Energy retrofit of existing building stock in Amman: state of the art, obstacles and opportunities

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Abstract

Energy security is one of the most important challenges Jordan is currently facing, as it imports 96% of its energy resources from foreign countries. Together with other sectors, the existing building stock is responsible for high energy consumption, as average energy performance levels are much lower than the standards prescribed in the recent Jordanian Energy Efficient Building Code. Addressing issues related to energy retrofitting will assist the country to develop effective plans to reduce the energy consumption of buildings and, therefore, decrease the associated energy costs on a large scale, thus helping Jordan's sustainable development.

This paper aims to provide a better understanding of the current situation of the building sector and the energy performance of existing buildings in Amman, identifying issues, obstacles and opportunities to be considered for retrofitting this stock. The paper also provides a critical reflection on interviews with six local experts in the fields of architecture and engineering, including governmental and non-governmental institutions, making recommendations and suggesting possible directions for future research.

1. Introduction

Jordan faces significant challenges in its sustainable development including ensuring its energy supply, as it has limited indigenous energy resources. The country relies on foreign resources, importing 96% of its gas and oil from its neighbours [1, 2]. The dominance of oil and gas as primary sources of energy in the country needs to be addressed urgently, as the building sector has a high energy consumption, and plans for alternative power generation have high initial costs [3]. To address this issue, the Ministry of Environment and UNDP [1] have defined a 20% national target for energy efficiency, and concrete measures have been proposed in many key sectors to achieve this objective by 2020. These measures deal with both demand and supply. For example, with regard to energy demand, a 10% target was set for reducing energy usage in Jordanian public buildings by 2020. Mohsen and Akash [4] stated that the Jordanian residential building sector relies on fuel for heating, and space heating accounts for around 61% of overall energy consumption, making the achievement of energy efficiency very significant in buildings, as they "offer enormous scope for energy savings" [5, p. 166]. Energy efficiency has been given a significant amount of attention in the Jordan Green Building Guide [6], i.e. the local green building rating system. It covers 33% of the overall scores in the assessment process. Katz (as cited in EBSCO Sustainability Watch) [7] states that the existing building stock is 80 times larger than the new construction sector. Therefore, from an economic point of view, retrofitting existing buildings is more feasible than constructing new green ones [8]. A transformation of the built environment in Jordan through a sustainable approach is an effective approach to conserving energy, water and other resources.

Perspectives on the issues related to the process of energy retrofitting of buildings, specifically the technological and non-technological challenges and feasibility, are varied. Konstantinou and Knaack [9] stated that there is a lack of specialised knowledge in the early strategy development for refurbishing existing residential buildings. Also, Ma et al.

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[10] stated that there is still a major technical challenge regarding methods used to identify the most cost-effective retrofit measures for a particular project. Ungureanu et al. [11] claimed that mastering the energy retrofit process requires identifying cost-optimal retrofit strategies to maximise the reduction of energy usage and carbon emissions. Their study, conducted on the building stock of Denmark, Finland, Romania, Sweden and Switzerland, resulted in recommending integrated strategies for retrofitting existing buildings to reduce primary energy use, costs and GHG emissions.

Concerning Jordanian building stock, Ouahrani [12], in his article on the thermal behavior simulation of a typical Jordanian flat with the highest energy consumption in Amman, argued that optimising the building elements, mainly the insulation of external walls and roof, can lead to a total of 72% energy saving on the heating and cooling loads, but optimising the window-to-floor ratio (WFR) is difficult in an existing flat as it requires altering the building's structure. When Attia and Zawaydeh [13] compared the potential and constraints of a number of passive and active design strategies for a typical existing flat in Amman to meet the local code requirements and the zero energy retrofit target, they proved its feasibility in the case of local code compliance, but highlighted that the main barriers for retrofitting in Jordan are still economic. The study stated that some passive and active design strategies are rewarding with payback periods from three to nine years.

Most buildings in Jordan do not meet the requirements of the Jordanian Energy Efficient Building Code. Daher [14] stated that although the Jordanian Thermal Insulation Code has always been mandatory, people in Jordan have ignored it in order to avoid additional costs accompanying it. Another study confirmed and discussed the inefficient performance of existing Jordanian buildings, through a long-term monitoring study conducted by the Housing Development & Management (HDM) and the Royal Scientific Society (RSS) [15] on the performance of a typical building in Jordan, with the aim of defining criteria to improve thermal performance and minimise energy use. In this regard, energy retrofit can play a relevant role, considering the current challenges the country faces, including energy and water security, unplanned population growth and urban expansion, and climate change.

