Research Article

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Sustainability in the design of liquefied petroleum gas systems used in buildings

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Abstract: With the spread of the use of liquefied petroleum gas (LPG) in developing countries for use in domestic cooking with the increase in the expansion and distribution of gas pipelines for residential buildings, the 2002 World Summit focused on sustainable development in clean energy for natural gas (NG) and LPG. The research aims to focus on the important aspects of design sustainability from an environmental point of view to reduce gas leakage, accidents, and explosions that occur socially to expand the distribution of LPG and motivate the consumers to use it instead of natural gas and other fuels, and from an economic point of view to take into account the annual cost and aesthetic impact of maintaining on the view of the building and the design of the pipes in ways that do not distort the public view. The study area was a building in a residential complex in Baghdad and the gas pipelines were connected to the building completely for studying. The axes of sustainability were applied to the building in an analysis method using the goals achievement matrix, which is divided into main goals and secondary goals. The results showed that the environmental and aesthetic sustainability were well applied to the building, but from a social point of view, in the dissemination of safety instructions to the consumer, and from a financial point of view, there were shortcomings in them, and this could lead to long-term damage to the building.

Keywords: LPG, sustainability, design, building, gas system

1 Introduction

Modern fuels include natural gas (NG) and liquefied petroleum gas (LPG). LPG is widely utilized in cooking applications all over the world, and it uses energy more efficiently than traditional biomass. The usage of LPG is no longer a viable financial option. The availability, applicability, acceptability, and affordability of modern fuels, as well as access to financing to cover initial investments, all play a role in sustainability [1]. One of the important issues in sustainable development is energy, which is considered a priority in the World Summits in the year 2002 for sustainable development to access modern and clean energy using program to enhance access through capacity building and technology transfer. Achieving this broad goal will require building a coalition to promote clean energy, and allocating resources for programming access to energy. Based on the analysis of proposals and negotiations, the institutional capacity to integrate energy and sustainable development are strengthened [2].

Aberilla *et al.* [3] reported that the access to clean fuels is essential for achieving sustainable development goals, particularly in poor countries, in order to minimize negative effects on human health and the environment. Focusing on liquefied petroleum gas (LPG) and other fuels, the environmental sustainability of cooking in houses was assessed. The findings revealed that LPG reduces environmental health effects by 78–97%, indicating that clean fuels can be developed to lessen environmental side effects and human health consequences.

The research's aim is to focus on the important aspects of design sustainability from an environmental point of view to reduce gas leakage, accidents, and explosions that occur, socially to expand the distribution of gas, and motivate the consumer to use it instead of another fuel, and from an economic point of view to take into account the annual cost and the aesthetic effect to maintain the building view and design the pipes in ways that do not distort the general view.

2 Sustainability concept

The concept of sustainability is to meet needs without compromising the ability of future generations to meet their own needs, in addition to natural resources.

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Among the sustainability goals, the seventh goal refers to "Ensure environmental sustainability." Environmental sustainability means maintaining the balance of the earth's ecological systems and human consumption of natural resources. Sustainable development was highlighted in 1994 by English planner, psychologist, and sustainability consultant, John Elkington where the "triple bottom line" was introduced in order to achieve a balance between the economic, the environment, and social development as shown in Figure 1 [4]. There is a relationship between the environment and the economy and how the society deals with it. It is believed that economic growth will eventually become unsustainable because it can be exhausted, but this growth also exceeds the environmental ability to deal with the waste produced by the resources due to the wrong handling of it in society. Therefore, it is important to redesign the forms of sustainable development. If the relationship between the forms of sustainability is closely related, then this growth creates a greater opportunity for the industry, promoting clean energy, achieving clean production, providing profits through investment, and maintaining life in good health [5]. There is a relationship between the development of sustainability and LPG. Japan's plan to achieve long-term environmental sustainability for LPG, presented goals and roles to work on them by 2030. The seventh goal stipulates ensuring access to modern energy. In order to implement this goal, the role is to contribute to diversifying the source of petroleum gas supply and the infrastructure for storage and distribution. The ninth goal is to increase the efficiency of the use of industrial processes and fuel to make them sustainable. The base in order to achieve the goal is the introduction of new technologies such as artificial intelligence and technology development [6].

