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Journal Renewable Energy

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The works must be unpublished and refer to topics of Solar energy and its applications, renewable energies and climate change, environmental impact, hydroelectric plants, renewable energies, energy geothermal power in the world and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Livestock Biomass: Energy source for 26 municipalities in Hidalgo State experiencing high marginalization*, by GONZÁLEZ-ROSAS, Angelina, ORTEGA-MARIN, Blanca Andrea, GONZÁLEZ-ISLAS, Juan Carlos and GODÍNEZ-GARRIDO, Gildardo, with adscription in the Universidad Tecnológica de Tulancingo, in the next article we present, *Nuclear energy as backup to renewable energies*, by JIMÉNEZ-ROANO, Guadalupe, CRUZ-GÓMEZ, Marco Antonio, MEJÍA-PÉREZ, José Alfredo and JUÁREZ-ZERÓN, Tomás Aarón, with adscription in the Benemérita Universidad Autónoma de Puebla, in the next article we present, *Characterization of a parabolic solar cooker made from recycled materials*, by MARROQUÍN-DE JESÚS Ángel, GALVÁN-MONDRAGÓN, Mayola, CASTILLO-MARTÍNEZ, Luz Carmen and OLIVARES-RAMÍREZ, Juan Manuel, with adscription in the Universidad Tecnológica de San Juan del Río, in the next article we present, *Dimensioning of a hybrid system boiler - solar collector of evacuated tubes, for the defrosting of fish*, by OVANDO-SIERRA, Juan, CAMACHO-UC, Giovanni, HUCHIN-MISS, Mauricio and UC-RIOS, Carlos, with adscription in the Universidad Autónoma de Campeche.

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Livestock Biomass: Energy source for 26 municipalities in Hidalgo State experiencing high marginalization

Biomasa ganadera: Fuente de energía para los 26 municipios de alta marginación del estado de Hidalgo

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Abstract

The high consumption of natural non-renewable resources has caused an exponential increase in the greenhouse gases which provoke global warming and as a result, every country on the planet suffers environmental issues due to the excessive use of fossil fuels. There are several different sources of gas production, principally caused by human beings, however there is little to no interest in mitigating them. Global interest is instead currently focused on containing them via the reduction of carbon dioxide (CO_2) and methane (CH_4). In the Paris Agreement, participating countries have committed to keeping the rise of the mean global temperature below 2 °C and to limiting its increase to 1.5 °C. Latin America as a whole (and principally, Mexico) has committed to lowering greenhouse gases 25% by 2030 and 50% by 2050 (AZEL, 2018). To achieve this, it is necessary to contribute by applying clean energy alternatives. The current project proposes using bovine and swine organic wastes for the production of biogas and electric energy in 26 cities of high marginalization in Hidalgo, a state in Mexico which contributes to lowering environmental pollution, providing access to better services for raising the quality of life of its inhabitants, and minimizing the use of (therefore saving the money provided for) subsidies for conventional electric energy.

Biofuels, Biogas, High marginalization

Resumen

El alto consumo de los recursos naturales no renovables ha producido un aumento exponencial de gases de efecto invernadero que están provocando el calentamiento global por lo que todos los países del orbe presentan problemas ambientales, debido a la excesiva utilización de los combustibles fósiles, existen diferentes fuentes de generación causadas principalmente por los seres humanos, sin embargo no hay interés por su mitigación. Actualmente el interés mundial es contenerlos mediante la reducción del metano (CH_4) y del dióxido de carbono (CO_2). En el Acuerdo de París los países que lo integran se han comprometido a mantener la temperatura media mundial por debajo de 2 °C y limitar el aumento de la temperatura a 1,5 °C; en América Latina y principalmente ~~en~~ México, tiene el compromiso de disminuir 25% de los gases de efecto invernadero para 2030 y el 50% para 2050 (AZEL, 2018), para lograrlo es necesario contribuir con la aplicación de energías alternas más limpias. En el presente proyecto se propone utilizar los residuos orgánicos de los bovinos y porcinos para la producción de biogás y energía eléctrica en veintiséis municipios de más alta marginación del estado de Hidalgo que coadyuve a la disminución de la contaminación ambiental, el acceso a mejores servicios en beneficio de la calidad de vida de los habitantes y el minimizar el subsidio de energía eléctrica convencional.

Biocombustibles, Biogás, Alta marginación

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I. Introduction

Global warming is one of the challenges that the United Nations has as one of its main roles, as stated in the Paris Agreement, to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty (A.P., 2015), (UNFCCC, 2015). It is a priority to give the world a fighting chance to limit the global temperature increase to 1.5°C and avoid the worst effects of climate change (IEA, 2022), which undoubtedly requires a total transformation of the way energy is produced, transported and consumed.

According to the United Nations Environment Programme (UNEP, 2020) in 2019 for the third consecutive year, global Greenhouse Gas (GHG) emissions increased to an all-time high (UN, 2020) and stood at 52.4 $GtCO_2e$, without considering emissions from land-use change, and 59.1 GtCO2e if they are included.

GHGs are those gases present in the atmosphere that contribute to the greenhouse effect - the process by which thermal radiation emitted by the atmosphere is absorbed by the gases present and radiated in all directions - are of natural and anthropogenic origin - the result of human activity - Water vapour (H_2O), Carbon Dioxide (CO_2), Nitrous Oxide (N_2O), Methane (CH_4), Ozone (O_3), Sulphur Hexafluoride (SF_6), Hydrofluorocarbons (HFC's) and Perfluorocarbons (PFC's), (CEPSA, 2015), with CO_2 and CH_4 having the greatest impact due to the amount of tonnes discharged into the atmosphere.

Among the irreversible effects that are occurring are the increase in temperature, which is causing glaciers to melt at a faster rate, causing sea levels to rise, forests to dry up, fauna and flora to struggle to survive in ecosystems that are undergoing dizzying and complex changes that often have a serious and irreversible impact on biodiversity. According to information from the International Energy Agency in the dossier of the Spanish oil company CEPSA (2015), in the world the sectors that generate the greatest contribution of CO2 are: electricity generation (40.1% with 13Gt); industry (20.1%, 6.5Gt); transport (24.7%, 8Gt); building (7.7%, 2.5Gt); others (including agriculture and non-energy uses)* (7.4%, 2.4Gt).

The energy sector contributes two-thirds of GHG emissions and accounts for 90% of total industrial CO_2 emissions, and as a major emitter, holds the key to meeting the climate change challenge (IEA, 2021). Net zero means huge decreases in coal, oil and gas use, yet achieving net zero emissions by 2050 will require nothing less than the complete transformation of the global energy system (IEA, 2021).

Even so, according to data provided by the Renewables Global Status Report (REN21), in 2019 approximately 771 million people (10 % of the world's population) lack access to electricity (REN21, 2020). It is necessary to support countries with a deficit in access to this energy source, otherwise the world will still not ensure universal access to affordable, reliable, sustainable and modern energy by 2030 (World Health Organization (WHO), 2021). Another important factor is that changes in climate affect the energy sector, directly impacting fuel supply, energy production, physical resilience of energy infrastructure and energy demand (IEA, 2022), increasing frequency or intensity of extreme weather events such as heat waves, wildfires, cyclones, floods and cold snaps lead to disruptions in energy supply and difficulties in demand management (IEA, 2022).

The estimated share of renewables in global electricity production in 2018 was 73.8% non-renewable electricity; 26.2% renewable electricity; 15.8% hydropower; 5.5% wind power; 2.4% solar PV; 2.2% bioenergy; and 0.4% geothermal, CSP and ocean energy (REN21, 2019). In 2020 global per capita energy consumption was 71.5 GJ and in Mexico it was 50.2GJ, which meant a reduction of 5.5% globally with respect to 2019, in Mexico it was 15.9% mainly due to the COVID 19 - SARS2 pandemic that affected the entire planet (BP, 2021). Energy consumption through renewable energy is barely detectable in 2019 representing 0.30 ExaJ, in 2020 of 0.36 ExaJ in Mexico, globally it was 31.71 ExaJ, renewable energy generation was 39.2 TeraWatt-h, however it does not include biomass.

