Sustainable Industrialization: Analysis of Methods for Carbon Dioxide Reduction in Brick Manufacturing Industries

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***Abstract*— The increasing demand for construction projects leads to a rise in production in brick manufacturing industries, resulting in the well-known problem of air pollution. These industries operate using solid fuels such as wood, charcoal, and animal dung, whose combustion produces an excess of carbon dioxide, the primary pollutant in greenhouse gas emissions and climate change. For this reason, carbon emissions from brick industries are a growing problem worldwide. The aim of this work is to analyze possible methods to reduce carbon dioxide emissions in brick manufacturing industries and achieve sustainable industrialization. To achieve this goal, this article is divided into three sections. Firstly, a description of some basic aspects of carbon dioxide production in the brick manufacturing industry is carried out. Secondly, an analysis of recycling methods is developed. Thirdly, efficient ways of reducing the carbon footprint are described. Fourthly, a technique for reusing carbon dioxide is presented. It is expected that this work will contribute to raising awareness about the significance of brick construction industries in terms of pollution.**

***Keywords:* brick manufacturing industries – carbon dioxide emissions – eco-bricks – renewable energies**

***Resumen*— La creciente demanda de proyectos de construcción lleva a un aumento de la producción en las industrias manufactureras de ladrillos, lo que genera el conocido problema de la contaminación del aire. Estas industrias operan utilizando combustibles sólidos como madera, carbón vegetal y estiércol animal, cuya combustión produce un exceso de dióxido de carbono, que es el principal contaminante de las emisiones de gases de efecto invernadero y del cambio climático. Por esta razón, las emisiones de carbono de las industrias ladrilleras son un problema que crece día a día en todo el mundo. El objetivo de este trabajo es analizar posibles métodos para reducir las emisiones de dióxido de carbono en las industrias de fabricación de ladrillos y lograr una industrialización sostenible. Para lograr este objetivo, este artículo se divide en tres secciones. En primer lugar, se realiza una descripción de algunos aspectos básicos de la producción de dióxido de carbono en la industria de fabricación de ladrillos. En segundo lugar, se desarrolla un análisis de métodos de reciclaje. En tercer lugar, se describen formas eficientes de reducir la huella de carbono. En cuarto lugar, se presenta una**

***Palabras clave*: industrias manufactureras de ladrillos – emisiones de dióxido de carbono – eco-ladrillos – energías renovables**

I. Introduction

The growing demand for construction projects leads to increased production in the brick manufacturing industries, which generates the well-known issue of air pollution. These industries operate using solid fuels such as wood, charcoal and animal manure, whose combustion produces an excess of carbon dioxide, which is the main pollutant for greenhouse gas emissions and climate change. For this reason, carbon emissions from brick industries are a growing problem around the world day by day.

As the brick manufacturing industry stands out as one of the major emitters of carbon dioxide, it is urgent to address this problem to promote sustainable practices. In this context, this paper focuses on examining methods and approaches to achieve sustainable industrialization in the brick construction field, with the goal of reducing carbon dioxide emissions. The central thesis of this work argues that, by adopting more efficient methods, it is possible to significantly reduce the carbon footprint of the brick manufacturing industry.

This aim is aligned with the United Nations Sustainable Development Goals (SDGs) Report, mainly with SDG #12. This SDG emphasizes the need to "Ensure Sustainable Consumption and Production Patterns" [1, p.59]. This SDG states that sustainable consumption and production aims at “doing more and better with less, increasing net welfare gains from economic activities by reducing resource use, degradation and pollution along the whole lifecycle, while increasing quality of life” [1, p.59].

The purpose of this paper is to identify and analyze specific methods that allow reducing the carbon dioxide emissions in these industries, thereby promoting more sustainable practices in accordance with the global development goals. The methods to be discussed are based on the 3R Initiative which aims “to promote the 3Rs (reduce, reuse and recycle) globally so as to build a sound-material-cycle society through the effective use of resources and materials” [2].

