technologies such as open source platforms.

4.4 Critical Response

Within the case study, a limited number of surveys were returned, meaning that the collated information could potentially be misleading. Of those returned, a disproportionate number were from teachers, which could sway the responses based on education and experience. In addition, the survey respondents’ salaries range hugely. This is a result of the researchers’ expectations not matching the wage correlation to job title. By the time this error was discovered, it was too late to gather new responses within the correct salary range for the target group, as outlined by OS House. To combat these errors, only the survey responses that were also addressed in one or more interview were included.

There was also a heavy reliance on interview information which, due to the nature of available data in certain areas, it was often not possible to double-check except through secondary word-of-mouth interviews. Despite these problems however, the researchers view the survey as a useful example of potential interest in the OS House project from members of the EMC and members of one class poorer who likely aspire to enter this class.

Ghanaian statistics in terms of population and some other key information are only collated every 10 years. The last poll was conducted in 2000, meaning new data will be collected this year and wasn’t available for the time frame of this research. This means that the only available information in these areas was 10 years old. Plenty of data was available about the environmental impacts of cement however, both within the literature and in experts’ knowledge; as a result the cement SLCA is more detailed than the others. In particular, it was difficult to gather information about clay. While it is the researchers’ inference that clay is more sustainable than cement if properly managed, more research must be performed in this area for a conclusive comparison.
5 Conclusions

5.1 Wider Implications of Study

5.1.1 Leadership in Transitioning towards a Sustainable Society

This research demonstrates potential for open source housing to contribute to sustainable development and in turn, aid in moving society towards sustainability, by helping to address sustainability challenges such as dwindling natural resources and physical degradation of land and by generating awareness, participation and resilience among individuals and communities. Equally important for a full transition is the incorporation of sustainability into mindsets, to shift behavioural change and thus affect business strategies and core activities, thereby gaining more credibility and leading stakeholders and other sectors in reducing violations to the 4 SPs.

Integrating a clear definition of sustainability into core open source housing design and realisation can seem demanding and daunting, yet it is argued this can be achieved with the help of a long-term vision of sustainability. A strong vision would promote sustainability as an overarching goal, a common ground for participants to address challenges together.

The guidance provides assistance for incorporating concepts of SSD into open source housing design, which can be used by diverse participants as a tool for the open source process. Meanwhile, the case study incorporates the FSSD into open source housing as an example of potential tools and processes.

5.1.2 A Systems Perspective

Through research on the housing sector, it is clear that current dominant housing practices are fundamentally inadequate for moving society towards sustainability. Key reasons for this are a lack of a systems perspective of problems and solutions in governments and business sectors; and a lack of recognition in these areas as well as in the general public of social and environmental implications, including the role of basic human needs and meaningful participation in the design process.
Combining time-tested knowledge such as vernacular architecture with cutting-edge ideas and technologies that incorporate sustainability is a way to capture the “best of both worlds” – meeting needs and desires in ways that work with local eco- and social systems. Open source platforms provide a space for bringing together these diverse kinds of knowledge – and enable the places with the most pressing housing needs to benefit from strategic sustainable development for long-term housing solutions. Ideally, the knowledge transfer can occur in both directions, with countries advancing the most quickly in terms of technology both freely sharing these advances and learning from countries with other types of expertise. A common language and mental model for defining success and the appropriate strategies, actions and tools can help people participate more effectively both during the housing design and realisation phases; the FSSD offers a system to achieve this.

Understanding the ecological and social system in which a housing project is being undertaken is essential in achieving success which gives individuals, communities and populations an opportunity to actualize their needs. A systems perspective also broadens the view of open source housing, aiding in the understanding of how the violation of the 4 SPs is relevant to sustainable housing.

