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Environmental Impact Assessment of Composition Wall Materials Alternatives

Ibny Baitak as a Case Study

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Abstract

This study investigated six wall composition material substitutes employed in constructing Egypt's Ibny Baitak Project for their potential environmental impact. Clay brick (20 cm), cement brick (20 cm), and autoclaved aerated concrete (AAC) (20 cm) blocks were the four materials evaluated. Each wall material is reinforced with (4 cm extruded polystyrene (XPS) insulation in the fourth, fifth, and sixth scenarios. The study used a life cycle assessment (LCA) technique to assess the environmental impact of these products from cradle to gate, including raw material extraction, processing, and transportation. The outcomes showed that the environmental effects of the four materials varied greatly regarding the three impact categories of potential global warming, non-renewable energy use, and respiratory pollution. Regarding the midpoint result, the AAC ranked second by 1.49 pt, followed by the cement bricks by 2.25 pt, with the clay brick recording the lowest environmental effect. The environmental impacts in the three final scenarios increased by 1.24 pt, 1.86 pt, and 2.55 pt, and an incremental rate of 13% when the XPS was added to the three wall types. The 20 cm cement brick recorded the highest value, 8.40K KG Co_2e, and the 4 cm XPS + 20 cm cement brick composition recorded the lowest value, 1.97K KG Co_2e. When considering the endpoint results, the cement brick recorded the highest values by 8.40K $KG\ Co_2$e, which show climate change has the most significant impacts. Regarding the resource's depletion impact, cement bricks recorded the highest values with 138.42K Mj primay. The study's findings provide important details regarding the environmental effects of composition wall materials. They can influence decisions made in the construction sector, favoring greener building practices.

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Keywords: Life Cycle Inventory; Life Cycle Impact; BIM; Insulation Material; Wall materials.

1. INTRODUCTION

In 2019, building operations and construction activities accounted for 38% of global energy-related CO_2 emissions, as highlighted in Figure 1, the highest level ever recorded, according to the United Nations Environmental Programme (UNEP) [1], [2]. The UNEP advises governments to prioritize low-carbon buildings in their stimulus packages and updated climate pledges to reach the net zero-carbon building stock by 2050. According to UNEP, direct building CO_2 emissions must be decreased by 2030. It translates to a decline in emissions from the building sector of almost 6% per year until 2030, or nearly 7% less than the global energy industry's CO_2emissions in 2020 due to the epidemic.

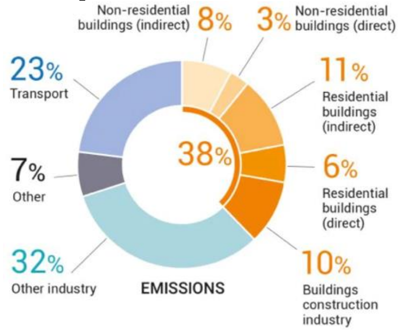

Figure 1 Distribution of emission among all contributors by UNEP [1], [2].

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In 2019, expenditure on energy-efficient buildings was increased, as presented in Figure 2. Although it represents a small percentage of the $5.8 trillion invested globally in the building and construction industry, there are encouraging indicators that energy efficiency and building decarbonization are altering investment choices [3].

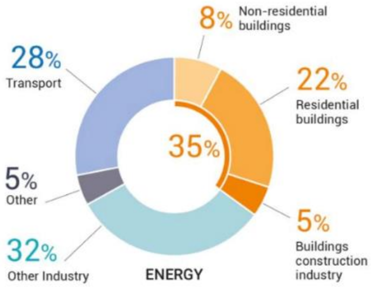


Figure 2 Distribution of energy consumption among all contributors by UNEP [1], [2].

On the other hand, modern urbanization includes creating new cities and urban regions, which is done to accommodate the expanding population and provide basic amenities and services. However, the development of new towns and buildings has the potential to significantly damage the environment through resource use, energy use, and emissions [1], [2]. It is crucial to assess the environmental effects of building materials and construction methods to reduce the ecological imprint and encourage sustainable development,

One essential part of the environmental impact assessment (EIA) is selecting appropriate building materials with a low environmental impact. This study intends to evaluate the environmental impact of six wall composing materials, including clay brick (20 cm), cement brick (20 cm), and autoclaved aerated concrete (AAC) (20 cm) blocks, used in the development of the Ibny Baitak Project, a new city in the region. In the fourth, fifth, and sixth scenarios, each wall material is reinforced with (4 cm) extruded polystyrene (XPS) insulation.

The life cycle assessment (LCA) methodology, which assesses the environmental impact of a product or material throughout its entire life cycle, from the extraction of raw materials to transportation, will be used to conduct the EIA. The LCA will consider several environmental impact categories, including the potential for eutrophication, acidification, global warming, and human toxicity.

The EIA's findings will offer insightful data on how various wall materials affect the environment, which can be used to inform and direct the choice of suitable building materials for the Ibny Baitak Project. The research's conclusions can also be utilized in other building initiatives that support sustainable growth and mitigate the adverse effects of urbanization on the environment.

This study's research subject is evaluating the environmental impact of various composition wall materials used to develop a new city, the Ibny Baitak Project. Due to the usage of non-renewable resources, energy use, and emissions, the development of new cities and buildings contributes significantly to environmental degradation. It is crucial to assess the environmental impact of various wall materials to choose materials with a smaller ecological footprint.

2. LITERATURE REVIEW

The three sections of the literature review are LCA application, AAC and bricks, and insulating materials. First off, according to the UNEP's Emissions Gap Report [4], global emissions have continued to climb, and the difference between current emissions and the emissions required to reach the Paris Agreement targets has widened. It is a valuable tool for decision-makers, researchers, and experts attempting to lessen the effects of climate change and reduce greenhouse gas emissions [5].

The ability of alternative materials to reduce significant environmental effects and advance sustainable building techniques has been highlighted by Asdrubali et al. [6]. In five heat zones in China, Dong et al. [7] used the LCA approach to examine the impacts of different connections on the whole-lifecycle energy consumption of sandwich wall panels. The energy efficiency of several construction materials has been evaluated by Yüksek [8]. The authors have evaluated the thermal resistance, thermal conductivity, and other energy-related factors of various building materials, including insulation, walls, and roofing. The research has demonstrated how using energy-efficient building materials can lower energy consumption and improve the thermal performance of the building exterior. Akadiri et al. [9] have proposed a multi-criteria evaluation technique for selecting sustainable building materials. The authors have investigated various building mat's availability, cost, toughness, and energy efficiency. Balali et al.'s [10] study on novel materials is centered on building facades that support the Sustainable Development Goals (SDGs). Among other qualities, the price, durability, energy efficiency, and environmental effects of several intelligent materials have all been investigated. Moussavi Nadoushani et al. [11] have proposed a multi-criteria decision-making framework for selecting building façade systems based on sustainability factors. The writers have investigated the cost, aesthetic value, environmental effect, and energy efficiency of various façade solutions. To evaluate the environmental consequences of building materials at an early stage of office building design, Najjar et al. [12] integrated Building Information Modeling (BIM) and LCA. The authors have investigated the cost, availability, and environmental impact of several building materials.

Prior research has focused on several studies on selecting ecologically friendly building materials and building envelope systems. The articles have demonstrated the usefulness of life cycle assessment (LCA) methodologies, multi-criteria decision-making frameworks, building information modeling (BIM), and LCA integration in evaluating the sustainability, energy efficiency, and environmental impact of building materials and envelope systems. The researchers have also provided recommendations for selecting and implementing eco-friendly systems and goods based on suitability and adherence to project requirements.

Regarding the LCA of AAC and various wall materials, Kamal [13] has examined AAC blocks, emphasizing their sustainability and potential. The advantages of AAC blocks for the environment, including lower energy use and greenhouse gas emissions during production and use, have also been covered in the article. The investigation has shown that AAC blocks are superior to conventional building materials in several ways, including their fire resistance, lightweight nature, and ability to insulate against heat.