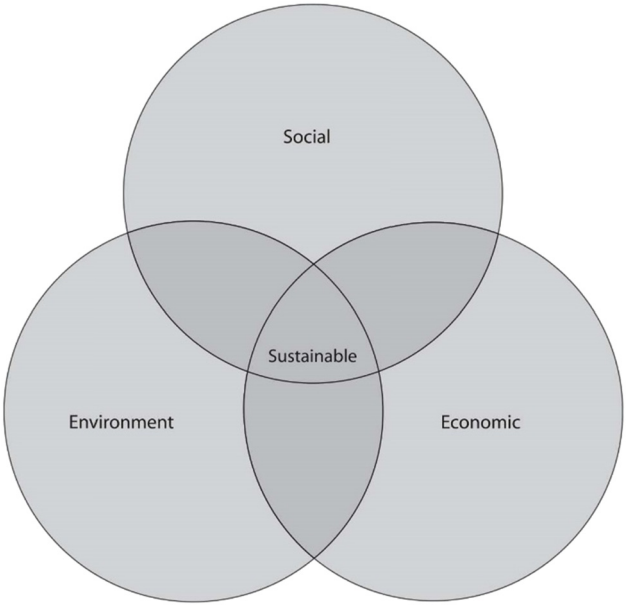

Figure 1: "Triple bottom line" sustainability types (Mulligan [4]).

3 Sustainability standards for LPG design in residential buildings

To apply sustainable development in the design of LPG, sustainability criteria must be taken into consideration, including environmental sustainability, aesthetic sustainability, social sustainability, and economic sustainability.

3.1 Environmental sustainability

The impact of LPG on the environment has a significant impact, as risks and explosions can occur in enclosed spaces, the causes of these explosions are not fully understood and cannot be predicted unexpectedly. Bulkheads are placed on the ground to limit the spread of liquids and the occurrence of leaks to ensure the safety of LNG tanks. Extensive experimental studies on LNG, which contains a high amount of ethane and hydrocarbons, have found that it can be exposed to flameless vapor and explode. Steam explosions are not likely to occur at LNG-bearing facilities. Individual and social hazards are two types of natural gas threats. Explosions caused by social risks that result in a rise in deaths and injuries. The dangers of liquefied gas are comparable to those of NG, and it has been noted that an explosion of LPG clouds with air mixtures cannot be foreseen, nor the occurrence of the explosion or the circumstances that led to the explosion can be predicted. The dangers of LPG are less established than those of LNG, and investigations have proved that LPG is more harmful than LNG due to the high number of incidents [7].

In order to implement environmental sustainability in the design of the LPG system, gas leakage must be reduced by using technology such as sending a text message to the user and stopping the process. It works through Global System for Mobile (GSM) by sending a message to both the gas distributor and the user at the same time to stop the operation [8]. There are two types of hazardous areas according to the Iraqi Standard, areas that contain hazardous gases under normal or continuous conditions, or as a result of maintenance,

malfunction, or failure of the equipment or processes that lead to the formation of hazardous gases, and areas where there is a harmful gas, such as closed equipment that carry LPGs or vapors, such as pressure vessels, tanks, pipes, pumps, and compressors, where the gas cannot be drained unless the equipment is broken or malfunctioning. It must be handled with caution, safety conditions must be applied, and warning signs must be put near it [9].

Figure 3: Covering the outer tubes for gas (Guevara [10]).