### 5.2 In Terms of OS House

OS House has taken the role of initiating an open source pilot project within the EMC in Cape Coast, Ghana within the context of its broader goal of addressing sustainable housing in the region and eventually in LEDC worldwide. While the initiation of this open source project is a step in the right direction, addressing sustainability in a strategic manner must become and remain a top priority. A principled definition of sustainability would give improved guidance for open source ideas to bridge gaps to full sustainability. One of the goals of this thesis is to see OS House expand their leadership role and fully realise success with respect to meeting the Principled-based definition of sustainability. Within the vision of meeting the 4 SPs, achieving the introduction and proliferation of sustainable, modular housing through open source design in LEDC can be included.

In order for housing to achieve complete sustainability, this translates not into a single activity, product, service or life cycle that contributes directly
or indirectly to the violation of any of the four SPs. Rather, the impact OS House could have on the overall, interrelated system is tremendous, as inhabitants, community leaders, engineers, funders/sponsors, manufacturers, NGOs, designers, architects, planners, government policy makers, and scientists could become involved.

In the future when this state has been established, the vision can expand with actions targeting the restoration of ecological systems to ensure future sustainability of natural systems and society. In terms of housing this could translate into housing sites being measured for the capacity to support a healthy ecology even within the built environment, as sites for food production, safe ecological havens for biodiversity, recreation and habitat, thereby creating a net benefit for natural, cultural and economic systems. From this vision of success many short- and long- term measures can be discovered, by OS House and other initiatives. When considering the OS House project, as aforementioned, any actions taken towards sustainability must be regarded from a whole-systems perspective to actualize as many possible outcomes of the project as desirable. As OS House gains momentum in its role as a leader towards sustainable housing solutions, it can be well-positioned to make a strong business case for other organisations to follow its path.

Overall, as with any location where open source housing is initiated, the development and maintenance of sustainable housing will be reliant on education, awareness and behaviour of inhabitants, access to tools such as the Internet, government and business compliance, and community infrastructure that continually fosters sustainable actions and living.

### 5.2.1 OS House Case Study Recommendations

In terms of the case study, the current use of rock and sand to form concrete for building in Cape Coast is frequent, haphazard and largely unregulated, and its impacts on ecosystems are not fully understood. This must be explored as part of the analysis of sustainable building materials in the region. Using a classic LCA coupled with a sustainability perspective as recommended in this thesis to process quantitative data and compare the results against the sustainability efforts currently underway in the cement industry will enable a more conclusive set of recommendations for or against using cement as opposed to other materials. As for the new housing
model, insight garnered on materials through the SLCA assessments is useful for designers and for conversations on the systematic overview in the area. However, based on the winning design the materials should be examined in more depth, especially when considering potential large-scale proliferation of housing models and effects on surrounding systems.

In addition, a more complete stakeholder analysis with mapping of interrelationships would provide more opportunities for understanding and developing the Future Extended Enterprise template of the TSPD, boosting the local business case for a sustainable materials industry.

5.3 Further Recommended Research

The authors recommend further investigation of utilizing SSD as an approach to open source housing, by applying FSSD tenets in more cases, as potential exists to leverage housing towards sustainability and this paper merely scratches the surface of the myriad different perspectives and areas of interest with this combination. As the field of SSD is relatively new, more information, acquired through practical applications and experience, can help to guide the process. Because the success of open source relies on ingredients such as transparency, cooperation, and involvement, these benefits provide an opportunity to test and progress with SSD by encouraging experimentation of ideas and projects, while supporting socially sustainable processes.

One area for ongoing testing would be the application of the guidance into a design challenge from the onset, as a testing ground to provide insight into feasibility and provide feedback for overcoming and improving shortcomings. A more comprehensive and detailed version of the guidance that is dynamic and adaptive online in a truly open source format could include in-depth information about key concepts, such as backcasting, systems thinking, etc. including online workshops and conversations, to aid in sharing aspects such as the scientific underpinnings of sustainability. This could evolve into case studies to further learning.