2. Aims of the research

Given the scarcity of publications in the energy-retrofit field in the context of Jordan, this research has involved experts from the local building sector, with the main purpose of providing the local market with useful information regarding the issues related to the construction of energy-efficient buildings. The interview questions are mainly focused on the energy retrofit of existing buildings in Jordan, thus addressing one of the highest energy burdens in the country. This contribution aims at providing a better understanding of the key aspects to be considered when retrofitting existing buildings in Jordan, identifying all possible issues for reducing the building stock's energy consumption on a large scale from technological and non-technological points of view.

3. Method of the research

The study used a qualitative approach for data collection through interviews with a sample of local experts in the field of energy retrofit in the context of Jordan. The sample for this study was characterised by its diversity as it included architects, engineers and experts representing governmental and non-governmental organisations. Participants were recruited primarily by a third party, the Jordanian Engineers Association (JEA), which has records of local experts in many related fields in Jordan. The third party suggested the participants and invited them to take part in this study, providing them with a Participant Information Sheet (PIP). Participants who agreed to take part in the study then contacted the authors via email. Before conducting the interviews, participants were required to sign two consent forms, one to confirm their acceptance of participating to the research and one to confirm their employers' agreement. The first author conducted the interviews with six local experts working in the Jordanian building sector who were willing to contribute to the development of the local practice of energy-efficient buildings. The interviews were audio-recorded, translated into English and transcripted by the authors who then returned them to the interviewees for their review and consent to use the transcripts. All participants had the right to withdraw from the study at any stage and to amend any data. Participants were classified into three groups as shown in Table 1. Two interviews were conducted for each group and each participant was given a code to be used in the following discussion.

Research questions focused on the issues related to energy retrofit and the extent of its feasibility, any possible obstacles, and potential impacts in Jordan. The focus was also on defining the state of the art of the current building stock in Jordan from technological and non-technological points of view. This paper critically discusses the answers of the participants to the interview questions and suggests recommendations to contribute to the further development of this topic in the context of Jordan.

Table 1. Summary and classification of research Participants.

	Group 1 (Architects)		Group 2 (Engineers)		Group 3 (Governmental and non-gov. national organisations)	
Participants' Codes	1a	1b	2a	2b	3a	3b
Academic background	Architect	Architect	Civil Engineer	Mechanical Engineer	Architect	Mechanical Engineer
Work Field	Green Buildings	Architect Consultant	Engineering	Energy Efficient Building Consultant	Green Buildings	Green Buildings
Years of experience	> 10 years	> 10 years	> 5 years	> 10 years	3 years	> 10 years
Organisation type	Government	International Organisation	-	Non-profit	Non-government	Government
Organisation size	Large	Large	Large	Large	Small	Large

4. Results of the interview and discussion

This part of the paper reviews the interview questions and critically discusses the participants' answers, and each question is studied in a separate section. Sections include: i) the question text; ii) a table summarising the answers; iii) a discussion; and iv) some conclusive reflections.

4.1. QUESTION #1: Which of the following aspects do you consider as the most significant for retrofitting the building stock in Jordan? Please rank them in order of importance.

- **Water efficiency.**
- **Energy saving.**
- **Improving the indoor environment for occupants.**
- **Other (please, specify).**

Table 2. Summary of answers to Question #1.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Energy saving	2nd	1st	1st	1st	1st	1st
2	Water efficiency	3rd	2nd	2nd	2nd	2nd	2nd
3	Improving the indoor environment	1st	3rd	3rd	3rd	3rd	4th
4	Other	-	-	4th: eco-friendly materials	4th: water leakage into buildings	4th: sustainable site 5th: local materials	3rd: recycling construction materials

It is clear that energy saving has been chosen as the most significant issue to be considered when retrofitting existing buildings in the context of Jordan. Participant 3a and participant 2a claimed that energy-saving solutions do not cost as much as water-saving solutions and, therefore, are more financially feasible. Participant 2b also stated that the results of energy-saving solutions in buildings appear once the process is complete. Also, participant 3b emphasised that Jordan is in need of such measures as the energy problem causes more burdens on the country's economy. However, participant 1a did not prioritise energy-saving solutions, in contrast to all other participants, saying that improving the indoor environment for occupants is more important due to its positive effect on occupants' productivity, especially in workplaces. The participant noted that people in Jordan are usually absent from work when there is no thermal comfort in a building and, therefore, the work environment affects their productivity.

4.2. QUESTION #2: From your point of view, in which of the following building categories would you invest in to implement a retrofit process? Please rank them in order of investment feasibility, and provide a reason.