To achieve this target, this paper is divided into three sections. Firstly, a description of some basic aspects of the production of carbon dioxide in the brick manufacturing industry is carried out. Secondly, an analysis of methods of recycling is developed. Thirdly, efficient ways of reducing carbon footprint are described. Fourthly, a technique of reutilization of carbon dioxide (CO2) is presented. This paper is expected to contribute to raising awareness of what the brick construction industries represent in terms of pollution.

II. CARBON DIOXIDE EMISSIONS IN BRICK MANUFACTURING INDUSTRIES

To be able to understand the origin of carbon dioxide in the brick manufacturing industries, it is important to know the manufacturing process itself. In the next paragraphs, a brief description of the brick manufacturing process will be developed to contextualize the source of carbon dioxide in the brick manufacturing industries. Additionally, causes and consequences of CO2 emissions in this type of industry will be highlighted.

A. Contextualization of the origin of carbon dioxide emissions in brick manufacturing industries

Bricks are construction materials that are generally available as rectangular blocks [3]. The manufacturing process of bricks involves a set of stages that transform the raw materials in solid units used in construction. The following is a brief description of the process for contextualizing the origin of carbon dioxide in brick construction industries. As stated in [4], the main steps in this process are the following.

1. Clay extraction: Clay, one of the main components of bricks, contains minerals and other impurities that need to be removed before its use in brick manufacturing.
2. Clay preparation: The extracted clay undergoes a cleaning and crushing process to remove impurities and achieve the desired consistency.
3. Mixing and kneading: The crushed clay is mixed with water and other materials to obtain a homogeneous mixture.
4. Molding: The clay mixture is molded into the desired shape of the brick using various methods.
5. Drying: The molded bricks undergo a drying process to remove moisture and harden them. This drying can be natural or done in controlled drying chambers.
6. Firing: After drying, the bricks are placed in special kilns where they are subjected to high temperatures, usually between 800°C and 1,200°C. During firing, the clay undergoes chemical and physical changes, becoming stronger and more durable, and it is also the stage where the majority of carbon dioxide emissions originate.

Although the traditional clay brick manufacturing stages are very popular around the world, they involve a significant number of negative impacts on the environment, mainly in the production of carbon dioxide.

B. Causes of carbon dioxide emissions in brick manufacturing industries

In general terms, carbon dioxide emissions in the brick manufacturing industries mainly come from firing in ovens that use fossil fuels. However, it is important to note that the process of manufacturing bricks depends on the region and the technology used. Therefore, reducing carbon dioxide emissions is crucial to move towards a more sustainable brick manufacturing industry.

As stated in [4] and [5] the main causes of carbon dioxide emissions in brick manufacturing industries are as following.

1. Extraction and processing of raw materials: The extraction of clay, which is the primary raw material for brick manufacturing, may require the use of machinery and vehicles that run on fossil fuels, contributing to CO2 emissions.
2. Fossil fuel combustion during firing: During the brick firing process, ovens burn fossil fuels such as coal, natural gas, or oil to generate the necessary heat, results in the release of carbon dioxide into the atmosphere as a by-product of the chemical reaction.
3. Electricity consumption: In addition to fossil fuels used in ovens, brick manufacturing industries also consume electricity in various stages of the process, such as crushing, material transportation, and machinery operation.

C. Consequences of carbon dioxide emissions in brick manufacturing industries

Brick manufacturing industries play a vital role in the development of infrastructures around the world. However, it is crucial to recognize the environmental consequences associated with these industries, in particular, the carbon dioxide emissions that are generated during the manufacturing process. “In 2014, energy consumption and CO2 emission in the brick manufacturing industry reached 2.39 billion tons of standard coal equivalent and 6.45 billion tons, respectively” [6, p.600]. These emissions have a significant impact on climate change and in the quality of air, which raises important challenges for the sustainability and the health of the planet. In this context, some of the consequences of CO2 emissions are mentioned by [7] and presented below.

1. Climate change: Carbon dioxide is a greenhouse gas that contributes to global warming and to climate change.
2. Degradation of air quality: CO2 emissions from brick manufacturing industries are often accompanied by the release of other atmospheric pollutants, such as nitrogen oxides and suspended particles, affecting air quality and having detrimental effects on human health.
3. Resource depletion: Making and using mined clay for bricks requires significant amounts of raw materials, such as clay and fossil fuels.
4. Impact on sustainability: High CO2 emissions in brick manufacturing industries can compromise long-term sustainability.