Another area for exploration is the human needs/HCD angle, exploring how SSD can be combined with open source in ongoing projects to address needs beside shelter. While there exists HCD initiatives that address sustainability challenges, these could be bolstered with SSD, allowing for flexible platforms and long-term sustainability success.
References


Kathryn Frankel. CC talks with Architecture for Humanity. http://creativecommons.org/weblog/entry/7026 (accessed on April 9, 2010)


Appendices

Appendix I: 8 eco-principles as prescribed by OS House by which the design competition will be judged for the winning pilot house

8 Principles

1. **Locally embedded**

The design is embedded in the local cultural context (e.g. socially, economically and technically); it can be produced locally, aims at improving local employment and know-how and strives to minimize the need for import and transportation.

2. **Design the whole life cycle**

The future disassembly and material-use are an integral part of the design. All organic and technical materials can be separated. Natural resources are renewable.

3. **Climate**

The design makes optimal use of its location and surrounding climate conditions in order to minimize energy consumption.

4. **Size**

The design adheres to local building standards. Elements are transportable and re-usable (e.g. elements of house ‘A’ are exchangeable with elements of house ‘B’).

5. **Structure**

The load-bearing structure is separated from the demountable building skin.

6. **Connections**

All connections between the components and the load-bearing structure are
dry and demountable. This makes re-assembly easy and clean.

7. Installations

All installations must guarantee a flexible organization of the household and provide a sustainable way of living. The installations are smart, safe, upgradeable and adapted to the local ecology. They can function independently from the structure and skin.

8. Open Source Share

All designs and ideas will be published and shared on www.os-house.org to inspire others. Others may use, improve and adapt them. For that purpose designs, drawings, and presentations are made in a clear, reproducible manner.

Appendix II: Traditional Life Cycle Assessment compared to Strategic Life Cycle Management

System Boundaries in traditional Life Cycle Assessment (LCA)- based on selected known issues. The sustainability arena of a company starts with the strategic business dimension under company control, and continues with the surrounding societal and ecological dimensions that the company ultimately depends upon. The gray areas represent hot-spots, that is, impacts and issues that are essential from a sustainability perspective within those dimensions. Traditional LCA focuses mainly on a selection of known environmental impacts (Ny, 2006).
Strategic life-cycle management (SLCM) – sustainability principles as system boundaries. This approach starts with an overview of the whole system through the lens of the four Sustainability Principles (SPs). The large gray areas denote related hot spots, that is, impacts and issues found to be in conflict with the SPs and therefore essential for winning in the system. The smaller areas (black, or gray enclosed by a dashed line) may partly be impacts and issues newly discovered using the SPs, and partly the same impacts that were identified in figure 1.4, but now put in context. Some of these impacts and issues may be sufficiently described from the overview, while others (the solid black areas) may require deeper analysis using tools such as comprehensive life-cycle assessment. Other hot spot areas may not require any further analysis if, for example, the initial overview analysis reveals a strategic need to completely phase out a flow regardless of its exact size (Ny, 2006).

Appendix III: Housing survey disseminated in Cape Coast, Ghana among OS House target group of emerging middle class

Affordable and Ecological housing

Thank you for filling out this survey! The research team (Charlotte Barrow and Stephanie Peterka) can be contacted at opensourcehousingthesis@gmail.com.

The purpose of this survey is look at possibilities for cheaper, more locally-controlled and ecologically friendly housing in the Cape Coast region. Your name will not be included in the research, only your answers. The results (your answers) will be used for general information about local needs for housing. This will be very helpful for us to determine how the housing options available today are meeting or not meeting people’s needs. The results will be in a master’s thesis, which you can access through the Blekinge Institute of Technology’s website: http://www.bth.se/mls

Please note we greatly appreciate your assistance in our research. This survey is voluntary and you are able to withdraw your response at any time while filling it out. If you later decide you would prefer your data not to be included in the study, you can notify us (before May 1st) and we will remove your responses.