An environmental product declaration (EPD) for AAC based on ISO 14025 and EN 15804 standards has been presented by Atacan et al. [14]. The analysis's findings demonstrate that AAC is less harmful to the environment than conventional building materials like brick and concrete. An analysis of AAC, a sustainable and lightweight building material, was conducted by Kalpana et al. [15]. The authors review AAC's characteristics, such as fire resistance, compressive strength, and thermal insulation. Khalil [16] has examined the characteristics of AAC, such as its lightweight, fire resistance, and thermal insulation, and its possible benefits in building construction. The study also investigated whether employing AAC in building construction is economically feasible and whether it might affect energy use and greenhouse gas emissions. The LCA of three types of interior partition walls used in buildings—gypsum plasterboard, AAC blocks, and calcium silicate blocks—has been given by Valencia-Barba et al. [17] and Ferrández-García et al. [18]. The findings indicated that gypsum plasterboard has the most significant environmental impact, whereas AAC blocks have the lowest, especially regarding energy consumption and ability to cause global warming. Employing the LCA technique, Muneron et al. [19] evaluated the environmental effects of using concrete and ceramic bricks in the vertical seal subsystems of residential buildings. The findings indicated that ceramic brick requires less energy and has a smaller carbon footprint during production than concrete blocks, so it has a lesser environmental effect.

In conclusion, previous articles have focused on AAC and its potential as a sustainable building material. The reviewed studies analyze AAC's properties, including its thermal insulation, fire resistance, and lightweight properties, and its potential impact on reducing energy consumption and greenhouse gas emissions. The studies also highlight the challenges and limitations of using AAC, such as its relatively low compressive strength.

To sum up, earlier articles have emphasized AAC and its potential use in sustainable construction. The examined research examines AAC's characteristics, such as its fire resistance, thermal insulation, and lightweight nature, as well as its possible ability to lower energy use and greenhouse gas emissions. The researchers also highlighted the drawbacks and restrictions of employing AAC, including its comparatively low compressive strength.

Gomes et al. [20] have examined the environmental impact of the tiles' complete life cycle, including raw material extraction, production, use, and disposal, considering the LCA of insulation materials. They contrast two expanded polystyrene (EPS) varieties and XPS insulating tiles. As a result of the production of EPS and XPS insulation tiles, the environment is impacted, particularly regarding the potential for global warming and the depletion of fossil fuels. An extensive review of aerogel insulation for building applications was conducted by Baetens et al. [21]. The assessment emphasized the benefits and constraints of aerogel insulation for use in construction. An experimental investigation of the thermal performance of a building wall using XPS foams and vacuum insulation panels (VIPs) has been described by Li et al. [22]. The authors examined the wall assembly's thermal conductivity and heat transfer coefficient and then contrasted it with a wall assembly devoid of VIPs. Building insulating materials' embodied energy and carbon have been thoroughly examined by Grazieschi et al. [23]. The review has emphasized the significance of considering building materials' whole life cycle in sustainability assessments. It highlights the need for more precise and transparent statistics on the carbon and energy embodied in insulating materials. The effectiveness and cost-benefit analysis of various insulating materials used to lower the heat load of an existing residential building were examined by Awadly et al. [24]. To lower operating energy consumption and CO_2 emissions, Leila Farahzadi et al. [25] investigated alternative building materials in the external walls of a typical residential structure in Tehran. The characteristics of several wall and insulation materials, such as AAC, hollow brick, EPS, and XPS, have been examined by the writers. The research discussed in this literature review concludes by emphasizing how crucial it is for sustainability evaluations to consider the entire life cycle of building insulation materials. The environmental effects of insulation material production are substantial, especially regarding the possibility of global warming and the depletion of fossil fuels.

Thermal conductivity, density, durability, and other attributes of several insulating materials, such as EPS, XPS, and polyurethane (PUR), have all been examined and assessed by Villasmil et al. [26]. Additionally, the study assessed the installation techniques of various insulations, such as wrapping, encapsulating, and embedding. Resalati et al. [27] examined the LCA of several vacuum insulation panel (VIP) core materials using a cradle-to-gate methodology. EPS, fiberglass, and silica aerogel are among the VIP core materials whose environmental effects have been assessed by the writers. An overview of conventional, cutting-edge, and renewable thermal building insulation materials has been given by Abu-Jdayil et al. [28]. The study has shown how insulating materials can save energy use and enhance the thermal efficiency of building envelopes. A comparative LCA of several insulating materials for buildings in the continental Mediterranean climate has been given by Llantoy et al. [29]. The study has shown that LCA is useful for assessing how insulating materials affect the environment.

The research discussed in this literature review concludes by emphasizing how crucial it is for sustainability evaluations to consider the entire life cycle of building insulation materials. The environmental effects of insulation material production are substantial, especially regarding the possibility of global warming and the depletion of fossil fuels.

Much research has been published in environmental impact assessments and LCA of various aspects of construction and industries in Egypt. Ali et al. [30] provided a case study on evaluating a residential building's environmental life cycle in Egypt. The authors examined the building's life cycle effects on the environment and took waste production, material consumption, and energy consumption into account. In 2023, Ali 2023 [31] examined the LCA of polymeric and traditional concrete used to build a clinic at Egypt's Assiut University Hospital. The objective was to assess the environmental sustainability of these building materials and determine the most sustainable. Yacout et al. [32] centered on evaluating paint production's environmental impact in Egypt. The authors assessed how the manufacture of paints affected the environment, considering things like resource usage, emissions, and waste creation.

Regarding the cement industry, Ali et al. [33] compared cement factories in Egypt and Switzerland using the LCA methodology. They evaluate the environmental effects of Egypt's cement production and contrast it with the environmental record of Swiss cement factories. Mousa et al. [34] discussed this construction method's benefits and sustainability features, emphasizing its potential for energy efficiency and less environmental impact. Abdelhalem et al. [35] used the LCA program to do an environmental analysis of a daycare facility in Egypt. They evaluate how the building's life cycle stages—construction, use, and end-of-life—affect the environment. Ali A. [36], [37], [38] has published many articles on the LCA applications on glass windows, wall paintings, insulation materials, and Polymeric and Conventional Concrete.

The combined effort of these articles raises awareness of sustainability issues and their effects on the environment in several Egyptian industries, including residential construction, building materials, the paint and cement industries, rice production, and building techniques.

The literature analysis highlights the significance of carefully choosing and utilizing suitable insulation and building materials to enhance structures' thermal efficiency, energy economy, and sustainability. Most studies above have concentrated on lowering energy usage and enhancing building thermal performance. As a result, this study will emphasize how crucial it is to weigh the environmental effects of various wall materials during their whole life cycle, from cradle to gate approach. The conclusions of these studies can support green building techniques and lessen the environmental impact of buildings [5].

3. CASE STUDY ANALYSIS

This study will use the New Assiut City (NAC) in Assiut, Egypt, as a case study because it is a new city that struggles to provide its citizens with the most significant structures and services [39]. As a result, the presentation of the NAC is the main topic of this part. The NAC lies about 15 kilometers from Assiut on the (Cairo - Sohag) desert route, close to its junction with the (Hurghada - Assiut) road. As seen in Figure 3., the urban block of the city is composed of two residential neighborhoods split by a critical service axis (city center), a third district (the extension area), an industrial zone, and a regional area.