3.2 Aesthetic sustainability

To apply the aesthetic sustainability of the LPG system design in the buildings, the building facade must be taken into account, meaning that the gas pipes are placed

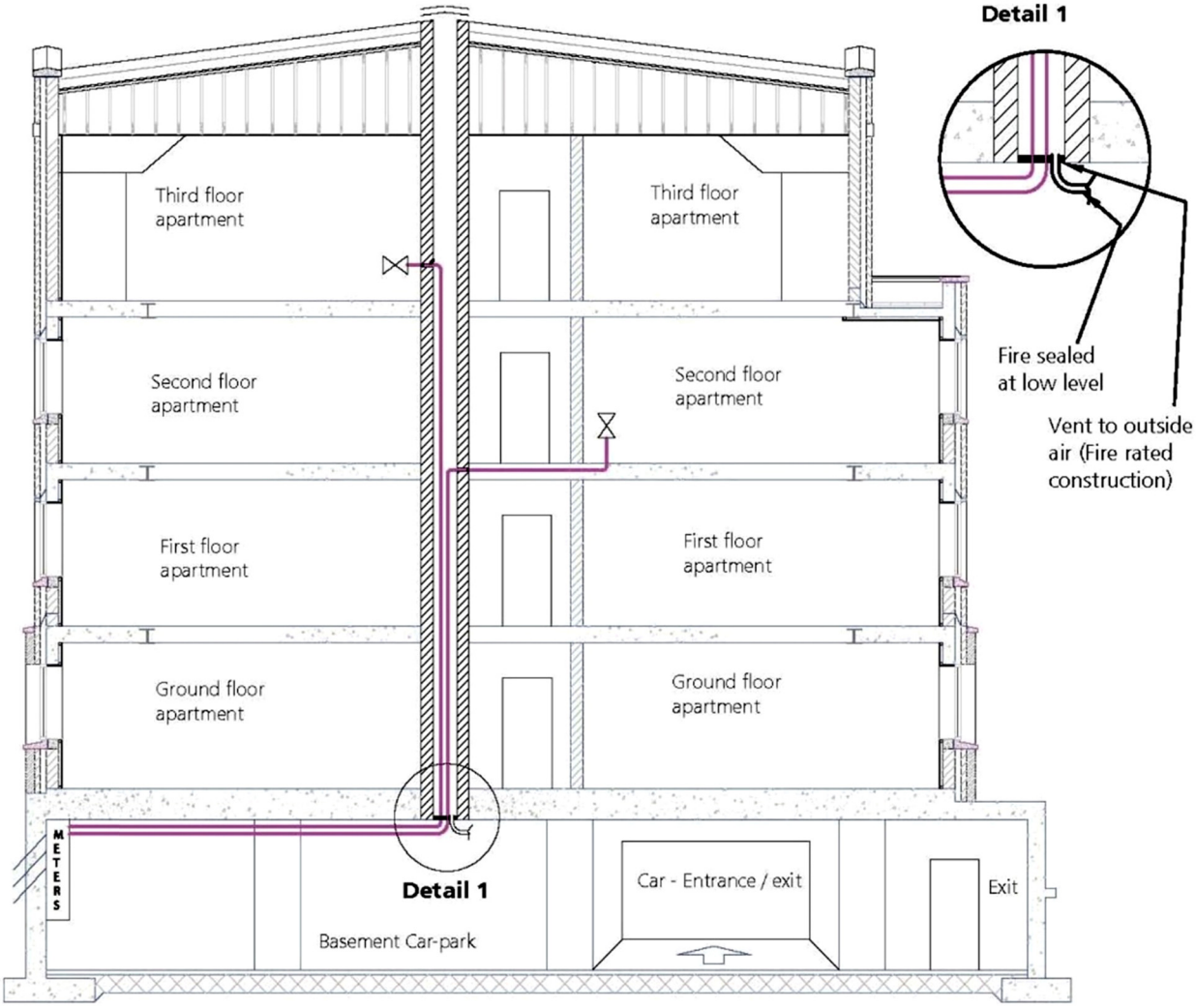

Figure 2: Placing the main pipe in the center of the building (Guevara [10]).