Definition of terms:

- Environment: In this survey, the “environment” means resources that are available in the area (ex. water, materials for building houses, energy for fuel, and others)

Questions:

1. How old are you? Please circle the correct option:
   a. 20 – 30
   b. 30 – 40
2. Are you female or male?
   a. Female
   b. Male

3. What is your job?

4. How much income do you earn (in cedis) each month?

5. Please circle the option that applies to you:
   a. I (and/or my spouse) own the house I live in
   b. A relative owns the house I live in
   c. I rent a room or the whole house I live in (if this is your answer, please skip to question 15. Otherwise please continue with question 6)

6. If you own the house you live in, did you (and/or your spouse) build it or witness it being built? (Please circle the correct answer. If your answer is no, please skip to question 15. If yes continue with question 7)
   a. yes
   b. no

7. How long did it take to build your house?

8. Please circle the materials that were used to build your house:
   a. Mud/mud brick
   b. Wood/bamboo
   c. Metal sheet/slate/asbestos
   d. Stone
   e. Burned bricks
   f. Cement/sandcrete blocks
   g. Landcrete
   h. Thatch
   i. Cardboard
j. Vinyl tiles  
k. Ceramic/marble/tiles  
l. Terrazzo  
m. Palm leaves/raffia/thatch  
n. Concrete  
o. Other (please label)

9. What was the most important consideration when choosing materials for building your house? Please write a number beside each option that was important when you were building your house, 1 being the most important, 2 slightly less important, etc.
   a. Price/affordability  
   b. Attractive appearance  
   c. Length of time the material is expected to last  
   d. Safety (i.e. not considered to have negative health impacts)  
   e. Ease of availability  
   f. Future ability to meet your needs through the surrounding environment (materials available, clean drinking water, etc.)  
   g. Other (please list here)

10. Would you have preferred to use different materials for your house?
   a. yes  
   b. no

11. If yes, which materials and why?

12. Was the environment an important consideration when designing and building (regarding materials, waste, carbon dioxide emissions and energy consumption?)

13. Who was the main designer for your house?
   a. Me and/or my spouse  
   b. A professional architect or house designer (can include friends, relatives, neighbours, etc.)
c. A friend, relative or neighbour or other who is not a professional house designer
d. A contractor
e. Other (please list)

14. What was the most problematic (difficult) part of the process in building your house? Please write a number beside each option that was problematic when you were building your house, 1 being the most problematic, 2 slightly less problematic, etc.
   a. Design
   b. Getting and/or choosing materials
c. Cost of materials
d. Other (please list)

15. How much time do you spend on the Internet, on average?
   a. No time
   b. 1 hour or less per week
c. Between 1 – 3 hours per week
d. Between 3 – 5 hours per week

16. If housing designs were made freely available on the Internet for you to use, along with the construction documents, would you make use of them if you were building your own house?
   a. yes
   b. no

17. Why or why not?

18. Do you belong to a community based organisation?
   a. yes
   b. no

19. If yes, how often do you meet?
a. Once a week
b. Once a month
c. Other (please specify)

20. Do you make decisions about your house based on discussions you have in these meetings?

21. Do you think the resources/materials used today for housing will be less or more available when the next generation (i.e. your children) build their houses?
   a. Less available
   b. More available