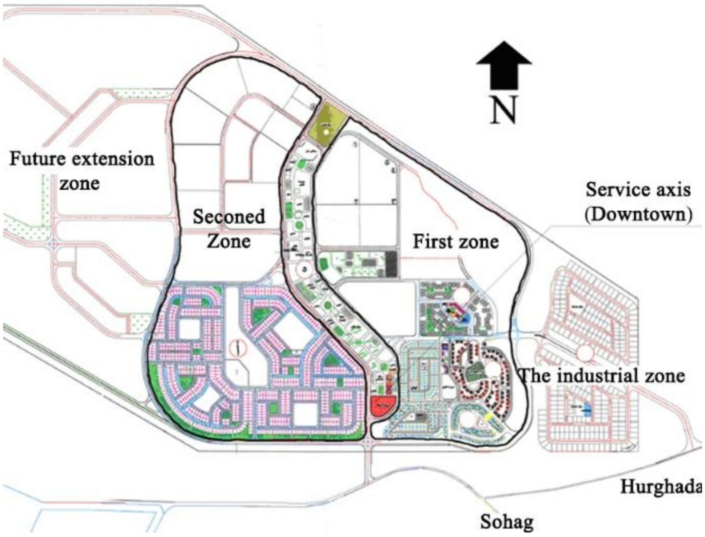
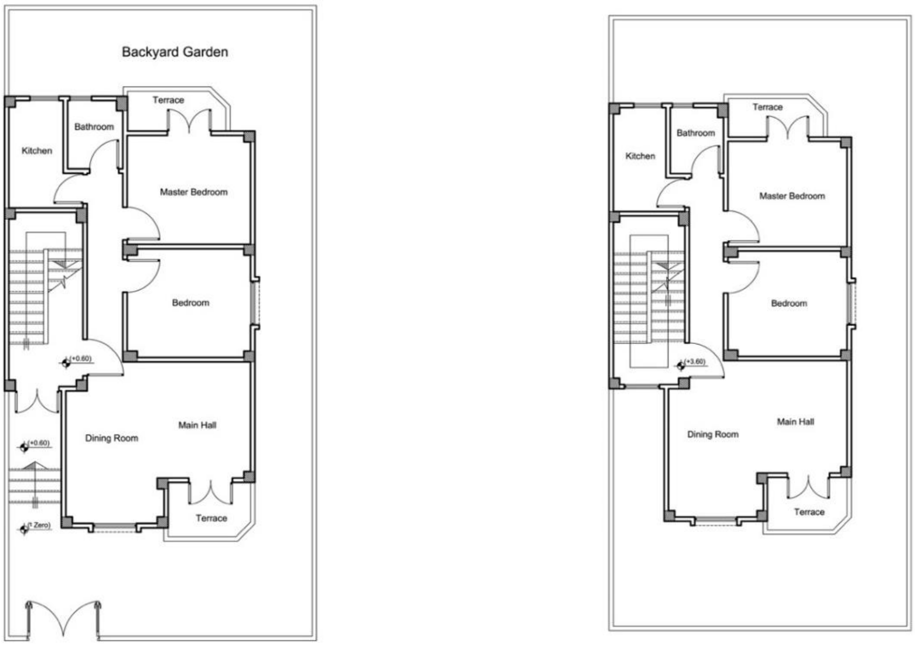


Figure 3 NAC master plan (by visiting the New Assiut City Municipal)

With a construction rate of 50% of the block, the beneficiary citizen constructs a housing (residential) unit on top of them. This residential unit has a floor area of ($63m^2$) and comprises two bedrooms, a hall, a kitchen, and a bathroom. It also has a stairway with a floor area of ($12m^2$) that leads to a flat floor of ($75m^2$). There are three different models (X), (Y), and (Z), and this essay will use model (X) as a case study, as shown in Figure 4.



(a) Ground floor (b) First floor

Figure 4 Ibny Baitak project model (X).

Figure 5 presents the justification for the author's choice to use the Ibny Baitak project in NAC as a case study for further investigation. Because the building construction process depended on the honors, significant problems have surfaced. These structures were constructed using various materials, including foundation materials, brick and concrete kinds, coatings, and insulating materials (with heat and water resistance); most of them were without approved specifications.

Figure 5 Example of structural problems of Ibny Baitak model (pictured in July 2023) [39].

4. LIFE CYCLE ASSESSMENT METHODOLOGY

Depending on the designated manufacturing procedure and transportation techniques, the LCA approach can change for each wall composition. Inventory analysis can be done using original data gathered from the manufacturers or secondary data from databases like Ecoinvent V3.2 [40]. It is possible to carry out the impact evaluation utilizing recognized impact assessment techniques. In conclusion, the LCA approach for various composition wall materials entails establishing the purpose and parameters of the investigation, carrying out an inventory analysis, determining the impact, and providing an interpretation. The methodology offers a thorough understanding of how wall materials affect the environment and may be used to inform decision-making when choosing suitable building materials to reduce environmental impact.

The following steps are included in the LCA approach for six wall composition materials, such as clay brick (20 cm), cement brick (20 cm), and AAC (20 cm) blocks were the four materials evaluated. In the fourth, fifth, and sixth scenarios, each wall material is reinforced with (4 cm) XPS insulation. As shown in Figure 6, the International Standards Organization (ISO) is a well-known standards body. (1) ISO 14040: Principles and Framework [41], (2) ISO 14041: Goal Definition and inventory analysis [42], ISO 14042: Life-cycle impact assessment [43] and ISO 14043: Life-cycle Interpretation [44].

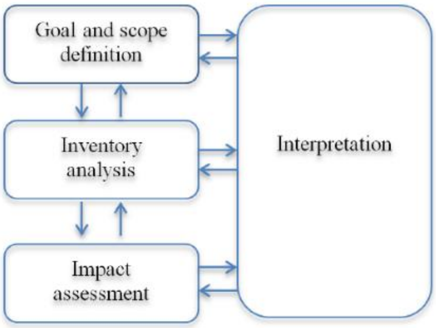


Figure 6 Four steps of the LCA approach [45].

Ali et al. [46] and Al-Ghamdi [47] have published their findings following a thorough comparison. It was determined that PRe SimaPro is the most frequently utilized LCA tool. As a result, all open-license Ecoinvent datasets were accessed using the academic PRe SimaPro V9.5 [48].

4.1. Goal and scope

This stage defines the purpose of the study, the functional unit, and the system boundaries. The study aims to evaluate the environmental impact of six wall compositions throughout their life cycle. According to the study, functional units of various materials used in an LCA should be carefully selected to ensure that the evaluation accurately reflects the product's environmental impact. According to what is stated, the functional unit for this inquiry is 1 kg for the various types of material. Figure 7 displays the specific system boundaries of compositions in more detail. This study will concentrate on the (cradle to gate) border, which includes (1) raw material extraction and continues through (2) raw material transportation and storage and (3) production and packing.

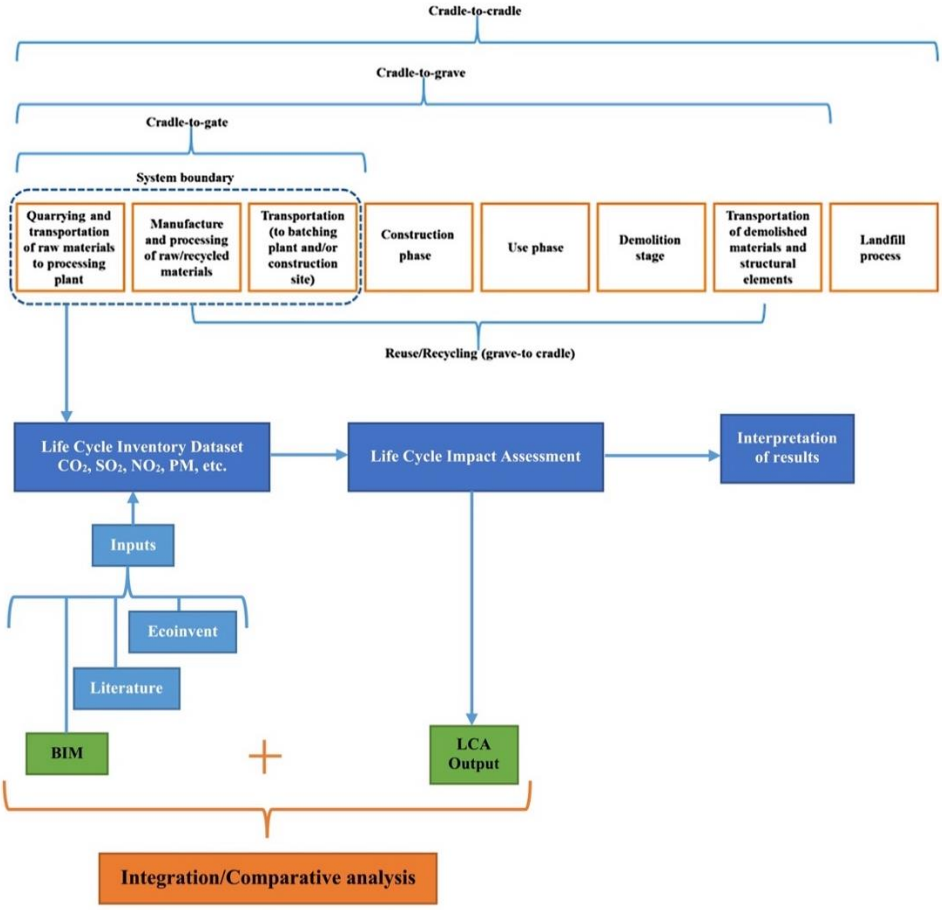


Figure 7 System boundary of LCA application in this study.