These consequences highlight the importance of addressing carbon dioxide emissions in brick manufacturing industries and working towards more sustainable practices that minimize environmental impact and promote balanced and responsible development.

III. RECYCLING WITH ECO-BRICKS

In the brick manufacturing industry, recycling with eco-bricks offers a practical and innovative solution to tackle the significant carbon dioxide emissions associated with this sector. By incorporating eco-bricks into this industry, it is possible to mitigate the environmental impact and promote sustainability.

A. *Description of Ecological Bricks*

Eco-bricks made from plastic bottles are an innovative and sustainable building material that uses recycled plastic bottles to create construction units [8]. Each construction unit refers to a filled and sealed bottle [9]. These bottles can be used directly as bricks or inserted into support structures, such as meshes or frames, to form a set of bricks. They can be stacked and bonded together using adhesives or mortar to construct walls, partitions, or any other desired structures.

B. *Characteristics of Ecological Bottle Bricks*

In terms of properties and characteristics, eco-bricks made from plastic bottles have certain technical considerations. Their strength and load-bearing capacity depend on factors such as the density and compression of the waste materials inside the bottles, as well as the quality of sealing and bonding between the units. It is important to note that these bricks are not as strong as traditional bricks, so they are recommended for use in simple structures or as complementary components in combination with other building materials.

Additionally, thermal and acoustic insulation should be considered when using eco-bricks. Their insulation capacity may vary depending on the density and composition of the fillings in the bottles. These bricks can provide some resistance to heat and sound transmission, although their efficiency will depend on other design and construction factors, as stated in [10]. Table I compares some characteristics of traditional clay brick and eco-bricks made from plastic bottles.

TABLE I
COMPARISON OF CHARACTERISTICS BETWEEN TRADITIONAL BRICK AND ECOLOGICAL BRICK [11]

Characteristics	**Traditional clay brick**	**Eco-bricks made from plastic bottles**
endurance	high	moderate
durability	high	moderate
thermal isolation	low	moderate
acoustic isolation	low	moderate
environmental footprint	high	reduced
cost	moderate	varied

C. *Manufacturing Process of Ecological Bottle Bricks*

The manufacturing process of ecological bricks undergoes different steps. It begins with the selection of empty and clean plastic bottles, preferably of the same plastic type to ensure material consistency. These bottles are filled with non-biodegradable waste, such as compressed plastic bags or compacted plastic waste. This filling is done compactly to ensure the stability and strength of the resulting brick. Once the bottles are filled, they are tightly sealed with caps or plugs to prevent the materials from shifting or spilling out. Depending on the project requirements, the bottle bricks can be placed horizontally or vertically.

It is important to note that the manufacturing process can vary depending on the techniques and tools used, as well as the specific requirements of each project. Additionally, proper waste management should be ensured throughout the process to comply with regulations and waste management practices [10].

D. *Feasibility and Cost Study of Ecological Bricks*

Detailed feasibility and cost studies of eco-bricks in the brick manufacturing industries can involve evaluating various aspects. Following [12], below are some of the elements that are usually considered in these studies:

1. Production cost analysis: The costs associated with the production of eco-bricks are evaluated, including bottle collection and processing, material filling and compaction.
2. Energy savings and operational cost study: The long-term energy-saving potential in the industries by using eco-bricks in construction is assessed. Operational costs, such as maintenance and repairs over time, are also evaluated.

According to [10], it is important to note that feasibility and cost studies can vary depending on geographical location, local regulations, resource availability, and specific project conditions.

E. *Advantages of Ecological Bricks in Brick Manufacturing Industries*

Eco-bricks provide a significant advantage in the brick construction industry, with reduced sustainability and environmental footprint [9]. Eco-bricks have a reduced environmental footprint in the brick construction industry compared to conventional bricks. By using recycled materials, the production of new materials is avoided, and the associated greenhouse gas emissions are decreased. This significant benefit makes eco-bricks a sustainable and responsible option for the brick construction industry.