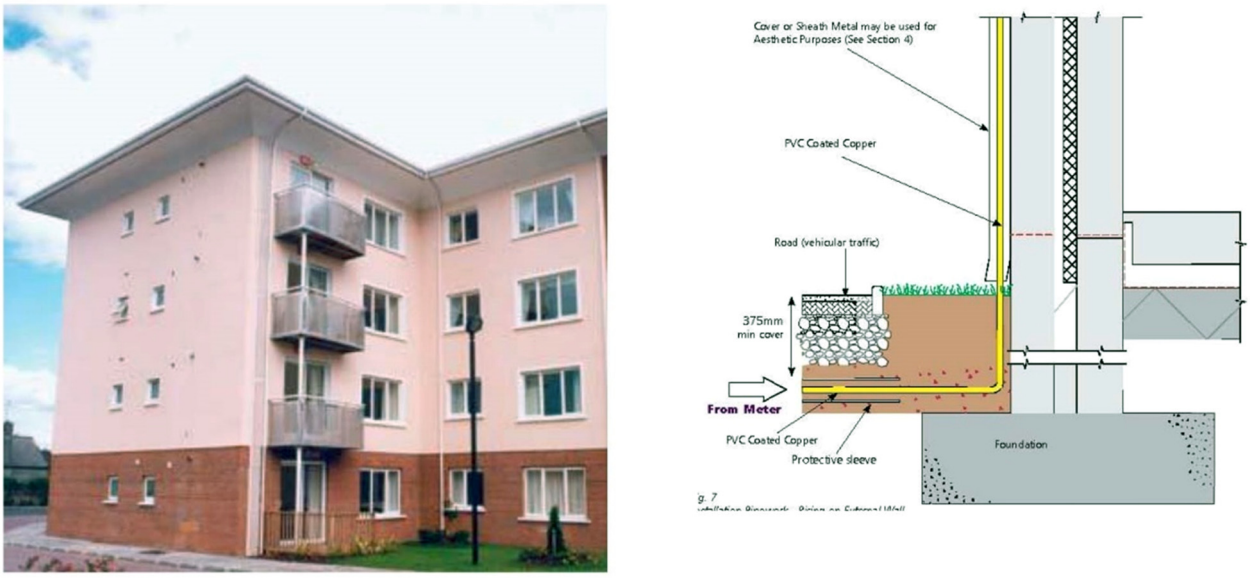

Figure 4: Installing pipes from the outer side (Guevara [10]).