Figure 8 depicts the complete brick manufacturing process and highlights the boundary under study.

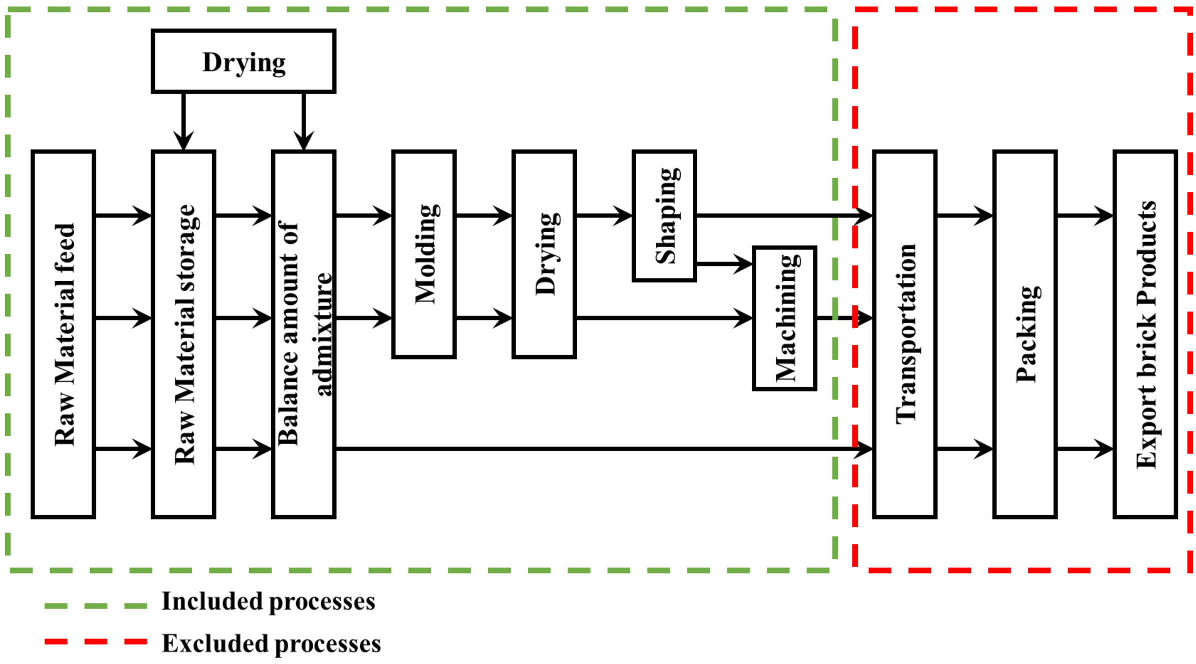


Figure 8 Process flow diagrams of brick manufacturing.

The effects of the six wall compositions on the environment will be evaluated in this study. Figure 9 shows that all materials have been constructed in SimaPro. Figure 10 depicts the network flows of the manufacturing processes for AAC blocks, clay brick, and cement brick, which are the main three wall compositions.

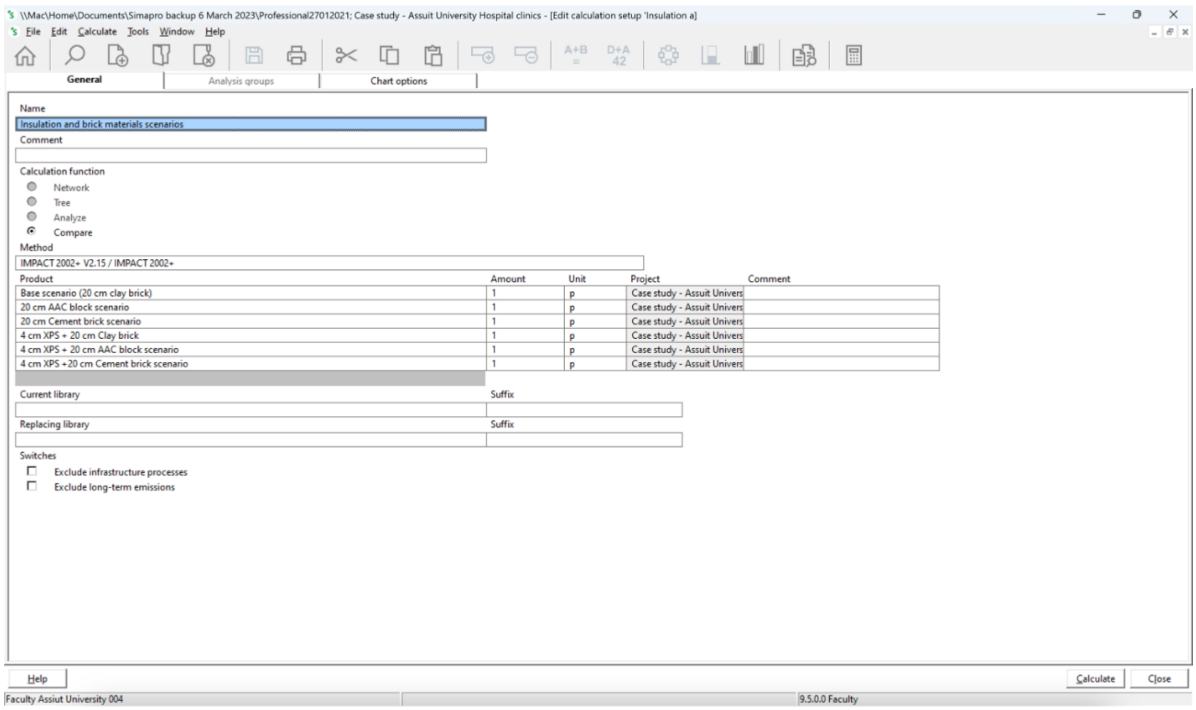
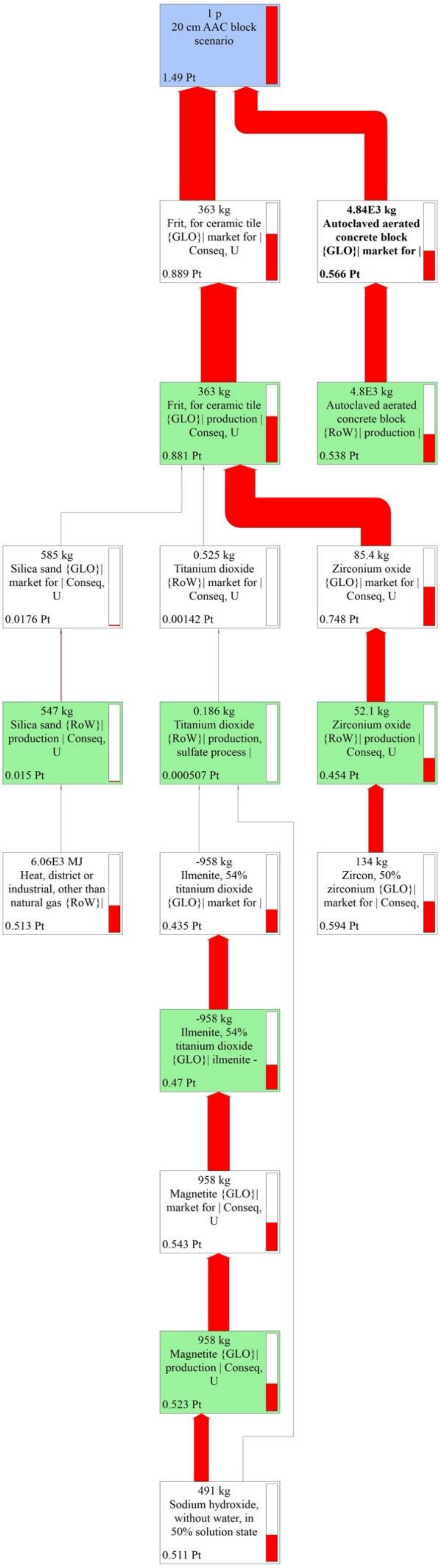
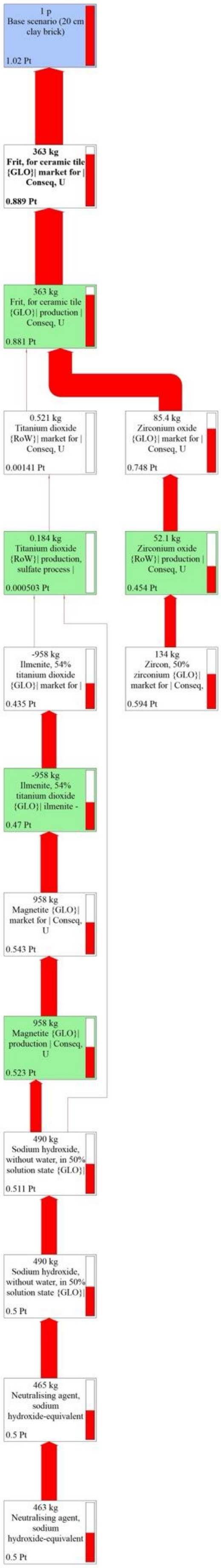