Mexico is expanding its solar PV capacity by 1.5 GW, despite difficult economic conditions, thanks in large part to abundant solar resources, falling prices and favourable policies in some countries (REN21, 2020), biomass energy use is still very low.

Due to energy marginalisation by communication routes to reach rural communities, the distance to rural communities is an important factor that makes access to natural gas and electricity more difficult. The way to reduce this gap is to use energy from the sun and organic waste (Barragan, 2018) to produce the biofuels (gas and electricity) needed to improve the quality of life of the most disadvantaged people, biomass can contribute significantly to sustainable development in both developed and developing countries, provided that the aspects related to its exploitation are carefully considered.

Bioenergy is a type of renewable energy from biomass (Sidartha et al., 2020) is defined as the biodegradable fraction of products, wastes and residues of biological origin is a source of solar energy stored by plants through the process of photosynthesis where carbon dioxide and water vapour are captured and converted into glucose with the help of sunlight, whose origin is starches, cellulose and lignin among others (Rincón et al, 2014), from agricultural activities - including substances of plant and animal origin - forestry, related industries, fisheries, aquaculture, and the biodegradable fraction of industrial and municipal waste.

The economic reuse of methane can contribute to the reduction of greenhouse gas emissions (García et al, 2016), (Ortiz, 2017) and contribute to reducing its consumption and the depletion of fossil fuel reserves, bringing with it the adoption of technologies in line with the possibilities of producers for the use of waste (Rivas et al, 2012) (Ortiz, 2017), in the generation of environmentally friendly clean energy. Organic solid waste - animal waste - can contribute to the reduction of the negative impact of methane and carbon dioxide.

Traditional biomass is mainly used for cooking and heating in rural areas of developing countries, accounting for approximately 8.5% of total final energy (Rincón et al, 2014). However it accounts for more than 10% of the world's primary energy supply and is the world's fourth largest source of energy (after oil, coal and natural gas) (Rincón et al, 2014), (SENER, 2012). In this sense, the global demand for biomass for energy purposes is estimated at 53 EJ (1,265 Mton eq oil) (Rincón et al, 2014), (Dávalos, 2012).

1.1 Impact of climate change on energy generation

Mexico is part of the Latin American region that contributes a large amount of natural resources to the world, particularly for its biodiversity; recognised since 2010 in the United Nations Development Programme, the United Nations Environment Programme, the Economic Commission for Latin America and the United Nations Conference on Trade and Development and the Environmental Conservation Monitoring Centre (UNDP, UNEP, ECLAC & UNCTAD, UNEP-WCMC, 2016) and UNEP in 2019 have suggested the desirability of its participation in programmes of environmental services derived from its ecosystems.

It should be noted that the systematic exploitation of natural resources over the centuries has contributed to the alteration of ecosystems, with negative results on the components of the environment; such as the variability detected in temperature, with effects on climate and bringing about climate change (CC); reflected in variations in hydrological cycles, in climatic seasons and in the increase and/or intensity of meteorological events. At the same time, the effect of all this brings changes in land quality, droughts, floods, loss of heritage, loss of human lives, which together increase poverty, especially among the rural population and/or those living in the countryside (ECLAC-European Union, 2017) and raise costs in both the production and sale of agricultural products. All of the above encourages further migration (Stein, 2018) to cities or other countries, abandoning agricultural production (Ortega-Marín et al, 2020).

In this order of ideas, maintaining natural resources entails a double responsibility: on the one hand, caring for biodiversity and, on the other, guaranteeing the availability of food for the 126 million Mexicans (National Institute of Statistics and Geography (INEGI), 2021). Currently, among the effects of the pandemic, food production is going through economic challenges in terms of income, and an increase in the population in situations of vulnerability and poverty is expected (Ortega Marín et al., 2020), which is why guaranteeing and making basic services available is a task that cannot be postponed.

In numerical terms, according to the National Evaluation Council (CONEVAL, 2021) between 2018 and 2020 the number of poor people increased from 51.9 to 55.7 million people. The population living in extreme poverty also increased from 8.7 to 10.8 million people. In terms of social deprivation, the lack of access to health services increased by 12.0 percentage points, from 16.2 per cent to 28.2 per cent.

On the other hand, to address CC in Mexico since 2013, a variety of research, public policies, programmes, models, among others, have been developed to understand, address and/or prevent climate change and vulnerability (Estrategia Nacional de Cambio Climático ENCC; 2013, National Institute of Ecology and Climate Change (INECC)-Government of Mexico 2022, National Institute of Ecology and Climate Change (INECC)-Global Environment Facility (GEF)-United Nations Development Programme (UNDP) and the Ministry of Environment and Natural Resources (SEMARNAT) 2012).

In terms of public policy, since 2001 the country has been part of ParlAméricas (2010), a Latin American initiative of countries that participate in the chambers of deputies, senators, legislative assemblies and/or parliamentary institutions of the Americas and the Caribbean, with the objective of improving and strengthening national and hemispheric democratic processes, through forums on key issues of common concern such as poverty and inequality (2006). In 2009 Altieri and Nichols published a proposal for attention to peasant agriculture with strategies and adaptive measures to protect and restore land properties in the face of events that affect them. In 2010, the ParlAmericas agendas included the new challenges for the Americas in the 21st century on climate change, foreseeing disaster and emergency preparedness and response, among other fundamental issues, particularly vulnerability, including Mexico (INECC, 2019).

The meeting included the topics of Disaster management in Latin America and the Caribbean (LAC): How to engage policy makers (Jeremy Collymore - WG1), Challenges for disaster preparedness, mitigation and response (Ricardo Mena - WG1) and Old and new threats to the security of Latin America (Gerardo Rodríguez Sánchez Lara - WG_2) where ECLAC (2018) has been documenting in its publication Social Panorama of Latin America.

In 2015, at COP 21 in Paris, the countries of the Americas and the Caribbean presented their national contributions to the United Nations Framework Convention on Climate Change (ParlAmericas, Summary of Contributions, 2015).

Since 2016, the CC Meeting has been held annually, exchanging knowledge among its members, experts and interested civil society, orienting its practices towards mitigation and adaptation through workshops, exchange of dialogues, the creation of specialised resources and, as of 2019, ParlAmericas is an observer of the Intergovernmental Panel on Climate Change (IPCC). On the other hand, ECLAC (2017) is the international body under the United Nations that has been responsible for promoting discussions on CC:

– The main public policy challenges and challenges arising for LAC countries.
– The linkages that exist between the challenges presented and how this contributes to advancing the development agenda.
– The options for mitigation and adaptation measures and policies to address them.
– The key sectors and activities affected and where opportunities for policy decisions are identified.

It is also responsible for promoting the evaluation and prioritisation of CC mitigation and adaptation policies within the framework of EUROCLIMA and monitoring nationally determined contributions (NDCs) within the framework of the ECLAC-BMZ/giz Programme.

The Economics of Climate Change Unit of the Sustainable Development and Human Settlements Division of the same ECLAC (2017.1), in the framework of the actions contemplated by the EUROCLIMA Programme and which it operates, has published 12 documents in which it shares public policy recommendations related to issues of agriculture; water, biodiversity and forests; economics of climate change; energy and gasoline; development styles; climate change mitigation and adaptation measures; environmental fiscal policy; and social policy and climate change.

UNEP (2019) operates in LAC the public policies they issue, through programmes and projects on issues such as: Regional Platform for Innovation and Technology Transfer for Climate Change (REGATTA), Microfinance for Ecosystem-based Adaptation to Climate Change (MEbA), Ecosystem-based Adaptation (EbA) Mountain Programme, Euroclimate, United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) and Joint Programmes. As can be read, CC represents a major challenge for LAC and Mexico, and taking up all available information to understand both the issue and the way in which it has been addressed over time and what should have been done from the beginning and was left at least three decades ago (Arellano, 2014), leads to the determination that the decisions currently being taken should be the closest to compensating for the late attention to the various problems caused by the abuse of natural resources in countries like Mexico, with its great natural and irreplaceable wealth.