22. Why?

23. What do you like about the house you live in?

24. What would you change about the house you live in if you could?
## Appendix IV: Human Needs Matrix

<table>
<thead>
<tr>
<th>NEEDS</th>
<th>Being (qualities)</th>
<th>Having (things)</th>
<th>Doing (actions)</th>
<th>Interacting (settings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsistence</td>
<td>physical, emotional, mental health</td>
<td>food, work, shelter</td>
<td>work, procreate, rest/sleep, clothe, feed</td>
<td>social setting, living environment</td>
</tr>
<tr>
<td>Protection</td>
<td>autonomy, care, adaptability</td>
<td>social security, health systems, rights, family, work</td>
<td>cooperate, plan, prevent, help, cure, take care of</td>
<td>living space, social space, dwelling</td>
</tr>
<tr>
<td>Affection</td>
<td>tolerance, respect, generosity, sense of humour, sensuality</td>
<td>friendships, family, relationship with nature</td>
<td>take care of, share, make love, express emotions</td>
<td>privacy, intimate spaces of togetherness</td>
</tr>
<tr>
<td>Understanding</td>
<td>critical capacity, receptivity, intuition, curiosity</td>
<td>literature, teachers, educational and communication policies</td>
<td>meditate, study, analyse, investigate</td>
<td>families, schools, universities, communities</td>
</tr>
<tr>
<td>Participation</td>
<td>adaptability, sense of humour, dedication, receptivity</td>
<td>responsibilities, duties, work, rights, privileges</td>
<td>cooperate, propose, dissent, express opinions</td>
<td>associations, parties, churches, neighborhoods</td>
</tr>
<tr>
<td>Idleness</td>
<td>imagination, curiosity, tranquility</td>
<td>peace of mind, parties, spectacles, clubs, games</td>
<td>daydream, play remember, relax, have fun</td>
<td>landscapes, intimate spaces, places</td>
</tr>
<tr>
<td>Spontaneity</td>
<td>to be alone, free time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>------------</td>
<td>------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creation</td>
<td>imagination, skills, abilities, invent, build, spaces for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>work, method, design, work, expression, workshops,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>curiosity, techniques compose, audiences, cultural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>inventiveness, interpret groups</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>autonomy, determination</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identity</th>
<th>sense of language, symbols, get to know places one</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>belonging, self-esteem, values, religion, oneself, grow, belongs to,</td>
</tr>
<tr>
<td></td>
<td>work, customs, commit oneself, everyday settings,</td>
</tr>
<tr>
<td></td>
<td>consistency, norms, habits, recognize oneself maturation stages,</td>
</tr>
<tr>
<td></td>
<td>historical memory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freedom</th>
<th>autonomy, equal rights dissent, choose, temporal/spatial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>passion, self-esteem, run risks, develop spatial</td>
</tr>
<tr>
<td></td>
<td>open-mindedness, awareness, disobey, plasticity</td>
</tr>
<tr>
<td></td>
<td>tolerance, be different from (anywhere)</td>
</tr>
</tbody>
</table>
Appendix V: Annual Income Levels Indication in Ghana 2009

Exchange Rate Ghana Cedi: Euro = 1: 0.47

<table>
<thead>
<tr>
<th>Social class</th>
<th>Income in Ghana Cedi</th>
<th>Savings (5-10) years</th>
<th>Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below poverty line</td>
<td>Below 5000</td>
<td>none</td>
<td>Artisans, laborers</td>
</tr>
<tr>
<td>Low income</td>
<td>5000-10000</td>
<td>1,500-4000</td>
<td>Sales men in food products, mechanics, masons, non-trained teachers, secretaries</td>
</tr>
<tr>
<td>Lower middle class or emerging middle class</td>
<td>11000-20000</td>
<td>3000-10000</td>
<td>Trained teachers, nurses, police, army, junior civil servants</td>
</tr>
<tr>
<td>Upper middle class</td>
<td>21000-30000</td>
<td>8000-10000</td>
<td>Junior lecturers, senior civil servants, junior doctors</td>
</tr>
</tbody>
</table>

### Appendix VI: Average Cost Breakdown of Building a House

Note: Price range based on 2009 prices when the inflation rate was about 20%, meaning when the houses will be sold in 2010 the prices will have increased by at least 20%.

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Proportion of Cost</th>
<th>Cost Ghana Cedi 15.000 House</th>
<th>Cost Ghana Cedi 25.000 House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>14%</td>
<td>2.100</td>
<td>3.500</td>
</tr>
<tr>
<td>Infrastructure &amp; Installation</td>
<td>22%</td>
<td>3.300</td>
<td>5.500</td>
</tr>
<tr>
<td>Material</td>
<td>41%</td>
<td>6.150</td>
<td>10.250</td>
</tr>
<tr>
<td>Labour</td>
<td>23%</td>
<td>3.450</td>
<td>5.750</td>
</tr>
<tr>
<td>Financing</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overheads &amp; Profit</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>15.000</td>
<td>25.000</td>
</tr>
</tbody>
</table>