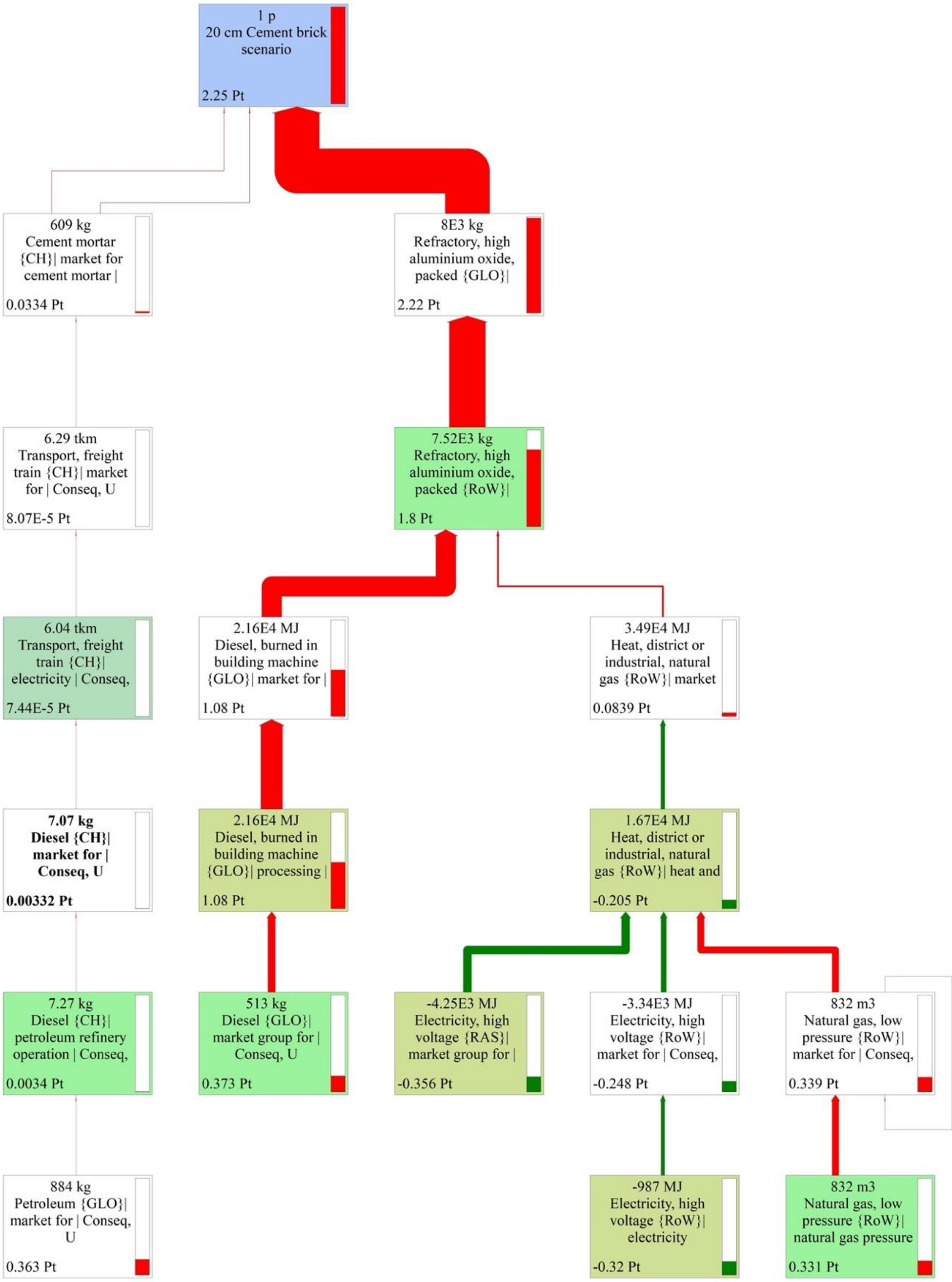
Figure 9 Scenarios' calculation setup of the six wall compositions built in SimaPro.



(a) Network flow of AAC block



(b) Network flow of Clay brick



(c) Network flow of Cement brick

Figure 10 Network flow of the main three wall compositions in SimaPro.

4.2. Life cycle Inventory database

This study had to depend on a few hypotheses from the literature review to make up for the lack of data for the input materials because there are few LCA and LCI applications in Egypt. Rocamora et al. [49] have assessed a wide range of LCA applications for construction materials. Figure 11 shows the database version used for this investigation, Ecoinvent V3.2 [40]. The Ecoinvent (SimaPro-based) database's worldwide market sector was chosen to be more compatible with Egyptian industrial methods.