- **Housing apartments (medium to high density).**
- **Villas and Dars (stand-alone dwellings).**
- **Commercial buildings.**
- **Private educational buildings.**
- **Public buildings.**
- **Other (please, specify).**

Table 3.Summary of answers to Question #2.

	Participants	Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Housing Apartments	5th	1st	1st	3rd	5th	5th
2	Villas and Dars	3rd	4th	5th	1st	1st	4th
3	Commercial Buildings	4th	2nd	2nd	2nd	2nd	1st
4	Educational Buildings	2nd	5th	4th	5th	4th	2nd
5	Public Buildings	1st	3rd	3rd	4th	3rd	3rd
6	Other	-	-	-	-	Industrial Buildings	-

Over 50% of the participants ranked residential buildings first, and most of them ranked commercial buildings second, except participants 1a and 3b, who prioritised private educational buildings. Participant 1a stated that the energy retrofit process provides marketing benefits for educational buildings, as many educational institutions are keen to show their affiliation to the sustainability movement in Jordan. In contrast, participant 2b believes that retrofitting would not be suitable for educational buildings as the operational hours are usually few and in the daytime. Participant 1a thinks the energy-efficiency issue is not a priority for commercial building owners, as their buildings are mostly rented and people do not prioritise this issue when renting. Also, providing their employees with a comfortable environment is not a target for this category. However, outreach programmes, more published studies in this field and publications of real cases that prove the benefits of energy-saving solutions would make the current situation different and, therefore, the market value would increase when people become more aware of sustainability, and thus Jordanian buildings would have a better chance of being more sustainable.

4.3. QUESTION #3: What are the obstacles and challenges you think the energy retrofit process might have to face for a diffusion in Jordan on a professional and cultural level?

Table 4.Summary of answers to Question #3.

	Participants	Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Technological barriers (professional level)	Not enough implementation techniques. Shortage of technicians.	Not enough experts and technologies	-	Lack of experience amongst engineers, supervisors, and technicians. Lack of experts. Lack of advanced auditing.	Lack of technical experience for the authorised entities. Resistance to implementing new technologies.	Weak oversight and auditing by responsible authorities. Poor implementation. Lack of technological knowledge.

2	Non-technological barriers (including cultural level)	Lack of funding. Lack of awareness.	Lack of awareness.	Lack of awareness.	High costs.	Lack of awareness. Impact of the high initial costs.	Amman's topography. Unplanned urban planning and expansion. Jordanian traditional tribal system. Traders (importers).

On the technological level, all participants claimed that there is not enough technical experience and skilled workforce available to implement the energy-retrofitting process on existing building stock in Jordan. Participant 1b added that there are also not enough local experts. In contrast, other participants believe that there are enough local experts and companies, but there is a lack of experience and research on the needs of the local market. In general, lack of experience in supervision work, technical skills and retrofit-oriented design are major obstacles for the energy-retrofit process in Jordan, resulting in buildings that are poorly constructed and, therefore, do not comply with local energy-efficiency standards. Participant 3b claimed that most of the engineering consultancy offices in Jordan do not have the required knowledge to design green buildings. Therefore, investing in training activities to qualify local practitioners, engineers, architects, contractors and builders should be a priority to contribute to Jordan's sustainable development.

Another important issue is that suppliers are not providing the local market with enough advanced systems, eco-friendly materials and high-performance appliances.

Auditing buildings is also a major problem in Jordan. Participant 3b stated that, unfortunately, there is a weak auditing process implemented by responsible authorities, including Greater Amman Municipality (GAM), Jordan Engineers Association (JEA) and the Jordan Green Building Council (JGBC). The main problem is the implementation and construction process does not match with project drawings. For instance, thermal insulation on site does not comply with the standards and with detailed drawings in terms of thickness and installation methods. Also, some important building elements like columns and beams are not thermally insulated in most buildings in Jordan, resulting in diffused thermal bridges and overall poor energy performances of buildings. In this regard, participants 2b and 3b also believe that there is a lack of up-to-date on-site auditing techniques, such as the use of infrared thermography to check upon thermal insulation and thermal bridges.

On the non-technological level, all participants stated that lack of awareness of the significance and benefits of retrofitting existing buildings within an energy-efficiency approach has been the major obstacle in Jordan. Participant 1a stated that people have lately begun to renovate existing buildings but within an architectural approach, rather than an energy-efficiency approach. Participants 3a and 1a noted that people in Jordan do not have enough knowledge of the advantages of the energy-retrofit process.