1.2 Problem statement

Inserted in the globally defined capitalist mode of production, the reality of Latin American countries and Mexico, over the centuries, has been that they have only been providers. They survive through inequality in access to food, housing, education, employment - to mention the most representative ones - in an environment of extreme poverty and vulnerability (Stein, 2018). This has been "addressed" by the UNDP and the UNEP promoted by the United Nations (UN) and the governments of each country, promoted - over time - in the Millennium Development Goals (ECLAC-UN 2010) and now in the Sustainable Development Goals (SDGs) 2030 (UNEP, 2021).

Among the actions developed to reduce GHGs, Mexico has participated in initiatives such as clean development mechanisms, payment for environmental services and the purchase of carbon credits. Particularly, the construction of biodigesters was an alternative that caused great interest at the beginning but unfortunately stopped being promoted and of the 720 biodigesters that were installed nationally (2005-2012), according to data from the Current situation and scenarios for the development of biogas in Mexico, 2024-2030. And one hundred between 2012-2018.

When designing the scenarios -according to the aforementioned publication-, it was concluded that the sectors with possibilities for profitable and productive application of biodigestion are large integrated livestock companies, corn flour plants (for vehicle methane), tequila plants (to generate steam) and PTAR (for self-consumption electricity). MSW treatment or dedicated crop processing are not yet validated.

However, generating biogas to access light or heat energy and biofertilisers, where several families benefit, in particular those considered to be highly and very highly marginalised. This is a feasible possibility and is what we intend to determine in this research, supported by biomass, manure and human waste generated in rural areas, and to achieve access to services for those who lack them, stop using fossil resources and join in caring for the environment, through the management of renewable energies and the application of viable adaptive measures (González Rosas et al, 2021).

1.3 Biomass as an energy source

Renewable energies, solar (thermal and photovoltaic), wind, hydro, biofuels and others, are in the transition towards a less carbon-intensive and more sustainable energy system (IEA, 2021).

The use of renewable energies is a way to mitigate the negative effects of environmental pollution. One of these types of energies is biomass, which through photosynthesis consumes carbon dioxide (CO2) and underproduces oxygen (O2) during the day and at night the opposite happens, capturing oxygen and releasing carbon dioxide.

The gas exchange that occurs during photosynthesis is essential for ecosystems and for life in general. Bioenergy accounts for about one tenth of the world's total primary energy supply. Currently (IEA, 2022), bioenergy accounted for approximately 11.6 %, or 44 exajoules (EJ), of total final energy consumption in 2019, more than half of this total bioenergy came from traditional biomass use, which provided about 24.6 EJ of energy for cooking and heating in developing and emerging economies (REN21, 2020).

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According to the IEA (2022) modern bioenergy is a major source of renewable energy, its contribution to final energy demand in all sectors is five times greater than wind and solar PV combined, even when traditional biomass use is excluded, while the use of biomass in energy production offers emissions reductions in a wide range of areas, including low-emission fuels for aircraft, ships and other forms of transport, and the substitution of natural gas by biomethane to provide heat and electricity, access to clean energy for cooking has made less progress in recent years.

Large numbers of people in the developing world have no choice but to cook using traditional biomass systems, such as indoor open fires or inefficient cookers, resulting in high levels of household air pollution with severe health impacts that fall disproportionately on women (REN21, 2020). Globally 2.6 billion people still rely on polluting fuels. An estimated 125 million people use biogas for cooking worldwide, a figure that has remained almost constant over the last decade (REN21, 2020). Sustainable bioenergy is therefore also essential to bring clean cooking solutions to the 2.6 billion people who currently lack them (WHO, 2021).

1.4 The context in Mexico

Mexico, due to its geographical location, has a great potential for solar irradiation that favours the development of renewable energies through solar, wind, geothermal and biomass resources, according to data from the International Renewable Energy Agency (IRENA, 2019), which is an inexhaustible resource as long as it is managed in a sustainable manner, it is an inexhaustible resource as long as it is managed in a sustainable manner; endogenously and due to its territorial availability (Jeloal, 2022), waste treatment, but above all its use to provide clean cooking, which is still the biggest challenge at the moment. Mexico is located between 15° and 35° latitude, a region considered the most favoured in terms of solar resources, receiving, on average, 5.5 kWh/m^2 per day. Figure 1 shows the horizontal solar radiation reaching the country.

Figure 1 Solar resource. Global horizontal irradiation of Mexico average 1999-2018.
Source: Image captured from Solargis 2017 and World Bank Group, https://olc.worldbank.org/content/global-solar-atlas

Mexico has 5.5 times more territory than Germany, 5.0 times more radiation and 44.2 times more solar energy generated. Compared to China, Mexico has a territory 4.9 times smaller and an average solar radiation 1.2 times higher, however, the solar energy generated is equivalent to 0.1% of China's (Limón, 2021). Despite having ideal geographic and climatological conditions for the development of solar energy, and despite some successful efforts, Mexico continues to lag behind worldwide, which is why it is important to use biomass waste available through a complex and degradative biodigestion system in which part of the organic materials (carbohydrates, proteins and lipids) of a substrate (animal and vegetable waste) are converted into biogas and biofertiliser (González, 2014).

In Mexico, two types of bioenergy are used: biomass and biogas for electricity generation, mainly using sugarcane sap, but organic matter from agricultural, livestock, forestry, aquaculture, algaculture, fishing waste and other activities can also be used (SENER, 2016). Mexico has a high potential of biomass resources to be used as waste from agriculture, livestock and agro-industry, according to the Energy Balance of 2019 indicates that the production of biogas was 2.8 PJ and biomass was 361.17 PJ.

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1.5 The context in the state of Hidalgo

The state of Hidalgo is one of the main energy suppliers in the central region of the country, whose geographical location places it among the primary energy exploitation sites oriented towards the high energy consumption region of Mexico. In the energy transformation process, the state plays a key role in the economic functioning of the region (PIAEE, 2018). In the State Development Plan 2016-2022 for the state of Hidalgo, in its Axis 2. "Hidalgo Prosperous and Dynamic", it proposes to generate economic growth locally, in balance with social development and the environment.

In Axis 5. "Hidalgo with Sustainable Development", it foresees providing energy to the population of Hidalgo under sustainable energy efficiency schemes and promoting the generation and consumption of electricity with sustainable sources, deciding to promote clean energy, accompanying the effort of the National Development Plan 2013-2018, with several Special and Sectoral Programmes (LOAEEH, 2018). It is located between the coordinates: Longitude 99°51'34.20" W 97°59'05.64" W, Latitude 19°35'52.08" N 21°23'54.60" N, its territory represents 1.1% of the national territory, with a population 3,082,841 inhabitants corresponding to 2.4 % of the country's total, 57 % is urban population and 43 % rural, representing at national level 79 and 21 % respectively, according to data from INEGI, 2020.

Considering the above described and taking into account the information that the Ministry of Welfare published by Decree of 30 November 2020, the Declaration of Priority Attention Zones for the year 2021 (DOF, 2020), of the 84 municipalities that make up the state of Hidalgo, 26 of them are in a situation of high and very high marginalisation, have economic limitations, communication routes and the cost of access to conventional energy sources is very high. However, these municipalities have sufficient solar radiation and biomass for their use and generation of clean biofuels. The objective of this project is to identify the energy potential of organic waste from cattle and pigs in the twenty-six highly marginalised municipalities of the state of Hidalgo to contribute to the generation of electricity for their inhabitants.