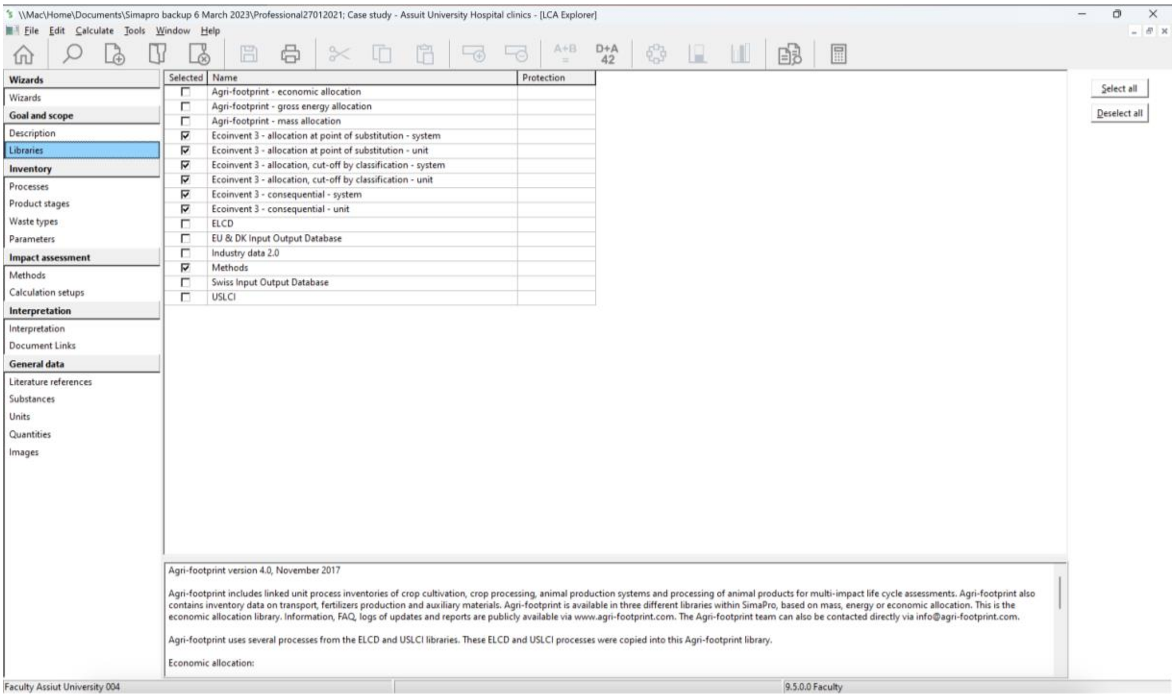


Figure 11 SimaPro V9.50 Library (Ecoinvent V3.2 database shown)

4.3. *Life cycle impact assessment (LCIA)*

This stage involves evaluating the environmental impact of the wall compositions using established impact categories, such as global warming potential, acidification, eutrophication, and human toxicity. The impact categories are weighted based on relative importance to obtain a single score for each material. As a result, based on the ISO standard, it distinguishes between the environmental effects of different wall composition materials. The midpoint and endpoint approaches will be used in this paper to calculate the environmental effects. The environmental impacts will be investigated in this work using the IMPACT 2002+ technique, which is detailed in Table 1 and is based on the literature review [46], [47], [50], [51].

TABLE 1 IMPACT 2002+ CHARACTERIZATION VERSION Q2.2 [52].

[source]	Midpoint category	Midpoint reference substance	Damage category (End-Point)	Damage unit	Normalized damage unit
[a]	Human toxicity (carcinogens + non-carcinogens)	kg Chloroethylene into air-eq	Human health		
[b]	Respiratory (inorganics)	kg PM2.5 into air-eq	Human health	DALY	Point
[b]	Ionizing radiations	Bq Carbon-14 into air-eq	Human health		
[b]	Ozone layer depletion	kg CFC-11 into air-eq	Human health		
[b]	Photochemical oxidation (= Respiratory (organics) for human health)	kg Ethylene into air-eq	Human health Ecosystem quality	n/a	n/a
[a]	Aquatic ecotoxicity	kg Triethylene glycol into water-eq	Ecosystem quality		
[a]	Terrestrial ecotoxicity	kg Triethylene glycol into soil-eq	Ecosystem quality		
[b]	Terrestrial acidification/nutrification	kg SO_2 into air-eq	Ecosystem quality	PDF·m_2·y	Point
[c]	Aquatic acidification	kg SO_2 into air-eq	Ecosystem quality		
[c]	Aquatic eutrophication	kg PO_{43}- into water -eq	Ecosystem quality		
[b]	Land occupation	m^2 Organic arable land-eq · y	Ecosystem quality		
	Water turbined	inventory in m^3	Ecosystem quality		
[IPCC]	Global warming	kg CO_2 into air-eq	Climate change (life support system)	kg CO_2 into air-eq	Point
[d]	Non-renewable energy	MJ or kg Crude oil-eq (860 kg/m^3)	Resources	MJ	Point
[b]	Mineral extraction	MJ or kg Iron-eq (in ore)	Resources		

[source]	Midpoint category	Midpoint reference substance	Damage category (End-Point)	Damage unit	Normalized damage unit
	Water withdrawal	inventory in m^3	n/a		
	Water consumption	inventory in m^3	Human health Ecosystem quality Resources		

[a]IMPACT 2002, [b]Eco-indicator 99, [c]CML 2002, [d] Ecoinvent, [IPCC] (IPCC AR5 Report), and [USEPA] (EPA). DALY= Disability-Adjusted Life Years; PDF= Potentially Disappeared Fraction of species; -eq= equivalents; y= year.

5. BUILDING INFORMATION MODELING (BIM)

The following methodology has been used to assess the wall composition materials using BIM:

1. Determine the project's scope while taking the location, size, and intended purpose of the building into account.
2. Gather information for each wall material's "cradle to gate" LCA on acquiring, extracting, and transporting raw materials.
3. Model the building in BIM software, considering the types of insulation utilized and how they affected the environment. This study will use the 2020 student-licensed version of Autodesk Revit.
4. Consider the types of wall material used while modeling the building in BIM software. The most extensively used BIM application, Autodesk Revit, will be utilized in this project with a student license for 2020.
5. Compare the environmental impacts of various wall material types using LCA data. LCA data can be obtained in one of two ways: by exporting BIM data to LCA software or utilizing BIM software that already includes LCA data. LCA and BIM combined, according to Senem Seyis and Shu Su et al. [53], [54]. This study will take a comprehensive approach, where LCA will examine the environmental effects of various scenarios, and BIM will offer data on the building's components for LCA input.
6. Using the environmental impact assessment's findings as a guide, make educated decisions about the wall material types used in the project.

In summary, the BIM approach for various composition wall materials entails modeling the building, picking the proper wall materials, incorporating material data into the model, analyzing material performance, enhancing the design, and documenting and sharing the outcomes. The BIM technique provides a more thorough and integrated approach to material selection and design optimization, which can enhance building performance and have a less negative impact on the environment.

6. RESULT AND DISCUSSION

This stage involves evaluating the results of the LCA and drawing conclusions based on the goal and scope of the study. The results can be used to identify areas for improvement and guide decision-making in selecting appropriate wall materials.

6.1. EIA Mid-point results

In this section, the results of all scenarios will be presented by the midpoint method for single score and weighting results.

6.1.1. Single score results

Concerning the midpoint result in Figure 12, the clay brick recorded the lowest environmental impact by 1.02 pt, the AAC came in the second rank by 1.49 pt, and finally, the cement bricks by 2.25 pt. However, the clay brick is produced by drying and firing clay or shale raw material, forming a sintered porous structure [55], [56], [57]. Also, the AAC contains cement, but it is lightweight to mitigate the harmful environmental impacts [13] Turning to the three last scenarios, when adding the XPS to the three wall types, the environmental impacts have been increased by 1.24 pt, 1.86 pt, and 2.55 pt, that is, an incremental rate of 13%. The highest value among all scenarios is the sixth one, which is (4 cm XPS + 20 cm cement brick) composition.