Participant 1a said that even some building owners, who have prepared policies to save energy in their buildings, have not included solutions to improve the building envelope situation. They mostly focus on encouraging green behaviour amongst building occupants, like turning off lights and heating systems when not needed. However, participant 2b thinks that people have realised the significance of thermal insulation in buildings to save energy, but they do not have knowledge on the correct implementation pathways.

Participants 1a, 2b and 3a believe that people think more about reducing their high initial costs than investing in energy efficient systems, whether active or passive. This is another significant challenge. People will never invest in an energy retrofit to be environmentally friendly, as they pay less attention to the environment than to their budget, according to participant 1b. In fact, people in Jordan would prefer a one-off lower initial cost than a higher one with a payback period, as they are sceptical about financial solutions for funding energy-efficiency measures. Hence, increasing people's awareness should be a priority. According to participant 1, a possible way is to persuade them of the financial feasibility of this investment and inform them of how this could this save on operational costs in their buildings.

Overall, energy retrofitting has some challenging obstacles in Jordan both from technological and non-technological points of view. Increasing people's awareness is the biggest goal, according to most participants, and a high level of cooperation between local community and the government is needed to achieve this. Regarding technological obstacles, a major achievement would be to qualify local technicians and builders by strengthening their relationships with academia and by improving research and educational activities, particularly focusing on the construction phase. Regarding funding, further work is also needed to better understand how energy-retrofit activities could be funded in Jordan, taking financial feasibility into account. For instance, special loan programmes supported by local councils and the government have been shown to be a valuable support for Jordan lately, and could be a pathway to explore.

4.4. QUESTION #4: How would you evaluate the current commercial building stock concerning the requirements of the Jordanian Energy Efficient Building Code of 2009?

- **High performing;**
- **Acceptable;**
- **Not acceptable**.

Table 5.Summary of answers to Question #4.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Insulated existing buildings	Acceptable	Not Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
2	Uninsulated existing buildings	Not acceptable	Not acceptable	Not acceptable	Not acceptable	Not acceptable	Not acceptable

Participant 3a said that the Jordanian Thermal Insulation Code has always been mandatory, but people in Jordan used to ignore it in order to avoid additional costs accompanying it [9], and because government supervision has not been strict enough to ensure that the requirements are being applied. They also stated that in reality penalties for non-compliance with codes are not implemented, with an exception for some large-scale projects. However, Jordanians are becoming more aware of the significance of thermal insulation after experiencing high energy bills in buildings that are not properly thermally insulated, said participant 3a. Indeed, participant 3a claimed that most buildings built before 2010 are not insulated and new buildings that comply with local Thermal Insulation Code requirements are not being implemented using the correct methods. Participants 1a and 1b claimed that thermal bridges are rarely avoided in Jordanian buildings, due to lack of knowledge and awareness among designers, engineers and contractors.

Lack of awareness on correct ways to implement thermal insulation in buildings is the main reason why the performance of insulated buildings is inefficient. For example, most people focus on walls and ignore roofs when implementing thermal insulation in buildings, said participant 2b. This creates thermal bridges.

Overall, all participants stated that most Jordanian buildings, including thermally insulated buildings, do not have a complete thermally insulated envelope, and thermal bridges are a major issue. This highlights the need for implementing passive design solutions in buildings to improve their envelope performance. Most participants said that the building envelope is the most significant issue and it should be prioritised in the energy-retrofit process. Further research is needed to identify current building envelope problems in the context of Jordan and the technologies available, assess their performance and suggest effective solutions to comply with building codes.

4.5. QUESTION #5: Regarding energy upgrade strategies, please put the following strategies in order of priority and give reasons for your ranking. If possible, please provide a reference to precedent research, projects and buildings.

- **Increase thermal insulation of the building envelope (mainly walls and roof).**
- **Improve the performance of building openings (e.g. double-glazing).**
- **Reduce internal loads (e.g. replace mechanical systems and electrical devices).**
- **Use energy generation from clean sources (solar, wind, geothermal, etc.).**
- **Shading devices.**
- **Reduce thermal bridges.**
- **Increase thermal mass.**
- **Airtightness.**
- **Improve natural ventilation.**
- **Other (please, specify).**

Table 6. Summary of answers to Question #5.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Thermal insulation	1st	2nd	1st	1st	1st	1st
2	Building openings	2nd	1st	3rd	2nd	2nd	2nd
3	Reduce internal energy loads	3rd	4th	2nd	3rd	7th	4th
4	Renewable energy generation	4th	3rd	4th	4th	8th	3rd
5	Shading devices	5th	8th	5th	-	3rd	5th
6	Reduce thermal bridges	1st	6th	-	5th	1st	1st
7	Increase thermal mass	-	7th	-	6th	6th	6th
8	Airtightness	6th	5th	7th	2nd	9th	7th
9	Natural ventilation	7th		6th	3rd	5th	8th
10	Other	-	-	-	-	-	-