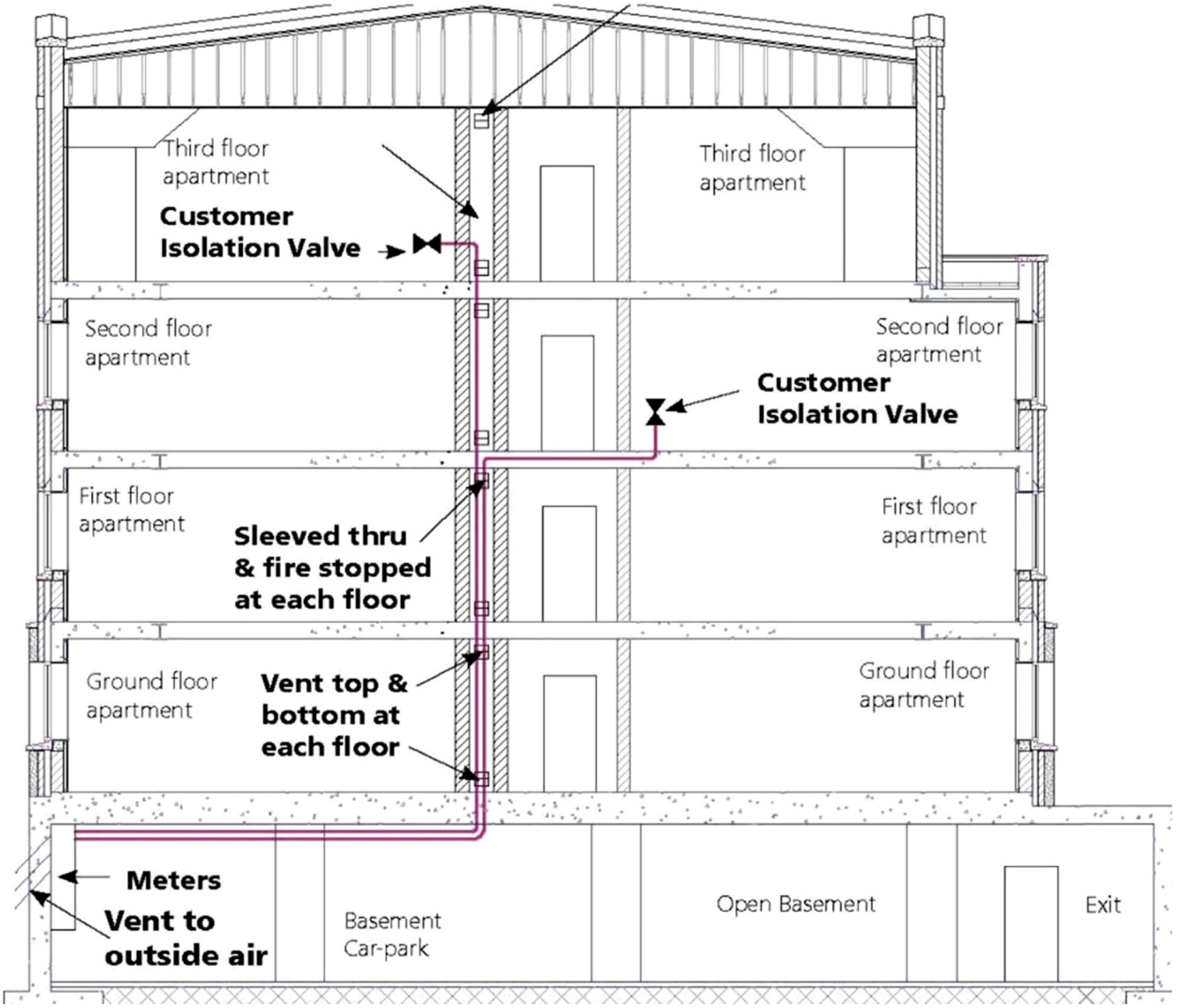

Figure 5: Installing gas piping on chasers (Guevara [10]).

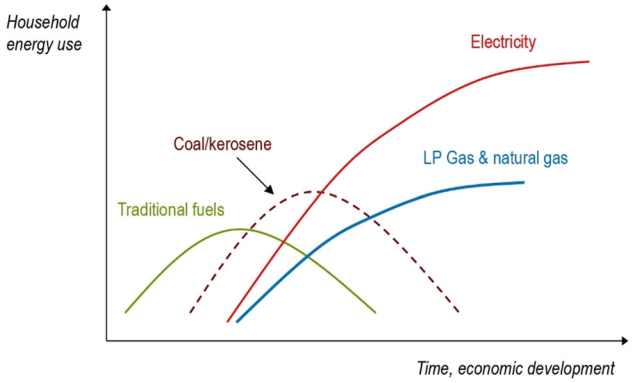

Figure 6: Household energy use by type of fuel for economic development (WLPGA [12]).

in a way that does not distort the general view. In some cases, the main pipe is placed in the center of the building, as shown in Figure 2, where venting is provided to the outside. In this case, environmental sustainability was also applied. In another case, the pipe is placed in the outer part of the walls of the building, but in a hidden way, as in Figures 3 and 4. Another method is to install the pipes on the chasers, where each floor is closed with a concrete slab and provided with openings at the top and bottom of the floor. The openings must be fire-resistant as in Figure 5 and the gas pipe is provided with a chaser in the outer wall and is provided with decorative nets that allow the pipes to be provided with natural ventilation. The annular space between the gas pipes and the cover must be sealed on the wall to prevent the entry of water, insects, or rodents [6].