2. Materials and Methods

- Determine the amount of excreta that can be obtained through the amount of livestock existing in the state of Hidalgo.
- Calculate the biogas production based on organic waste by livestock type.
- Estimate the energy content of organic waste from its chemical content.
- Define the volume of biogas based on the amount of livestock produced in Hidalgo (26 high marginalisation municipalities).
- Calculate the use of biogas in high marginalisation municipalities.

The proposed techniques allow visualising the performance of the different excreta and the possible combination between them, in order to obtain maximum efficiency.

3. Results

When manure is used for agronomic purposes it can cause different impacts on soil and crop, depending on the management system, it is a valuable source of nitrogen (N), being able to fully or partially replace mineral fertilisation (Biau, 2012), (Osejos, et al, 2018). In natural decomposition processes, biomass releases methane (CH_4), methane is a gas with severe consequences for the greenhouse effect, having a global warming potential of up to 23 times greater than that of CO_2 (Martínez, 2015).

For this reason it is important to take advantage of it, considering the 26 High Marginalisation Municipalities and the information regarding livestock production in each of them reported in the SIAP to 2020, Table 1 presents the volume and variety of livestock available to use their excreta as a means to generate another form of environmentally friendly energy. Goats have not been considered in this study because only some of the municipalities have them, but cattle, sheep and pigs, as well as information for turkeys and poultry that is available in the study municipalities.

No.	Municipality	Bovine Ton	Sheep Ton	Pigs Ton
1	Huehuetla	1332.20	8.01	99.86
2	Xochiatipan	180.66	3.66	95.18
3	Yahualica	267.51	1.94	69.18
4	Acaxochitlán	336.59	130.20	236.91
5	Agua Blanca de Iturbide	514.40	94.05	186.17
6	Atlapexco	567.78	5.96	148.92
7	Calnali	358.87	21.09	160.87
8	Chapantongo	809.68	97.94	288.74
9	Chapulhuacán	1177.09	11.07	137.28
10	Huautla	1237.94	6.08	209.29
11	Huazalingo	552.10	2.27	123.08
12	Jacala de Ledezma	373.65	30.89	127.95
13	Lolotla	616.42	7.85	121.94
14	Metztitlán	313.13	91.66	243.26
15	Mineral del Chico	131.71	221.76	27.02
16	La Misión	631.40	15.02	103.95
17	Nicolás Flores	207.41	21.37	83.92
18	San Felipe Orizatlán	2815.06	23.04	514.29
19	Pacula	325.52	20.32	128.48
20	Pisaflores	718.96	19.64	160.81
21	San Bartolo Tutotepec	1839.12	19.91	104.86
22	Tenango de Doria	793.20	16.60	177.81
23	Tepehuacán de Guerrero	634.25	19.72	191.19
24	Tianguistengo	458.92	13.63	84.93
25	Tlahuiltepa	559.16	35.26	91.08
26	Tlanchinol	1022.28	19.91	174.95

Table 1 Volume of livestock available in Highly Marginalised and Socially Backward Municipalities of the State of Hidalgo in 2020
Source: Own elaboration with information from SIAP http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php

Table 2 shows the production of excreta by type of animal, the biogas obtained needs to be converted from chemical energy to calorific energy, it has a high calorific value of 4700 to 5500 Kcal/m^3, which is equivalent to having a cubic metre of biogas and can be used in cooking food, for lighting homes, electric generators, water pumps among others (Villegas Aguilar, 2006), (Osejos, et al, 2018).

Assuming control of the variables of the biodigestion process, it could be considered that on average the energy content of this mixture is 20 MJ/m^3, which by changing units means 5.56 kWh/m^3, or similarly, each m^3 of biogas represents 0.0033 barrels of oil equivalent (BEP) or 305.8 m^3 of biogas has the energy content of a BEP (Martinez, 2015).

Type of animal	Size	Amount of excreta per day	Biogas yield	Biogas production (m3/y/day)	Relation
		(ETM) Kg/d	(m^3/Kg excreta)	(m^3/a/día)	Excrete : Water
Cattle	Large	15	0.04	0.6	1:1
	Medium	10	0.04	0.4	
	Small	8	0.04	0.32	
Pig	Large	2	0.07	0.14	1:1a 1:3
	Medium	1.5	0.07	0.1	
Poultry	Large	0.15	0.06	0.009	1:3
	Medium	0.1	0.06	0.006	
Sheep	Large	5	0.05	0.25	1:2a 2:3
	Medium	2	0.05	0.1	

Table 2 Excreta produced by type of animal
Source: Carlos Martínez Collado, 2007

According to the study conducted by Martínez Lozano in 2015, it indicates that pigs produce 4 kg of fresh manure per head per day; so each pig is capable of producing 0.33 m^3 of useful biogas per day (Osejos, et al, 2018); if it is considered to generate electricity.

Then additional aspects must be considered such as the type of biodigester to be used for chemical-thermal-mechanical-electrical conversion, which implies that for each cubic metre of biogas, 1.67 kWh of electricity can be obtained. This information and the information in Tables 1 and 2 were used to obtain the information in Table 3, concerning the biogas production generated from cattle, sheep, pigs, turkeys and poultry.

The volume in tonnes of each type of animal was converted to head of livestock to determine the volume of biogas and kWh of electricity available, for reasons of space only 10 of the 26 municipalities analysed are presented.

The study shows that in all municipalities sufficient energy is obtained to meet the energy demand that each household needs for cooking, lighting and the electricity required by each household.

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No.	Municipality	Heads of livestock Prom	Biogas production m3/a/d	Consumption kWh/year per dwelling
1	Huehuetla	2664.40	1065.76	103.68
2	Xochiatipan	361.33	144.53	20.20
3	Yahualica	535.01	214.00	20.78
4	Acaxochitlán	673.18	269.27	15.72
5	Agua Blanca de Iturbide	1028.80	411.52	87.98
6	Atlapexco	1135.56	454.22	52.20
7	Calnali	717.74	287.09	36.95
8	Chapantongo	1619.36	647.74	101.58
9	Chapulhuacán	2354.18	941.67	91.75
10	Huautla	2475.88	990.35	108.95
11	Huazalingo	1104.21	441.68	88.71
12	Jacala de Ledezma	747.30	298.92	48.67
13	Lolotla	1232.84	493.14	115.48
14	Metztitlán	626.25	250.50	24.50
15	Mineral del Chico	263.42	105.37	25.36
16	La Misión	1262.79	505.12	105.12
17	Nicolás Flores	414.82	165.93	57.63
18	San Felipe Orizatlán	5630.12	2252.05	134.23
19	Pacula	651.04	260.42	111.01
20	Pisaflores	1437.92	575.17	71.87
21	San Bartolo Tutotepec	3678.24	1471.30	179.33
22	Tenango de Doria	1586.39	634.56	83.58
23	Tepehuacán de Guerrero	1268.50	507.40	41.29
24	Tianguistengo	917.84	367.14	55.59
25	Tlahuiltepa	1118.32	447.33	95.67
26	Tlanchinol	2044.56	817.82	52.20

Table 3 Biogas production by type of animal, kWh generation per day and kWh/year consumption per household in municipalities in the state of Hidalgo to 2021.
Source: Own elaboration with information from SIAP, of the volume of livestock production by municipality, http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php.

Considering that the biogas demand for 4 inhab/d in a rural area is 24m^3/d (taking into account that it is required for: cooking= 2.1 m^3/d; lighting= 3.5 m^3/d; and electricity= 18.3 m^3/d), and that the electricity consumption of a household for 4 inhab/year is 2,956 kWh/year, it is observed that the production of kWh of electricity per municipality using cattle excreta is sufficient to meet the consumption demand required by each of the households in each municipality. Similarly, it was obtained that the energy demand per household in each municipality is satisfied with pigs and sheep; in the case of the amount of excreta from turkeys and poultry it is not sufficient separately, but the combination could give a favourable result, this is a second study to be carried out; as well as using excreta from dogs, cats and humans.