Most participants consider the increase in thermal insulation in buildings as the first priority, in addition to reducing thermal bridges. Urgency should be given to strategies for saving energy in buildings, in order to reduce the energy demand for heating, cooling and hot water supply [12]. Participant 3a claimed that thermal bridges are responsible for approximately 33% of heat loss in buildings and this would be avoided through insulating thermal bridges, for instance. However, participant 2b believes that reducing thermal bridges is very difficult in existing buildings and is very expensive as well. This is supported by participant 3b, who said that increasing thermal insulation could be applicable in Jordan from a technical point of view, and could achieve a considerable amount of energy saving but it is costly. There is a need for identifying the amount of energy saving which could be achieved through increasing thermal insulation, and further research is needed not only to illustrate the expected energy saving, but also the expected thermal comfort. Participant 1b stated that this strategy makes a difference, and participant 1a stated that it is economically feasible and would have a considerable impact not only on the internal comfort of buildings, but also on the climate of Jordan through the reduction in CO^2 emissions. This intention is supported by literature from local authors as well. For instance, in his research conducted to identify the optimum thermal transmittance (U-value) for walls and roofs in a typical apartment in Amman, Ouahrani [12] argues that it is possible to achieve an overall energy saving of up to 70% for heating and cooling, and a good thermal comfort level when the U-values range between 0.50 and 0.70 W/m²K for walls and roofs.

Improving the performance of building openings like windows and doors has mostly been ranked second. Participant 3a said that this is needed to prevent heat loss through windows. Replacing inefficient windows with energy-efficient ones is becoming more feasible in Jordan, financially and technically, as the Jordanian market is developing. Participant 1a said that double-glazed windows used to be expensive (costing about 90-100 JD per m^2, equal to 140 USD), but have recently become cheaper (about 45-60 JD per m^2, equal to 60-85 USD). Participant 1b believes that this strategy should be prioritised, as windows in Jordan cause a considerable amount of heat leakage while the strategy of airtightness would not be possible because there are no quality control measures available in Jordan. However, participant 1a said that reducing air leakage from windows and doors is applicable, easy and cheap.

In Jordan, shading devices are important to take advantage of free solar gains in winter, in order to achieve thermal comfort, but overheating in summer can be avoided through the use of solar shadings, said participant 3a. Most participants agreed that external shading devices are more efficient than internal shading devices. However, participants 2b and1a stated that external shading devices were not appropriate solutions for existing buildings because they altered the building's design, and people in Jordan pay attention to the external appearance of the building.

Regarding renewable energy generation integrated into the building, participants believed that improving the energy efficiency in buildings and reducing their energy demand should be prioritised more than generating clean energy from local sources. Participant 3a even stated that there would be no need for it if passive design solutions were applied correctly. However, participants 1a, 2a and 2b stated that there was a growing market for this strategy because the Government supported it by exempting any renewable system from customs duties. However, the Government allows for the installation of PV systems on empty lands (rented or owned), a method that is appropriate and efficient for commercial buildings or companies that have high energy consumption, but do not have enough space for integrating PV systems in the building itself.

Regarding natural ventilation, participant 3a said that, because of Jordan's mild climate, people use air conditioning for a short period in summer. In general, natural ventilation is better than air conditioning and it is part of the Jordanian

culture, where people prefer it over air conditioning. Most participants said that Jordanians prioritise heating, not cooling, as they can deal with hot weather better than with cold weather. Participant 2b agreed that improving natural ventilation in buildings is an effective strategy, also because there is still a high smoking rate inside buildings in Jordan. This could be achieved in the case of retrofitting through operating mechanical ventilators or improving building openings, which would not be feasible as it would change the facades, said participant 1a.

Regarding increasing thermal mass, participant 1a said that increasing the thickness of roofs and walls would require too much space. In fact, traditional Jordanian buildings used to be built with a high thermal mass by using thick, natural stone walls, but this is not happening today because buildings are mainly built with concrete or steel, and stone is used only as an external cladding [13]. Therefore, increasing thermal mass would not be a possible solution for energy retrofitting as it is costly and occupies too much space.

In conclusion, it is evident that all participants preferred passive design solutions over active ones. They agreed that improving building envelopes and openings has to be prioritised in the energy retrofit process to optimise energy efficiency and thermal comfort.