F. *Considerations of Ecological Bottle Bricks in Brick Manufacturing Industries*

Eco-bricks present some challenges and considerations that need to be taken into account. One of them is ensuring the quality and strength of bottle eco-bricks. It is important to conduct strength and durability tests to ensure that bottle eco-bricks meet the required standards since these bricks have a longer lifespan than traditional bricks. By using eco-bricks, the demand for common bricks would decrease, leading to a reduction in carbon dioxide emissions in the brick manufacturing industries [11].

Another important consideration is environmental education and awareness. It is crucial to educate the community and professionals in the brick manufacturing industries about the benefits and improvements that bottle eco-bricks offer in reducing carbon dioxide emissions.

IV. EFFICIENT WAYS OF REDUCING CARBON FOOTPRINT

Using eco-bricks in construction is a game-changer for sustainability. To make it truly eco-friendly, we must reduce carbon emissions in brick manufacturing. Incorporating clean and renewable energies such as photovoltaic solar, wind, or thermal energy to power manufacturing processes can significantly decrease carbon dioxide emissions.

A. *Impact of Using Non-Renewable Energies in Brick Manufacturing Industries*

Non-renewable energies, such as coal, natural gas, and oil, release significant amounts of carbon dioxide (CO2) and other greenhouse gases when burned to generate heat in the firing kilns. These emissions contribute to global warming and climate change [13]. Greenhouse gas emissions are a significant impact of the use of non-renewable energies in the brick manufacturing industries [14]

B. *Renewable Energies*

1. The integration of photovoltaic solar energy into brick manufacturing industries can offer several benefits, including reduced energy costs, lower carbon emissions, and increased sustainability.

   a. On-site photovoltaic solar energy systems: Installing photovoltaic solar panels on rooftops or available open spaces at brick manufacturing sites can generate clean electricity. This energy can be used to power various processes within the manufacturing plant, such as lighting, machinery, and other equipment [16].

   b. Environmental benefits: Brick manufacturing can contribute to greenhouse gas emissions. Transitioning to photovoltaic solar energy can help reduce the carbon footprint of the industry. Solar energy is a clean and renewable energy source that does not produce direct emissions during its operation [13].

It is important to conduct a feasibility and benefits study before implementing photovoltaic solar energy systems in brick manufacturing industries. Factors to consider include available space, sunlight exposure, energy consumption patterns, initial investment costs, maintenance requirements, and potential savings over the system-lifetime.

2. The integration of wind energy into brick manufacturing industries can also offer benefits which are similar to those of photovoltaic solar energy.

   a. Electricity generation: Wind turbines can be installed at brick manufacturing facilities to harness wind energy and generate electricity. Wind turbines convert the kinetic energy of the wind into electrical energy, which can be used to power various operations within the plant [16].

   b. Environmental benefits: Similar to solar energy, the integration of wind energy can help reduce greenhouse gas emissions and the carbon footprint of the brick manufacturing industry. As well as this, wind energy is a clean and renewable energy source that does not produce emissions during its operation [13].

The integration of wind energy into brick manufacturing industries may require a significant initial investment. However, it can offer a range of advantages in terms of reduced operational costs, environmental sustainability, and social responsibility. Determining feasibility and effective implementation planning are crucial steps in this process.

3. Integrating thermal energy into brick manufacturing industries involves using renewable heat sources for production processes, as proposed by [13].

   a. Environmental impact: By using renewable heat sources, greenhouse gas emissions and the carbon footprint of brick manufacturing can be significantly reduced. This contributes to environmental sustainability.

   b. Energy efficiency: In addition to introducing new thermal energy sources, brick manufacturing industries can optimize their processes to make more efficient use of heat. For example, insulation systems and temperature control can help retain heat and reduce losses.

The adoption of renewable thermal energy in brick manufacturing can enhance sustainability, lower costs, and contribute to the environmental responsibility of the brick. To ensure a successful and effective integration of these renewable heat sources, conducting a feasibility and benefits analysis is essential [13].

Overall, reducing greenhouse gas emissions is essential to address the impacts of carbon dioxide emissions and their consequences. That is why it is important for brick manufacturing industries to consider transitioning towards cleaner and renewable energy sources, as well as implementing more efficient technologies, to lower their carbon footprint and contribute to a more sustainable future.