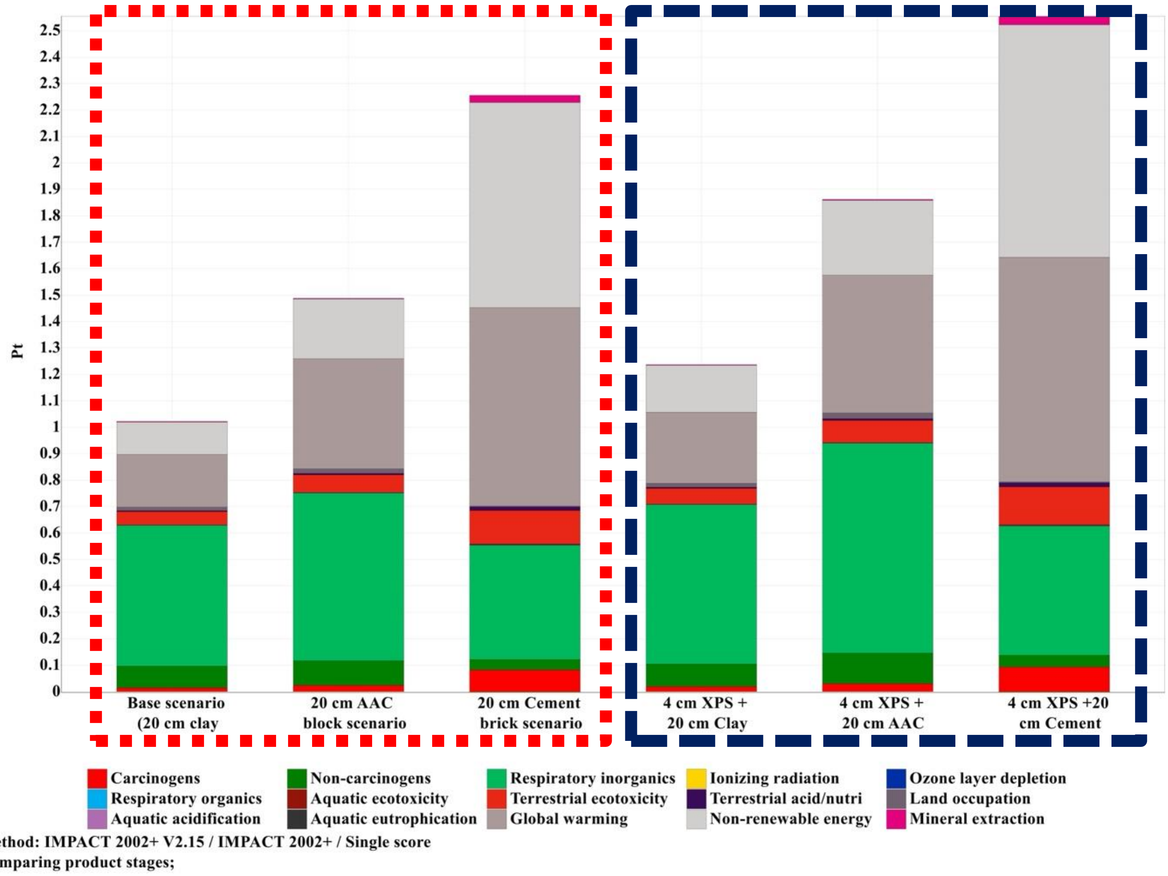


Figure 12 Single score result of LCA scenarios by midpoint method.

6.1.2. Weighting results

In Figure 13, three main environmental categories have recorded the highest impacts: global warming, non-renewable energy, and raspatory inorganic. Regarding global warming, the 20 cm clay brick has recorded the lowest value by 1.97K $KG\ Co_2$e and the highest value with the four cm XPS + 20 cm cement brick) composition by 8.40K $KG\ Co_2$e. As for the respiratory inorganic impact, the column bar has recorded different results among the six scenarios. The AAC scenarios have recorded the highest values; however, a slight increase can be ignored because AAC is made from a mixture of fly ash, cement, lime, water, and an aerating agent. According to Kamal [13], the AAC is superior to other types of cement concrete in many ways.

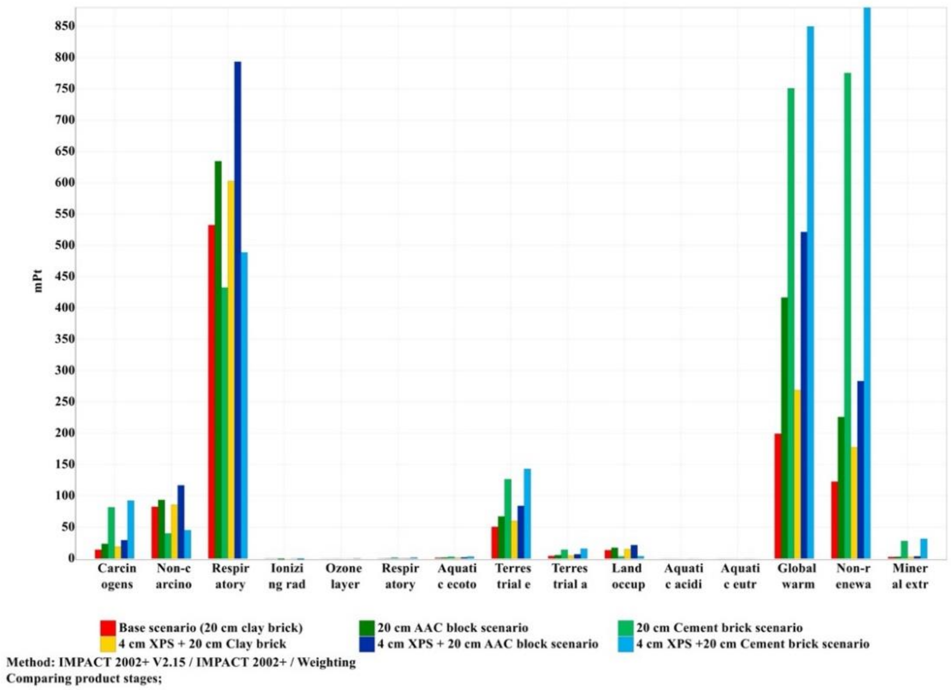


Figure 13 Weighting result of LCA scenarios by midpoint method.

6.2. EIA Endpoint results

In this section, the results of all scenarios will be presented by the endpoint method for single score and weighting results.

6.2.1. Single score results

The endpoint method contains four impacts: (1) human health, (2) climate change, (3) resource depletion, and (4) ecosystem quality. The cement brick has pointed to the highest environmental impacts compared to the wall material scenarios. In contrast, the two clay brick scenarios recorded the lowest environmental impact, and the AAC scenarios are in the middle rank. The endpoint results are consistent with the midpoint results in Figure 14.

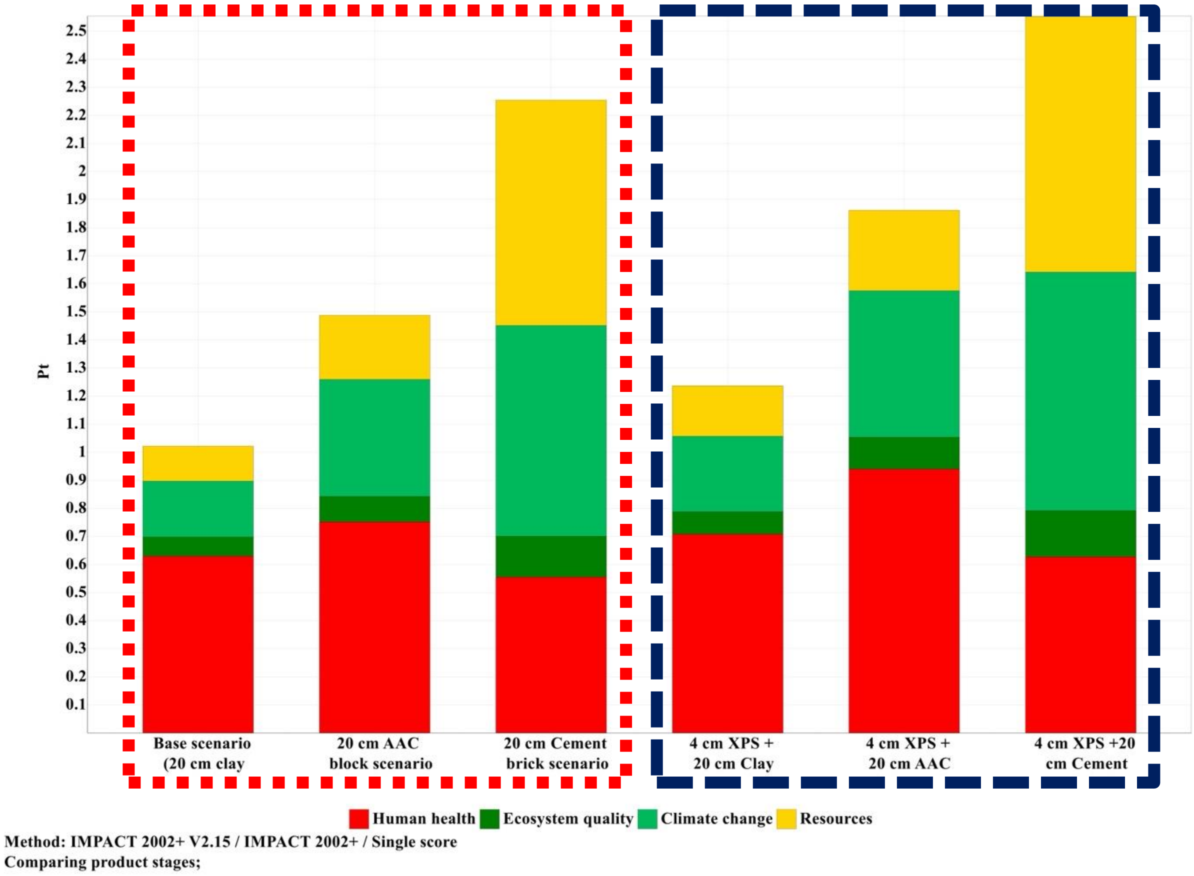


Figure 14 Single score result of LCA scenarios by endpoint method.