Regarding the adaptive measures of environmental care, it is possible to recover the actions learned over time for the care of their natural resources, considering ancestral practices, complementing them with the use of organic compost, a combination of planting nutrient-extracting vegetables that balance the properties of the soil and contribute to stop the deterioration of its layers, by building dams that contain it, to mention the most common in agriculture.

Conclusions

As has been observed, using bovine excreta provides the amount of energy needed to provide electricity, lighting and biogas in the households of the 26 Highly Marginalised Municipalities in the state of Hidalgo. Using the excreta obtained from sheep and pigs is also favourable for each household in the municipalities described above to have access to the minimum 24m^3/d of biogas required, or the 2,956 kWh/year that 4 inhabitants need for electricity. A second study is considering the use of excreta from poultry, turkeys, dogs, cats and people that each household owns, increasing the options for more biofuel and electricity available, so that all available organic waste can be used.

However, depending on the type and size of the biodigester to be used, the quantity and quality of the biol obtained can be used as organic fertiliser to help improve the quality of farmland in the municipalities under study. The energy obtained from a process of using biomass of animal origin can be considered "clean", if we also consider the low cost of its implementation compared to obtaining a barrel of oil equivalent, then it is a perfectly viable alternative.

The main component of this biofuel is methane, which is slightly lighter than air and has an average ignition temperature of 700°C, the flame reaches around 850°C, it can have an energy content of 20 to 25 MJ/m^3, while natural gas has an energy content of around 38 MJ/m^3; this is due to the CO_2 content and traces of hydrogen sulphide, hydrogen and nitrogen. However, in Mexico, producing 1 kWh of electricity with the primary energies currently used generates 0.675 kg of CO_2. So for every kWh generated with biogas, there is an equivalent saving in CO_2.

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Article

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Nuclear energy as backup to renewable energies

Energía nuclear como respaldo a las energías renovables

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Abstract

Due to climate change, the use of nuclear energy for electricity production has been presented as a backup alternative to renewable powers to reduce CO2 emissions while maintaining energy stability. Currently, the carbon dioxide emissions produced related to the energy sector increased by 6% by 2021, reaching 36.3 billion tons (their highest level in history), the cause of this event is due to the global economic recovery after the COVID-19 crisis, which relied heavily on coal to fuel its increase. The main problem with nuclear energy lies in the waste produced by the nuclear fission reaction, therefore, the objective of this research was to gather information on why nuclear energy is considered clean energy, the current management of nuclear waste, and public opinion, with information obtained from the most recent articles on the production of electrical energy through nuclear energy.

Nuclear power, Fission, Clean energy

Resumen

Debido al cambio climático el uso de la energía nuclear para la producción de electricidad se ha presentado como una alternativa de respaldo a las energías renovables para reducir las emisiones de CO2 manteniendo una estabilidad energética. Actualmente las emisiones producidas de dióxido de carbono relacionadas con el sector energético aumentaron un 6% para 2021, alcanzando los 36300 millones de toneladas (su nivel más alto en la historia), la causa de este acontecimiento se debe a la recuperación económica mundial tras la crisis de COVID-19, la cual dependió en gran medida del carbón para impulsar su crecimiento. De acuerdo con un estudio realizado por la comisión europea, las emisiones de CO2 producidas por la energía nuclear son similares a las energías verdes, a diferencia de estas últimas, la energía nuclear puede producir grandes cantidades de electricidad de manera estable y continua. La principal problemática sobre la energía nuclear radica en los desechos producidos por la reacción de fisión nuclear, por lo tanto, esta investigación tuvo como objetivo recabar información sobre por qué la energía nuclear es considerada una energía limpia, el manejo actual de los desechos nucleares y opinión pública, con información obtenida de los artículos más recientes sobre producción de energía eléctrica a través de energía nuclear.

Energía nuclear, Fisión, Energía limpia

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Introduction

Energy demand is increasing, so it is necessary to find a viable solution to maintain stable and sustainable energy consumption, which is why nuclear energy has been presented as an option to make the energy transition to renewable energies. A system is sustainable if it can survive or persist over a time scale that is conscious of its spatial scale. There are 3 pillars for sustainability, these are the economy, the environment, and society. (Andrea Bersano, 2020)

Misinformation and historical events surrounding this type of energy are the main reason why people oppose its use. There are divided opinions within the scientific community, the strongest argument as to why we should not use nuclear energy is its waste, however, there is an increasing number of experts who agree that nuclear energy should be part of the solution to combat climate change, it already emits few greenhouse gases and has had no negative consequences for health during normal operation and even has limited consequences after accidents. (Anne-Sophie Hacquin, 2022)

It is a fact that a decrease in dependence on fossil energies is required, which is why nuclear energy is sought after as transitory energy because it produces large amounts of stable energy compared to renewable energies. Over time, society has experienced exponential growth, causing high energy demands, and depleting resources. As a society develops, greater energy consumption is generated, leading to negative consequences, mainly of an environmental nature. (Orozco, 2022)

Nuclear energy is what keeps the subatomic particles in the nucleus (protons and neutrons) together and is responsible for giving them stability. (Marcos, 2022). Plutonium, uranium, and other radioactive elements are used as fuel because "they are considered unstable". The energy is obtained or caused through a method called nuclear fission, when hitting the nucleus of unstable atoms with other neutrons, a colossal burst of energy is produced. At the end of the process, the so-called "nuclear waste" remains, are the plutonium and uranium atoms that are unused, these remains emit large amounts of radiation and are toxic to living beings and the environment.

Currently, deep geological repositories in vaults with specific characteristics are considered the most durable way to dispose of high-level radioactive waste and aim to transform much of the accumulated nuclear waste into innocuous compounds over time. (Rohini C.Kale, 2021)

Methodology

This research was carried out under a mixed, quantitative, and qualitative methodology with a mixed approach based on scientific articles, as well as interviews, international reports, and videos on nuclear energy. Due to the difficulty of access to this topic, information was collected on why nuclear energy is considered clean energy? the current management of nuclear waste, and public opinion, with information obtained from the most recent articles on nuclear production. of electrical energy through nuclear energy.

The application of the qualitative method allowed us to obtain comparison graphs between the types of energies and their effects in different ecological environments. From the results obtained, a discussion of results will follow on the use of nuclear energy as a support for green energies.

1 What is nuclear energy and how is it produced?

Nuclear energy is a form of energy that is released from the nucleus (central part of atoms) consisting of protons and neutrons. This source of energy can be produced in two ways: through the fission (when the nuclei of atoms are divided into several parts) or through fusion (when they merge). (Galindo, IAEA Organismo internacional de energía atómica, 2021)

Fission receives this name because when a nucleus is bombarded by neutrons it subdivides into more neutrons, which in turn bombard other nearby nuclei causing a chain reaction. This is the science that nuclear power plants use for the production of energy. (Marcos, 2022)

To achieve a nuclear fission reaction, elements that can be easily altered and that release thermal energy are required. Uranium is the most widely used element as nuclear fuel. Not all cores of a given element are built the same.

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An element is defined by the number of protons within the nucleus, and varying the number of neutrons in the nucleus can cause it to behave differently. Natural uranium is mostly made up of uranium-238 (99.3%), with uranium-235 (0.7%) and a very small amount of uranium-234 (0.0055%). Most reactors require a higher percentage of uranium-235, which is why to maintain nuclear fission reactions, uranium enrichment processes are usually used. (Enciclopedia de energía, 2021)

1.1 Nuclear reactors

Nuclear reactors produce electrical energy from the thermal energy that is produced through fission reactions and is found inside nuclear power plants, these are industrial facilities that produce electrical energy. The fuel used for the fission reactions is found in the reactors and they have systems capable of starting, maintaining, and stopping the reactions caused to release large amounts of thermal energy. It is estimated that 11% of the total energy around the world is produced by reactors in nuclear power plants. (Hermosilla, 2022)

1.1.1 Operation of a reactor

Pressurized water reactors are the most widely used. When the heat produced by the fission reaction increases, the coolant begins to rise in temperature, producing the steam responsible for turning the turbines. The thermal energy produced is transformed into kinetic energy, then it is transformed into mechanical energy and finally, it is converted into electrical energy. Figure 1 shows the cycle of a pressurized water reactor. (López, 2019) (Galindo, IAEA Organismo internacional de energía atómica, 2021).