V. REUTILIZATION OF CARBON DIOXIDE IN BRICK MANUFACTURING INDUSTRIES

Efficient ways to reduce carbon footprint, such as the use of renewable energies, are crucial to address the challenges posed by the carbon dioxide emissions released by brick manufacturing industries. An innovative solution lies in the reutilization of carbon dioxide within the brick manufacturing industries. By harnessing carbon dioxide emissions and incorporating them into the brick production process, these industries can significantly lower their environmental impact.

A. *Cogeneration*

Cogeneration in the brick manufacturing industry is one of the ways to save energy and use it efficiently. Brick production requires a significant amount of heat for drying and firing the bricks, as well as electricity to operate machinery and equipment. Cogeneration addresses this energy demand by generating both heat and electricity from a single fuel source, such as natural gas. By using engines or turbines, the fuel can be converted into both thermal and electrical energy simultaneously, enhancing the overall efficiency of the process [18].

B. *Use in Brick Manufacturing Industries*

In the context of brick production, cogeneration involves the simultaneous generation of electricity and heat from a single fuel source. This approach capitalizes on the waste heat produced during electricity generation, which is harnessed and utilized for various thermal processes within the brick manufacturing process. Cogeneration systems can offer a highly efficient solution by utilizing the residual heat from electricity generation for these thermal processes, optimizing the utilization of resources [19].

C. *Advantages in Brick Manufacturing Industries*

Cogeneration systems emerge as a highly efficient solution by harnessing the waste heat generated during electricity production to fuel thermal processes in brick manufacturing. This optimizes resource utilization and translates into more effective use. The inherent benefits of cogeneration in brick manufacturing industries become apparent [19]:

a. Greater efficiency: Cogeneration systems can achieve higher energy efficiency compared to separate electricity and heat generation methods. Captured waste heat enhances fuel utilization, resulting in improved energy conversion rates.

b. Lower emissions: Cogeneration systems have the potential to reduce greenhouse gas emissions due to higher energy efficiency and optimized fuel utilization.

c. Sustainable practices: By minimizing energy waste and utilizing heat that would otherwise be released into the environment, cogeneration aligns with sustainable practices and responsible resource management.

In conclusion, cogeneration has the potential to revolutionize energy management in brick manufacturing industries by offering a more efficient and sustainable approach to meeting their energy needs. By optimizing the utilization of both electricity and thermal energy, cogeneration can contribute to reducing operational costs, environmental impact, and dependence on external energy sources.

VI. COMPARATIVE ASSESMENT OF SOLUTIONS

Cogeneration systems offer a remarkably efficient solution, effectively repurposing waste heat generated during electricity production to power thermal processes in brick manufacturing. This approach maximizes resource utilization, resulting in greater efficiency, as cogeneration systems can achieve higher energy efficiency compared to separate electricity and heat generation methods. The captured waste heat enhances fuel utilization, ultimately improving energy conversion rates.

Additionally, cogeneration systems contribute to environmental sustainability by lowering greenhouse gas emissions through their higher energy efficiency and optimized fuel utilization. They align with responsible resource management and sustainable practices by minimizing energy waste and effectively utilizing heat that would otherwise be released into the environment, making them a key asset in environmentally conscious brick manufacturing industries.

The comparative viability assessment of three solutions to reduce carbon dioxide emissions in the brick manufacturing industry involves analyzing three key approaches: the use of efficient energy, cogeneration, and the use of bottle bricks.

The choice of the most viable solution will depend on a combination of economic, environmental, and resource factors. Continuous monitoring to assess performance over time should follow implementation. It is also essential to consider that viability may vary depending on the geographical location and the context of the brick manufacturing industry. Therefore, a detailed and customized analysis is required before making a final decision.

CONCLUSION

In conclusion, the pursuit of sustainable industrialization in brick manufacturing is essential to mitigate carbon dioxide emissions and reduce the environmental impact of this industry. The combination of methods such as cogeneration, energy efficiency improvement, and the adoption of eco-friendly bricks offer a comprehensive and effective approach to addressing this challenge.