4.6. QUESTION #6: Based on your professional experience, what are the most common insulation materials and installation methodologies used in Jordan?

Table 7. Summary of answers to Question #6.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Thermal insulation material	Polystyrene	Polystyrene (5 cm thickness)	Artificial materials	Polystyrene	Polystyrene	Polystyrene
2		Polyethylene	Polyethylene	-	Rock wool	Polyethylene	Polyethylene
3		-	foam concrete	-	-	Rock wool	Thermal blocks
4		-	-	-	-	-	AAC block

Participant 2b said that the two main common thermal insulation materials in Jordan are polystyrene, both expanded and extruded, and rock wool. Expanded polystyrene is the preferred choice; it is usually blue and water resistant, and it lasts longer than extruded polystyrene, according to participant 2b. Rock wool is cheap, easy to use even in irregular-shaped buildings, and flexible. However, other participants stated that people in Jordan prefer not to use it in walls as it slips down in the cavity. Also, rock wool is not water resistant and when it is used in roofs, it must be covered by water-proofing materials, such as nylon, to prevent it from losing its insulation property. Participant 1a also stated that rock wool is mainly used to insulate ducts and pipes. Although rock wool and polystyrene have similar thermal conductivity values (k-value) of 0.040 and 0.035 W/mk respectively [10], polystyrene is easier to deal with than rock wool due to its texture. However, some participants said that polystyrene is not easily used in buildings with irregular shapes or curvilinear plans because it is breakable. In many cases, polystyrene boards are broken into pieces when pumping concrete into walls, said participants 1b, 2b, and 3a. Participant 3b stated that, unlike polystyrene, polyethene is an effective material applicable to all shapes of buildings, and its foam can fill all the gaps, which results in less thermal bridges. Nevertheless, it is more expensive than polystyrene, said participants 1b and 3b.

To conclude, polystyrene is the most commonly used insulation material in Jordan. According to the participants, natural insulation materials, like timber wool, bio-based materials, wood wool and sheep wool, are not commonly used locally.

4.7. QUESTION #7: From your perspective, what would the priority be in retrofitting between generating renewable energy and reducing energy demands? Can you explain why?

Table 8.Summary of answers to Question #7.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Generation of renewable energy	-	-	-	-	-	-
2	Reduction of energy demands	Yes	Yes	Yes	Yes	Yes	Yes

All participants preferred reducing energy demands over generating clean energy. Participant 1a claimed that the energy retrofit process might require a higher initial cost to reduce energy demand but does not require maintenance, unlike power plants and PV panels which require regular maintenance, said participants 3a, 3b and 1a. PV cells also occupy a

large space and, according to participant 3b, most buildings in Jordan do not have enough space to host PV panels because their roofs are usually occupied with solar heaters and water tanks. Some participants said that this obstacle caused some building owners to rent a piece of land outside cities to install renewable generators to utilise a new system called the 'Wheeling System'. This system has been issued for people who do not have space in their buildings for the installation of PV cells, allowing them to generate electricity on other sites. Participant 1a said that this system is efficient for companies with high energy consumption rates. Another disadvantage of the renewable generators is that they have high initial costs. Also, participant 3a stated that the generators have to be replaced, unlike passive design solutions, which last as long as the buildings.

In conclusion, using passive design solutions is worthwhile, but people in Jordan do not seem to realise their significance. They do not realise that this should be prioritised over the generation of clean energy. Effective plans are needed for ensuring the safety of PV cell installations as their use is increasing in Jordan. The participants have not considered other forms of renewables other than solar energy such as wind power.

4.8. QUESTION #8: Based on your professional experience, what are the benefits of upgrading the performance of a commercial building in Amman, in terms of reducing energy demand and providing indoor thermal comfort for tenants, for both the building owner specifically and the country generally?

Table 9.Table 1 Summary of answers to Question #8.

Participants		Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Benefits for building owners	Increase occupants' productivity. Reduce employee absence. Reduce energy bills.	Reduce energy bills.	Reduce operational costs.	Improve thermal comfort. Reduce the use of HVAC systems. Reduce energy bills.	Higher productivity levels for occupants.	Direct benefits for building users and owners.
2	Benefits for the country	Reduce burdens on the country.	Reduce CO_2 emissions. Improve the thermal comfort of outdoor spaces. Reduce energy demand on a larger scale.	Move towards a greener economy. Reduce the need for providing infrastructure for new areas. Conserve cultivated land.	Reduce burdens on the country.	Reduce energy demand.	Indirect benefits for the country. Reduce energy demand.