6.2.2. Weighting results

The weighting result by the endpoint method is shown in Figure 15. For human health, the AAC has recorded the highest value by 0.005 Disability Adjusted Life Years ($DALY$) because it contains fly ash in its manufacturing [13]. Regarding climate change, it has the most significant impact, and cement brick has recorded the highest values of 8.40K $KG\ Co_2$e. Also, the cement bricks have recorded the highest values in the resource's depletion impact by 138.42K $Mj\ primay$, due to the limestone (as raw materials need more energy to be acquitted) is the main components of its manufacturing, as it is documented by [58]. Compared to all the wall materials examined, the ecosystem quality is deficient. According to the LC-Impact database [59], which has explored this phenomenon, the ecosystem is a geographical area where plants, animals, other organisms, weather, and topography collaborate to produce a life bubble.

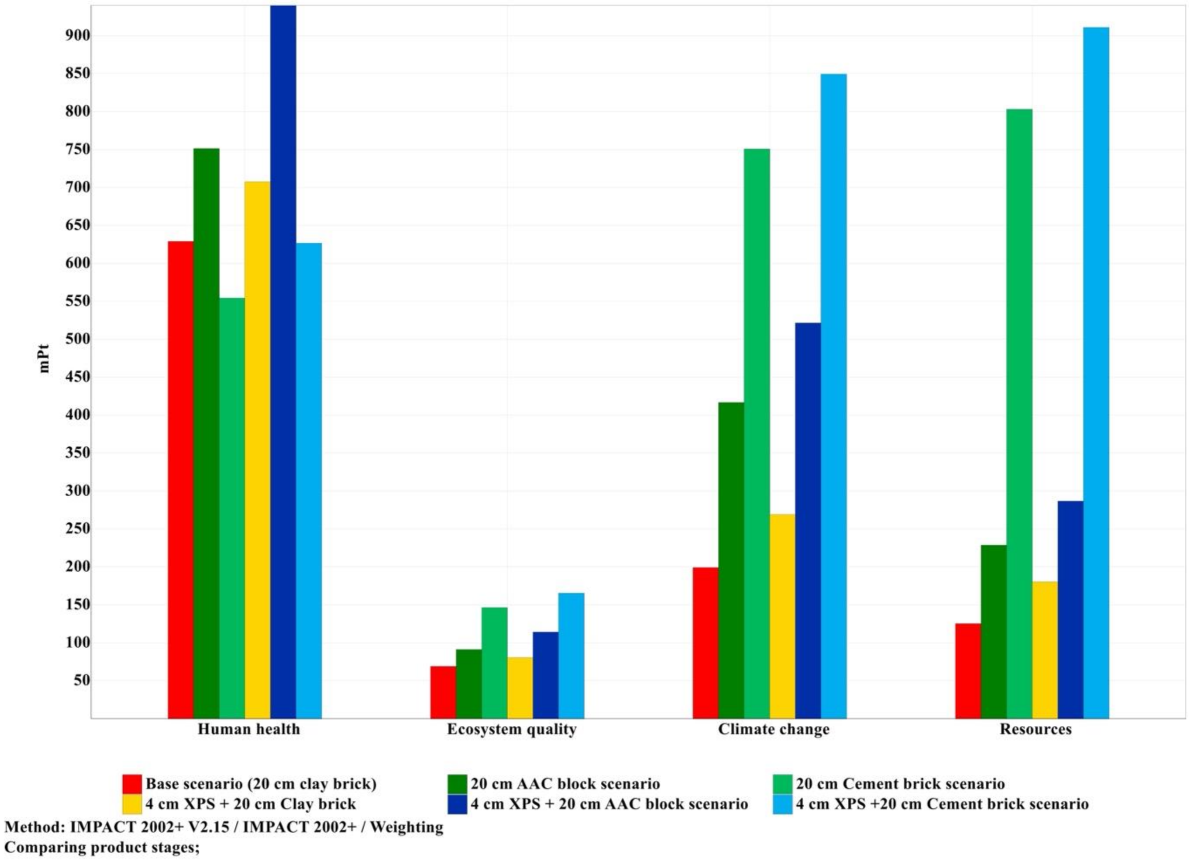


Figure 15 Weighting result of LCA scenarios by endpoint method.

7. CONCLUSION

Insights into the environmental effects of various wall materials are provided by the EIA of Composition Wall Materials Alternatives in the Ibny Baitak Project as a new city. Clay brick (20 cm), cement brick (20 cm), and AAC (20 cm) blocks were the four materials examined out of the six wall composition materials used in the study. Four cm of XPS insulation is used as an additional reinforcement in the fourth, fifth, and sixth situations for each type of wall material.

LCA results have revealed that clay brick and AAC blocks had a lower environmental impact than cement brick. Due to their excellent thermal insulation qualities, which lower the need for heating and cooling energy throughout the usage phase, clay brick and AAC had a reduced impact. However, using XPS insulation with cement brick may cause increased energy demand and emissions during the use phase.

The study's results emphasize how crucial it is to consider how building materials may affect the environment during construction. Using suitable building materials can aid in mitigating the environmental impact of the construction industry, which contributes significantly to environmental degradation. The study offers insightful data that might aid in directing the choice of suitable building materials for the Ibny Baitak Project and other construction initiatives meant to further sustainable development.

The study does, however, have significant limitations, such as the scope of the study, data availability, regional variations, social and economic factors, and comparative analysis. Future research could solve these issues and offer a more thorough understanding of how construction materials affect the environment.

8. LIMITATIONS AND RECOMMENDATIONS

The EIA of composition wall materials alternatives has some limitations that could be addressed in future work. Here are some limitations and potential future work [5]:

7. Study scope: This investigation concentrated on the environmental impacts of wall materials; however, flooring, windows, and roofing materials are not considered. Subsequent investigations may broaden the study's focus to encompass the ecological consequences of extraneous architectural elements.
8. Data accessibility: The study's reliance on readily available and high-quality data impacts the precision of the LCA findings. The data provided by the EIA may not be up-to-date or reliable due to its several sources. Future

studies might collect more trustworthy data or employ primary data collecting to improve the accuracy of the LCA results.

9. Regional variations: Depending on the climate and geographic location, wall materials might have different environmental effects. The Ibny Baitak Project is the subject of the EIA in a particular area. Future research could examine how wall materials affect the environment in various locations and climates.
10. Social and economic variables: The EIA does not consider the social and economic factors that could influence the choice of wall materials. Future studies should look at how decision-making might incorporate social and economic factors and how they influence the selection of wall materials.
11. Comparative analysis: While the EIA assesses the environmental impacts of different wall materials, it does not provide a detailed study of the trade-offs between environmental impacts and other factors such as cost, fire resistance, and durability. Subsequent studies could evaluate different wall materials while accounting for various factors.

Lastly, selecting appropriate wall materials involves various stakeholders with differing interests and perspectives. Conflicting stakeholder interests can hinder conducting a comprehensive EIA and implementing sustainable solutions. Stakeholders, including developers, contractors, and policymakers, may prioritize cost and convenience over environmental sustainability. Therefore, it is essential to engage stakeholders in the EIA process and ensure that their perspectives are adequately considered.

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