Cogeneration utilizes energy resources more efficiently, reducing carbon emissions associated with energy generation. Energy efficiency optimizes manufacturing processes, reducing energy consumption and, consequently, emissions. Eco-friendly bricks not only reduce the need for traditional raw materials but also contribute to waste management by using recycled bottles filled with waste.

The implementation of these methods requires significant investments and efforts, but the long-term benefits are remarkable: a decrease in carbon emissions, increased sustainability in brick manufacturing, and a positive contribution to environmental conservation. Ultimately, sustainable industrialization in brick manufacturing is not only environmentally responsible but can also result in cost savings and enhanced competitiveness in the industry.

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REFERENCES

[1] The 2030 Agenda and the Sustainable Development Goals An opportunity for Latin America and the Caribbean, repositoriocepal.org, Goals, Targets and Glob. Available: https://repositorio.cepal.org/bitstream/handle/11362/40156/S1801140_en.pdf?sequence=27&isAllowed=y (accessed June 2, 2023).

[2] The 3R Initiative. Available: https://www.env.go.jp/recycle/3r/en/outline.html#:~:text=The%203R%20Initiative%20aims%20to,use%20of%20resources%20and%20materials (accessed June 17, 2023)

[3] Manufacturing of Bricks for Masonry Construction – Methods and Process. Available: https://theconstructor.org/building/manufacturing-of-bricksmethodsandprocess/11972/#:~:text=The%20process%20of%20manufacturig%20of,simple%20compared%20to%20stone%20masonr (accessed June 13, 2023)

[4] N. Dalkılıç, A. Nabikoğlu, "Traditional manufacturing of clay brick used in the historical buildings of Diyarbakir (Turkey)", Frontiers of Archit. Res., vol. 6, no. 3, pp. 346-359, Sept. 2017. Accessed: June 19, 2023. doi: https://doi.org/10.1016/j.foar.2017.06.003 [Online]. Available:https://www.sciencedirect.com/science/article/pii/S20952635173090

[5] M. Dabaieh, J. Heinonenc, D. El-Mahdy, D. M. Hassan, "A comparative study of life cycle carbon emissions and embodied energy between sun-dried bricks and fired clay bricks", *J. of Cleaner Production*, vol. 275, no, 122962, Dec. 2020. Accessed: June 19, 2023. doi: https://doi.org/10.1016/j.jclepro.2020.122998 [Online]. Available:https://www.sciencedirect.com/science/article/pii/S0959652620330432

[6] B. Xu, B. Lin, "Reducing carbon dioxide emissions in China's manufacturing industry: a dynamic vector autoregression approach", *J. of Cleaner Production*, vol. 131, no. 10, pp. 595-606, Sept. 2016. Accessed: June, 19, 2023, doi: https://doi.org/10.1016/j.jclepro.2016.04.129 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652616304176

[7] S. Salomónun, G. K. Plattnerb, R. KnuttiCy, P. Friedlingstein "Irreversible climate change due to carbon dioxide emissions", *PNAS*, vol.106, no. 6, pp. 1704-1709. Feb.2009. Accessed: June 20, 2023. [Online]. Available: https://www.pnas.org/doi/epdf/10.1073/pnas.0812721106

[8] C. L. Mei, A. Roslinda, M. Noraini, "A Comparison of Properties Between Eco-Brick and Lightweight Brick by Using SolidWorks Software", *Progress in Eng. App. & Tech.*, vol. 3, no 3, page 2, June 2022. Accessed: July 5, 2023. doi: https://doi.org/10.30880/peat. [Online]. Available: https://publisher.uthm.edu.my/periodicals/index.php/peat/article/view/6564/1958

[9] E. E Uche, A. Oko, O. Dadá, "Production and optimization of eco-bricks", *J. Cleaner Product*., vol. 266, no 1, Sept. 2020. Accesed : July, 5, 2023. doi:https://doi.org/10.1016/j.jclepro.2020.121640 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652620316875