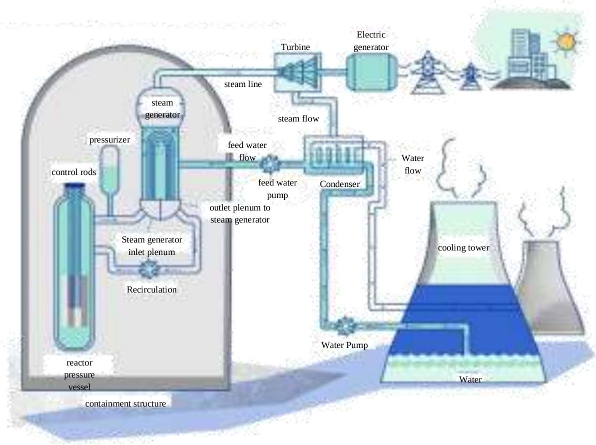

Figura 1 Cycle of a pressurized water reactor (PWR) *(Galindo, IAEA Organismo internacional de energía atómica, 2021)*

The process can be simplified into four phases;

1) The fission reaction is carried out in the reactor, and the water that works as a coolant is heated and transported to the steam generator to produce steam.
2) Steam is transported to the turbine, followed by a secondary circuit to the generator.
3) In the turbine, the blades rotate by the action of steam and the turbine shaft moves the alternator, transforming mechanical energy into electricity.
4) The vapor is sent to the condenser through a secondary circuit to be transformed into a liquid again.(SectorElectricidad, 2021).

1.2 Types of reactors

Some of the existing reactors are:

CANDU Reactors (Canadian), Boiling water reactors, pressurized water/prismatic reactors, molten salt reactors, modular reactors, supercritical water-cooled reactors, and research reactors, currently, Actually, no fusion reactor allows obtaining electrical energy, however, if there are research centers that study fission reactions. (Adetunji, The conversation, 2022).

2 Nuclear energy as clean energy

It is important to know the difference between green, clean and renewable energies to understand why, according to the European Commission, nuclear is considered clean energy. The definition of green energy says that it encompasses all clean, non-polluting energy that comes from 100% renewable sources. All renewable energy is clean, but not all clean energy is renewable. Renewable energy is defined as one whose energy source is based on the use of inexhaustible natural resources, such as the sun, wind, water, or biomass. Renewable energies are characterized by not using fossil fuels, but natural resources capable of unlimited renewal. (Garrett, 2022)

Non-renewable clean energies are those that consist of energy production systems that exclude any type of pollution, mainly due to the emission of greenhouse gases, such as CO_2, which cause climate change.

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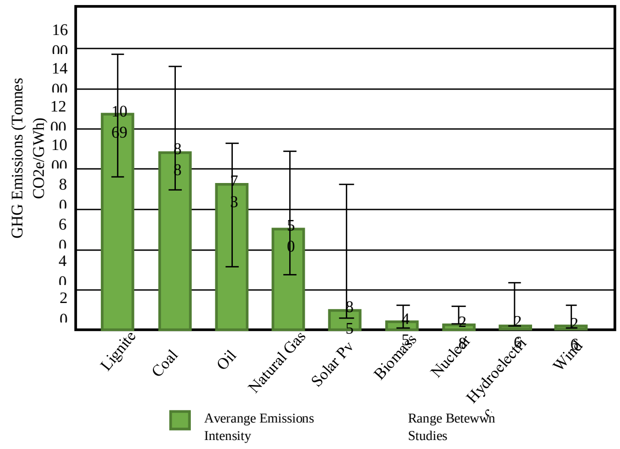
They promote advances to preserve the environment and reduce the crisis of exhaustible energies. (IBERDROLA, 2022). Nuclear energy according to the configurations fits as clean energy, this is because it is decarbonized and "does not emit" greenhouse gases compared to fossil energies, however, it is not considered renewable energy because the Uranium (a component used to carry out nuclear fission) is a limited resource.

To label nuclear energy as green, the European Commission establishes that those energies that can play a crucial role in decarbonizing our economies during the coming decades can be classified as such. (Gallo, 2022) (Petten, 2021)

According to the technical report published by the European Commission on the ecological impact of nuclear energy, this is one of the sources of electricity production that generates fewer greenhouse gases throughout its cycle.

As can be seen in graph 1, the source of electrical energy that generates the most tons of CO2 for every gigawatt-hour (GWh) of production is lignite (fossil coal) with 1069 tons for every GWh and natural gas as an energy source. electricity generates an average of 500 tons of CO2 for each GWh produced, this data is significant because the strategy that governments such as Spain or Germany are following is to use gas as complimentary electrical energy for renewable energy sources, the idea is to replace coal plants by plants that use natural gas since coal emits much more CO2 into the atmosphere, however, natural gas is still a source of electricity production that emits large amounts of CO2 (Gallo, 2022).

In comparison, nuclear energy can be seen with a considerable minimum production of greenhouse gases, reaching an amount not so separate from that emitted by renewable energies.



Graph 1 The intensity of GHG emissions of the life cycle of electricity generation technologies *(Petten, 2021)*

From the broader perspective, the European Commission argues that nuclear power further contributes to climate change mitigation through synergy with renewable energy technologies. Nuclear is the main source of manageable low-carbon electricity next to hydroelectricity. When used as a baseload technology, it provides flexible operation to supplement intermittent renewable energy sources.

Therefore, wind and solar energy are deployed more efficiently. This avoids, on the one hand, the use of highly carbon-intensive generation technologies that are often used as a backup or main source of energy. On the other hand, this integration, together with the storage of electricity, brings benefits to the electricity grid, by minimizing short-term interruptions.. (Petten, 2021)

The report also compares the precursor compounds of acid rain, sulfur dioxide (SO2), nitrogen oxide (NOx), nitrogen monoxide (NO), nitrogen dioxide (N2O), and various other substances. Emissions of these acidifying substances can persist in the air for a few days, undergoing a chemical conversion into acids (sulfuric and nitric), causing changes in the chemical composition of the soil and surface water, contaminating jungles and forests, and in turn, damaging the flora and wildlife.

Graph 2 shows the grams per kilowatt-hour (kWh) of electricity that is generated by the different sources that produce electricity. (Petten, 2021)

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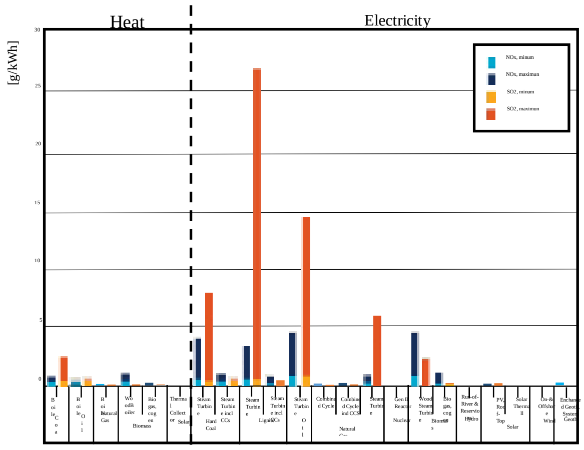

Gráfico 2 Cumulative life cycle emissions of NOx and SO2 per unit of energy for current heat and power supply technologies *(Petten, 2021)*

It can be seen that fossil energies stand out as the most harmful, coal, oil, and, to a lesser extent, natural gas. On the other hand, renewable energies have a minimum production like nuclear. Another factor taken into consideration in the report is the abiotic depletion potential (ADP). This indicator refers to the depletion of non-living (abiotic) resources such as metals, minerals, and fossil energy (Graph 3). The scarcity of the different natural resources used is a factor in the calculation of the indicator and is measured in kilograms of Antimony (Sb).