On an individual level, most participants agreed on the benefit of providing thermal comfort for occupants. Some participants believe that this process improves productivity in the workplace as staff feel more comfortable and, therefore, it provides benefits to building occupants. This would reduce, for instance, employee absences in office buildings, which are often caused by building-related diseases. Therefore, improving the indoor environmental quality results in long-term benefits that are greater than reducing energy costs. Also, reducing energy costs has financial benefits on an individual level. Increasing people's awareness is important as well. For example, when people understand that thermal bridges are the reason behind mould in buildings, occupants will focus on increasing thermal insulation.

On a national level, reducing energy consumption in buildings reduces the energy demand on a large scale, said participant 1b. This would reduce the energy problem in Jordan, said participants 1a, 3a, 2b and 3b and. therefore, benefit the country. Another advantage is the reduction of the country's budget for developing new infrastructure for new areas, and therefore conservation of greenfields, due to retrofitting existing building stock.

In conclusion, there are many advantages for the energy-retrofit process on both an individual and country level. The more people that understand the significance of passive design strategies, including thermal insulation, the more productive building occupants would become. These strategies have considerable impacts on individuals, including improving building occupants' health, and on the conservation of resources for the country.

4.9. QUESTION #9: Do you think that this process could be financially feasible for Jordanian building owners, and why?

Table 10.Summary of answers to question #9.

	Participants	Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Participants' answers	Yes	Yes	Yes	Yes	Yes	Yes

All participants stated that an energy retrofit is a financially feasible process. Participant 2a said that it reduces costs and the time required for construction. In the case of commercial buildings, participant 1b said that it would be financially feasible only if the building owner uses the building, i.e. not renting it to other occupants. Participant 1a noted that the initial cost is usually paid once, while the energy savings would be reflected in the electricity bills and heating or cooling costs throughout the building's lifespan, and the payback period would be shorter, not exceeding five to eight years in many cases, according to participant 2b. Participant 3a also said that the process is financially feasible, especially in commercial buildings where usually high electricity bills are reduced.

Therefore, the energy-retrofit process can be financially feasible in Jordan, but this needs further work to provide the local community with successful cases and studies proving it. Also, a special focus should be given to identifying the payback period for energy retrofitting strategies.

4.10. QUESTION #10: Concerning people's perceptions about green buildings in Jordan, including building certification systems, do you think that this retrofit process can deliver benefits to the building market? Please give a reason.

Table 11. Summary of answers to Question #10.

	Participants	Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Participants' answers	Yes*	Yes	No	No	No	Yes

Certified green buildings still need some time to become a common practice in Jordan, but this is already a trend in Amman amongst large corporations and national and international organisations. Participant 1a stated that some companies are developing policies to follow the sustainability movement in the country to improve their businesses in the market. They have become more aware of the financial benefits of energy-efficient buildings. However, this is not yet applicable to small-scale corporations and half of the participants said that energy retrofits do not provide marketing benefits at the moment, as they need a lot of time and work. Participant 2a gave an example, saying that if someone needs to rent an office, the initial cost would probably be prioritised in the buying decision regardless of whether the building is sustainable or not. The Government in Jordan has issued new incentive systems to encourage people to invest in energy-efficient buildings [18]. Participant 1b said that people's buying decisions in the building market might be influenced by a trusted green building certificate issued by a local independent party. The best practical marketing tool would be using real cases of energy-retrofitted buildings as models, showing the amount of energy and operating costs that could be saved.

In conclusion, much more time and work is needed to increase people's awareness of the significance of energy efficiency in buildings, and this will definitely provide marketing benefits to the building market.

4.11. QUESTION #11: Do you think this upgrade could result in energy-retrofitted buildings that meet similar standards for new buildings that already adhere to Jordan's energy-efficient building code?

Table 12.Summary of answers to Question #11.

	Participants	Group 1		Group 2		Group 3	
		1a	1b	2a	2b	3a	3b
1	Yes	Yes	Yes	-	-	-	Yes
2	-	-	-	Maybe	-	-	-
3	-	-	-	-	No, it is not possible.	No, it is not possible.	-

On one hand, half the participants believed that the energy-retrofit process could ensure existing buildings have a similar performance to new energy-efficient buildings. Participant 1a said that it could not achieve more than 90% of the

Jordanian Energy Efficiency Building Code requirements as there are some recommendations that can not be achieved in existing buildings, such as the building orientation and opening sizes. However, it can meet the mandatory requirements when implementing the passive design solutions using the correct methodology and ensuring thermal bridges are avoided. Participant 2a claimed that an energy-retrofitted building can achieve the new local Jordanian Green Building Guide rating system with a level (A) depending on technical aspects [18]. On the other hand, other participants think that it is challenging for energy-retrofitted existing buildings to have energy-efficiency performances similar to new green buildings. The reason is that a new building is designed from the ground up, sometimes starting from site selection, so it iseasier to deal with these projects from the early stages.