[10] S. Madan Raj, M. Nandha Gopal, T. Palani Kumar, G. Guru Prasath, S. Rajesh M.E, "An Experimental Study on the Strength & Characteristics of Eco-Bricks from Garbage Dump," *Int. j. Latest Tech. Eng. Manag*., vol. 7, no, 4, pp.3-6, April, 2018. doi: https://www.researchgate.net/publication/371044426 [Online]. Available: https://www.researchgate.net/profile/Sofia-Rajesh/publication/371044426_An_Experimental_Study_on_the_Strength/links/647077e26fb1d1682b0af2e3/An-Experimental-Study-on-the-Strength.pdf (Accessed, Aug. 5, 2023)

[11] Shakir, A. Mohammed, "Manufacturing of Bricks in the Past, in the Present and in the Future: A state of the Art Review," *Int. J. Advances Appl. Sci*., vol. 2, no. 3, pp. 3-13, Sep. 2013, Accessed: Aug. 5, 2023. doi: https://www.researchgate.net/publication/270751259 [Online]. Available: https://www.researchgate.net/profile/Ali-Mohammed-10/publication/270751259_Manufacturing_of_Bricks_in_the_Past_in_the_Present_and_in_the_Future_A_state_of_the_Art_Review/links/578503c508ae36ad40a4b4f8/Manufacturing-of-Bricks-in-the-Past-in-the-Present-and-in-the-Future-A-state-of-the-Art-Review.pdf

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The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar

[12] H. Sharma, "Innovative and Sustainable Application of PET Bottle a Green Construction Overview," *Indian J. Sci. Tech*., vol. 10, no.16, pp.2-4, April, 2017. doi:10.17485/ijst/2017/v10i16/114307 [Online]. Available: https://www.researchgate.net/publication/317303927_Innovative_and_Sustainable_Application_of_PET_Bottle_a_Green_Construction_Overview

[13] P. Simon, "Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors". *Energy*, vol. 33, no. 10, pp. 1489-1497, Oct. 10, 2008. Accessed: Aug. 6, 2023 doi: https://doi.org/10.1016/j.energy.2008.03.008 [Online]. Available:https://www.sciencedirect.com/science/article/abs/pii/S0360544208000911

[14] U. Brad, "The greenhouse gas and energy impacts of using wood instead of alternatives in residential construction in the United States," *Biomass and Bioenergy*, vol. 32, no 1, pp. 1-10, Jan. 2008, Accessed: Aug. 6, 2023 doi: https://doi.org/10.1016/j.biombioe.2007.07.001 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0961953407001109

[15] R. Elghamry, "A parametric study on the impact of integrating solar cell panel at building envelope on its power, energy consumption, comfort conditions, and CO2 emission". *J. of Cleaner Production*, vol. 249, no. 10 pp. March 2020. Accessed, Aug. 6, 2023. doi: https://doi.org/10.1016/j.jclepro.2019.119374 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652619342441

[16] IJSRP, "Wind Turbine Blade Efficiency and Power Calculation with Electrical Analogy". *Int. J. Sci. and Res. Publications*, vol. 2, n° 2, Feb. 2012. Accessed: Aug. 7, 2023. [Online]. Available:https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a2186c16f6a58e02e5d7556bb2f08fcc06ea503c#page=233

[17] H. Schnitzer, "Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes," *J. Cleaner Production*, vol. 15, no. 13, pp. 1271-1286, Sep. 2007. Accessed: Aug. 7, 2023 doi: https://doi.org/10.1016/j.jclepro.2006.07.023 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652606002642

[18] U. Cakir, K. Comakli, F. Yüksel, "The role of cogeneration systems in sustainability of energy", *Energy Conserv. & Manag.*, vol. 63, Nov. 2012, pp. 196-202, Accessed: Aug. 30, 2023, doi: https://doi.org/10.1016/j.enconman.2012.01.041 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0196890412001264

[19] C. A. Frangopoulos, G. Dimopoulos, "Effect of reliability considerations on the optimal synthesis, design and operation of a cogeneration system", *Elsevier Energy*, vol. 19, no. 3, pp. 309-329, March 2004. Accessed: Sep. 6, 2023. doi: https://doi.org/10.1016/S0360-5442(02)00031-2 [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0360544202000312