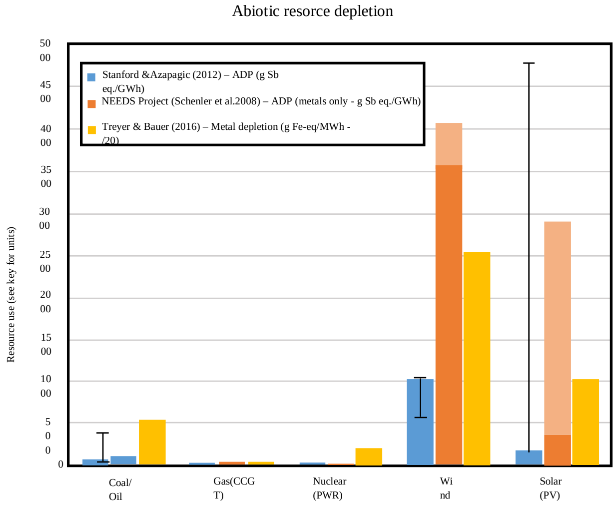

Gráfico 3 Use of natural resources *(Petten, 2021)*

These maximum and minimum values correspond only to national differences in the implementation of the different technologies, except for photovoltaic solar energy. (Petten, 2021). Nuclear energy consumes the fewest metallic and non-metallic mineral resources. The graph shows that the potential for abiotic depletion with nuclear energy is much lower than with solar or wind energy.

To complement the energy transition through renewable energies such as solar or photovoltaic, a brutal increase in the mining extraction of the entire planet would be necessary, since these energy sources consume many mineral resources. The available scientific evidence allows nuclear energy to be classified as green, that is, it does not have a significantly negative impact on the environment across the production. (Gallo, 2022).

Despite its drawbacks, a large number of experts consider that they are not enough to rule out this source of energy, in an article in "The Conversation" they conclude that "there is no science-based evidence that nuclear power causes more damage to humans or the environment than other electricity production technologies".(Marcos, 2022) (Adetunji, The conversation, 2022).

According to José Pardo de Santayana in Energy security in the transition towards clean energies, the proposal to integrate nuclear energy as green is defended, stating that to meet the objectives of the energy transition, the European Union must include nuclear energy, implying an investment in new reactors between now and 2050. In Construction and positioning of the sociotechnical imaginary: "Energy 2050" by Juan Carlos Imio, it is stated that planning is necessary due to the importance of sociotechnical phenomena in promoting the energy transition to sustainability. (Imio, 2022)(de Santayana, 2022)

3. Waste radioactive

Radioactive waste is defined as any material derived from the peaceful use of nuclear energy that contains radioactive isotopes for which reuse is not anticipated. Most of the nuclear waste generated comes from spent nuclear fuel in nuclear power plants. (Planas, 2022).
Each country has its policy and strategy for the management of its waste, they are important since they guarantee the position and plans agreed upon at the national level for the management of said materials. In Mexico, radioactive desire is considered to be any material that contains or is contaminated with radionuclides in concentrations or levels of radioactivity greater than those indicated in NOM-035-NUCL-2013, and for which no use is foreseen. (SEGOB secretaria de gobernación, 2021) (IAEA, 2022)

3.1 Radiation levels and types

There are levels of medium, low and high activity, this classification depends on the concentration of radionuclides. Short-lived waste has radionuclide contamination with a half-life of less than or equal to 30 years, and long-lived waste with alpha-particle emitters has a decay period greater than 30 years. Medium-level waste is generated in the fission process in small quantities and is placed in steel drums for treatment. Low-level waste is also added to drums. High-level waste can be active for thousands of years and its treatment consists of three stages: initial storage, intermediate storage, and final storage. (Planas, 2022).

In turn, radiation is divided into ionizing (capable of ripping electrons from atoms and molecules) and non-ionizing (of lesser intensity). In the case of non-ionizing radiation, its energy is not enough to remove the electrons from the atoms or molecules that make up matter, however, it is capable of generating heat through the vibration of said molecules. Ionizing radiation can produce changes at the atomic level and in high doses, it can be lethal, however, the reality is that with controlled and adequate doses, in addition to protection measures, it has positive uses such as energy production and the treatment of diseases stories like cancer. (Galindo, IAEA Organismo internacional de energía atómica , 2022)

In the case of nuclear power plants, the type of radiation is ionizing and is emitted naturally by the uranium and during nuclear fission, despite this, it does not represent a danger outside of the radiation emitted by the waste. (Galindo, IAEA Organismo internacional de energía atómica, 2021)

4. Countries and their opinion

According to the International Electric Power Agency by the end of 2020, the world's total nuclear power capacity amounted to 392.6 GW(e)[1] produced by a total of 442 functional reactors in 32 countries. In the same year, nuclear power supplied 2,553.2 terawatt-hours of GHG-free electricity, about 10% of the electricity generated globally and one-third of the world's low-carbon output. (General, 2021).

In Latin America, the first country to build and commit to nuclear energy was Argentina. Julian Gadano, the former Argentine undersecretary for nuclear energy, says that he is convinced that there is no solution to climate change in the short term without nuclear energy, since "This one is clean and at the same time, somehow, it's always available." He also talks about the fact that, in addition to public opinion, another challenge he faces is cost, due to the search for clean, permanent, and safe energy that is also found at competitive costs.

Germany currently has six nuclear reactors in operation that produce 8,113 MWe, previously 25% of the country's electricity was produced by 17 reactors and this percentage was reduced to 10%. Germany has stated that it does not have construction planes for future reactors and has closed a total of 30 that have a production capacity of 18,262 MWe. (Español, 2021).

Countries such as France and the United States are in favor of the production of electrical energy through nuclear power, the latter being the largest producer in the world with 93 active reactors and an average production of 95,523 MWe per year, in addition to having reactors under construction. France, for its part, has been openly in favor of the energy transition, supporting renewable energies through nuclear due to the scarcity of resources such as gas, coal or oil. It has 56 reactors with a production of 61,370 MWe equivalent to 70% of its electricity and about 17% of its electricity is generated through recycled nuclear energy. (Español, 2021). Mexico has two nuclear reactors that produce 1,552 MWe, covering 4% of the country's electricity, but there are currently no plans to build more reactors. (Portillo, 2022)

5. Métodos de eliminación de desechos nucleares

Proper disposal of nuclear waste requires strict guidelines to ensure proper handling from start to finish. There are different methods, including incineration, storage, burial at shallow, medium and deep depths, and even recycling. The most common way to eliminate high-level waste is deep burial, countries with resources use this method, creating "bunkers" with strict characteristics for proper storage accompanied by laboratories that monitor the use and storage of materials. (Mundial, 2022)

5.1 Bunkers de almacenamiento

Specifications for nuclear waste storage bunkers are extremely limited, however, the basic principle of disposal is the use of multiple barriers designed specifically for the area. (Rodney C.Ewing, 2021)

"Waste Isolation Pilot Plant" (WIPP) is one of the pilot nuclear cemeteries located in New Mexico, EU. Since the beginning of the 21st century it has received highly radioactive waste and it is expected to receive containers until the year 2070. This cemetery stores 185,000 containers of radioactive waste 660 meters below ground. The Hanford complex in Seattle is one of the largest, storing 177 tanks containing 200,000 cubic meters of waste. It is not known for sure how many cemeteries there are, however, it is understood that they are desolate places that cannot be accessed, even on the surface, since people can be exposed to harmful chemicals such as radioactive cesium – also known as isotope cesium 134 or 137. (Avramow, 2022)

6. Waste management

There is no single solution to develop a waste management program, each country has taken its path to deal with the problem, most technological development refers to waste storage, however, this is not the end of waste management. waste, the next step is to put said waste to use to obtain an efficient life cycle. Achieving the closure cycle is the essential factor to guarantee sustainability, the fissile material of the spent nuclear fuel can be recovered to produce non-irradiated fuel. Few water-cooled reactors are currently licensed to use recycled fuels. (General, 2021)

Countries like Japan have invested in reprocessing infrastructure, thereby recycling as much plutonium as possible. The socio-economic aspects and environmental ratios are expected to be a guide to the emerging market for the nuclear industry, which tends to adhere to the "wait and see strategy" for nuclear waste management but will soon struggle with nuclear waste management. (Lim, 2016) (Jung WooSuh, 2020).