3.3 Social sustainability

The use of solid fuels for cooking led to a negative effect. In a study conducted with the aim of reducing the use of solid fuels and replacing them with LPG by 2024 in a master plan to promote the expansion of gas use to determine market conditions, public and private sector interventions, and expected social impacts to achieve the 2030 goal of "universal access to clean modern energy," LPG usage is expected to be 13.2% by 2024 and 38.5% by 2030 [11].

3.4 Economic sustainability

In the energy market, LPG is going through a transitional phase where it will be the main source for a sufficient number of people and companies. LPG remains a vital and economically important complement to energies such as electricity and natural gas and this is conceptually reflected in the Figure 6 of energy use in developing energy markets over time [12].

To apply economic sustainability in the design of LPG in residential buildings, attention must be paid to

Figure 7: Building view case study.

Figure 8: Finished building.

payment methods, usually consumer billing is calculated using hourly energy consumption data from building simulation results and appropriate gas rates are applied for each utility service area to arrive at an estimated cost of utility bills. In order to implement long-term economic sustainability, the rate of reimbursement to the consumer should be maintained, that is, prices should not exceed the reasonable rate, and discounts should be applied on the account at time periods of the year to encourage the consumer to use clean energy [13].

4 Case study description

The residential complex for optimization of sustainability standards for LPG design is located in the city of Baghdad/Karkh. Each building contains eight floors and each floor contains six apartments as shown in Figures 7 and 8. The gas pipes in the building are designed in such a way that the pipe passes from the roof of the building to the first floor of the skylight, with gas leakage sensor. The presence of warning signs on the box responsible for regulating pressure and flow for each apartment and safety measures in the event of a fire are as shown in Figure 9. There is a monthly payment on the bill for consumers, calculated on the hours of use, and the cost is almost acceptable.

5 Results and discussion

Four axes of sustainability are analyzed in an objective achievement matrix method, which are divided into main

Figure 9: Warning signs in building.

Table 1: Objective achievement matrix

Main goals	Weight	Secondary goals	Weight
Environmental sustainability	25	Warning signs in dangerous places	5
		Gas leak sensor	10
		Ongoing maintenance	10
Aesthetic sustainability	25	Maintaining the facade of the building	13
		Bury the pipe from the tank to the building	12
Social sustainability	25	Expansion of gas distribution designs for consumers	13
		Directing safety instructions to consumers	12
Economic sustainability	25	Monthly payment is acceptable	13
		Offers and discounts to encourage consumers	12
Total sum	100	Total sum	100

Table 2: Objective achievement matrix results

Secondary goals	Weight
Warning signs in dangerous places	5
Gas leak sensor	10
Ongoing maintenance	10
Maintaining the facade of the building	13
Bury the pipe from the tank to the building	12
Expansion of gas distribution designs for consumers	13
Directing safety instructions to consumers	10
Monthly payment is acceptable	13
Offers and discounts to encourage consumers	0
Total sum	86

goals and secondary goals. The main goals include environmental sustainability, aesthetic sustainability, social sustainability, and economic sustainability. The secondary goals are branched from the main goals of each axis of sustainability as shown in Table 1.

Through Table 1, the building taken in the study is analyzed and the sustainability criteria axes are applied to the weights of the secondary goals to find out which axis is more achieved, while highlighting the weak axis. Table 2 explain the objective achievement matrix results.

6 Conclusion

The main results achieved from this research can be explained below:

(a) Sustainability is essential in the design of gas pipelines in the data in order to maintain safety, aesthetic, and public health, which causes to reduce the risk of accidents and explosions if it is used incorrectly.
(b) When the weight matrix is applied to a building as a case study, it turns out that the environmental and aesthetic sustainability are achieved by 100%, so the ratio is positive and excellent.
(c) Social and economic sustainability is achieved by 72%. There is a failure in the goal of directing safety instructions to consumers and the goal of offers and discounts to encourage consumers, so focus must be placed on them to achieve the axes of sustainability.

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