In conclusion, the success of the energy-retrofitting process depends on the quality of buildings, their age, materials and many other factors, so some could achieve a similar performance to new energy-efficient buildings while others would not. In general, retrofitting buildings gives a chance to control the growth of cities, improve the lifespan of buildings, and preserve the embodied energy in buildings.

5. Conclusions

Amongst the issues discussed in this paper, a number of points can be highlighted.

First, it is clear that the performance of most Jordanian buildings in regard to energy efficiency and thermal comfort is poor. They do not comply with the standards of the local Energy Efficient Building Code for new buildings, so it is significant to define a target for making existing building stock meet those standards by encouraging all sectors towards retrofitting. This will save energy on a large scale, starting from the building level, through to the city, the district and the whole country. Energy efficiency is a fundamental issue and it *"should be the cutting edge of national energy policies for sustainable development"* [5, p. 163]. Since all participants stated that buildings consume the greatest amount of energy in Jordan, it is recommended to develop strategies encouraging people to invest in the improvement of their buildings through energy retrofitting. The development of effective plans to optimise energy efficiency in Jordanian buildings is needed to accelerate the achievement of national targets in regards to energy policy to overcome Jordan's ongoing challenges.

Second, retrofitting existing buildings provides many advantages to improve the quality of life and wellbeing inside buildings, as well as in the surrounding environment. Uncontrolled urbanisation in the main northern cities in Jordan threatens vegetation and water resources [19] and, therefore, retrofitting the main existing urban areas through a sustainable approach could be an effective strategy to reduce the demand for new urbanisation and to protect arable land. Hence, retrofitting is an opportunity to control the unplanned growth of urban areas in Jordan, to improve building lifespans and to preserve their embodied energy. Wilkinson et al. [20] said that the longer the lifecycles of buildings, the less carbon will be released. In other words, buildings would be responsible for fewer GHG emissions throughout their lifecycle.

Another significant point is a lack of knowledge, research, publication of real cases, and documentation in this field in the context of Jordan, and this has created a gap between what happens in Jordan in regard to local practices and projects and accessible databases. Also, independent organisations specialising in developing sustainable buildings are urged to establish bases in Jordan to help local engineering offices that do not have the requiste knowledge and expertise to design and build sustainable buildings, including energy-efficient buildings. This will increase the number of buildings that can potentially achieve local or international green building certifications and, therefore, spread this concept into the local community. Also, effective outreach programmes are needed across society, starting from schools, universities, engineering offices, contractors etc. When people understand the real benefits of having energy-efficient buildings, the energy-retrofitting process can deliver market benefits.

Therefore, the first author, Sameh Shamout, has started an initiative in 2017 to create a local guideline for retrofitting the existing building envelope. Furthermore, he has started developing a local existing building rating tool under the umbrella of Jordan Green Building Council. His initiative also aims to organise an effective advertising campaign to raise awareness amongst the public.

Current practices in the Jordanian construction market give the lowest priority to environmental aspects and first priority to affordability. Therefore, the financial factor seems to be the greatest obstacle to the development of the energy-retrofit concept in Jordan. Overcoming this obstacle requires effective cooperation between the local community and the Government to achieve the aim of reducing energy usage in buildings. Since the Government cannot provide enough financial support to people to encourage them to undertake retrofitting, it is recommended that strategies are developed to encourage the private sector to invest in such processes, especially the commercial sector. For example, since the main barriers to the spread of energy-efficient solutions in Jordon appear to be mainly economic, Attia and Zawaydeh [13] conducted research to prove the economic success of compliance with the Energy Efficient Building Code using different design strategies for an existing apartment in Jordan.

Moreover, there should be more focus on developing strategies to strengthen the supervision and auditing of works by corporate parties, including the Jordanian Engineers Association, Municipalities and the Ministry of Public Works and

Housing. Royal Scientific Society (RSS) and Friedrich-Ebert-Stiftung Amman (FES Amman) [21] stated that the lack of supervision and laxity in adopting green building codes for construction plans in Jordan is a major challenge.

Regarding the participants' answers, it could be observed that their academic backgrounds and work fields have an influence on their answers. For instance, architects have prioritised occupants' needs and local practices when answering the questions, while participants with engineering backgrounds have focused on the technological aspects. The third group have particularly focused on building regulations.

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