Results

According to the Director-General of the International Atomic Energy Organization, nuclear power can help address pressing global issues. However, misconceptions about nuclear power continue to outpace public acceptance and policy making. Public perception of the benefits and risks associated with nuclear energy and, in particular, concerns about radiation risks, radioactive waste management, safety and security remain the aspects that most influence public acceptance. As public opinion plays a critical role in how governments choose to produce their energy, understanding the views, perceptions, and knowledge of stakeholders regarding nuclear power is important for the programs for nuclear power. Establishing strong, positive and long-term relationships with stakeholders is a key factor for existing, new and future nuclear power programs. (General, 2021)

Discussion of results

Implementing waste treatment plans and providing active knowledge to society about the benefits and safety measures of nuclear power production is essential to opening up its acceptance. It is not about moving from fossil to nuclear energy, but about giving priority to clean energy in general, renewable or not. The benefits of nuclear power are obvious, there can be no transition to green energy without support because renewable energy, such as solar or wind, is intermittent. The constant and growing energy demand, together with the depletion of fossil resources and the worrying environmental situation, make the need to use this type of energy evident. Furthermore, prioritizing waste treatment plans, primarily waste recycling, maybe the method to achieve a full cycle for nuclear power.

Conclusions

It has been verified with statistics that the environmental impact on the ozone layer is much lower with nuclear power, maintaining a high energy production capacity. Nuclear reactors are safe, they are controlled at all times by trained personnel and each radioactive waste has a process for its containment or elimination. Public opinion influences how countries manage this sector, a firm and informed decision is required more than the public.

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Article

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Characterization of a parabolic solar cooker made from recycled materials

Caracterización de una cocina solar parabólica elaborada con materiales reciclados

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Abstract

Currently, in some communities, firewood is still used to cook or conserve heat; this action generates great problems for health and the environment, one of them is the great risk of fires and/or asphyxiation due to smoke inhalation, another is the deforestation that is carried out to obtain firewood and, finally, the generation of methane, ozone precursors and carbon dioxide when burning any of these. This work proposes the use of a parabolic solar stove, made from recycled materials, such as cardboard, self-adhesive contact paper as reflective material, Masking tape®, which allows reducing manufacturing costs, helping low-income families and being environmentally friendly. The results obtained with respect to the time required for cooking various foods, the temperatures reached throughout the process, as well as information on meteorological variables obtained from the IQUERETA29 meteorological station located at the Technological University of San Juan del Río and administered by the Querétaro State Water Commission are shown.

Solar stove, Satellite dish, Recycled materials, Cardboard

Resumen

Actualmente en algunas comunidades se sigue haciendo uso de la leña o boñiga para cocinar o conservar el calor, esta acción genera grandes problemáticas para la salud y el medio ambiente, una de ellas es el gran riesgo de incendios y/o asfixia por inhalación de humo, otra es la deforestación que se lleva a cabo para conseguir leña y, por último, la generación de metano, precursores de ozono y dióxido de carbono al quemar cualquiera de estos. En el presente trabajo se propone el uso de una estufa solar del tipo parabólica, elaborada a base de materiales reciclados, tales como cartón, papel contact autoadherible como material reflejante, cinta Masking tape®, lo que permite reducir los costos fabricación, ayudando a familias de escasos recursos y siendo amigables con el medio ambiente. Se muestran los resultados obtenidos con respecto al tiempo necesario para la cocción de diversos alimentos, las temperaturas alcanzadas a lo largo del proceso, así como información de las variables meteorológicas obtenidas de la estación meteorológica IQUERETA29 ubicada en la Universidad Tecnológica de San Juan del Río y administrada por la Comisión Estatal de Aguas Querétaro.

Estufa solar, Parabólica, Materiales reciclados, Cartón

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1. Introduction

The use of solar energy throughout history has been reflected in different cultures and in different ways, the first reference we have about this is in the year 400 BC where the Greeks began to build their houses with reference to the angles of the sun. The Roman Empire in turn began to implement in their homes windows made of glass, to thus take advantage of the incoming sunlight. Archimedes, an Italian physicist, developed a military invention that consisted of setting fire to enemy fleets using a piece of glass to concentrate solar radiation on a single point. But it was not until 1767 when the botanist Horace-Bénédict de Saussure (1740-1799) invented for the first time a black solar stove, where he achieved the cooking of fruit, reaching approximately 88ºC, which consisted of two wooden boxes isolated from each other with glass covers.

In 1792 Lavoisier built his own solar oven consisting of two large lenses that concentrated solar radiation in a focus, this radiation was used to melt metals.

By 1830 astronomer John Herschel used a solar stove, which he designed himself, during a trip to Africa. Astronomer Charles Abbot built a concentrating mirror with which he was able to reach a temperature of 200 °C, heating oil, thus retaining some of the heat to be able to cook some food even when the sun was not shining. Many organizations are currently working to improve the efficiency of solar stoves. Some of these organizations are the German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit, GTZ) and Solar Cookers International (Solar Cookers International) and others in Europe and North America.

Society has been looking for different ways to satisfy food needs, looking for the easiest and cheapest way to be able to eat those foods that are raw, and for this task it has been looking for ways to be efficient in cooking food. There are several ways to perform this task, among these ways we can find: the wood stove, gas, gasoline and solar stove.

Firewood

The use of firewood is a great benefit, but also a big problem, since firewood is very cheap, but it is very difficult to ignite when it is wet, it depends on the availability in the environment, it generates a lot of smoke and there may be a risk of contamination with the ashes, although it allows reaching high temperatures ideal for cooking, it allows baking, and the cooking speed is very good.

Gasoline

Non-renewable fossil fuel, explosive product with an easy fire risk. Dangerous for people and children if ingested, the wind intervenes a lot in the moment of its operation, it allows the control of the baking and the operation is at the desired moment.

Gas

It requires to be transported, it is a non-renewable fuel, the leakage of this type of fuel can be dangerous and even cause death, among its benefits, you can control the temperature and cooking, the use of this can be at the time required, in relation to its price, this is high.

Solar stoves

On rainy days and in winter it is very difficult to cook any food, the cooking of food takes much longer compared to traditional fuels, they are not efficient in retaining heat, which means that after cooking they can easily lose heat, the advantages of using solar stoves are the reduction of carbon monoxide emissions, the considerable saving of money since this energy is free, the easy use of the stoves without the risk of burns.

2. Types of solar stoves

The most commercial versions of solar stoves are: box, parabolic and panel, being the parabolic stove the most efficient and advanced.

Box solar stove: Its operation is based on solar energy, which is captured, accumulated, concentrated and transferred to the stove. The sun's rays hit the surfaces and in this way heat the pot. It contains an insulating material that prevents heat loss.

Main components: Cardboard boxes, where the pot will be placed, these boxes should be smaller than each other to allow the insulating material between them.

Aluminum foil: To cover the upper lid where the heat is reflected and this will allow it to concentrate inside.

Black paint: To keep the heat inside the box.

Insulating material: Prevents heat from escaping between boxes.

Glass: Used as the lid of the pot to prevent the heat from dispersing.

The main advantages of this type of stove is that it allows cooking food in two or three hours only with solar rays, the materials for the elaboration are very easy to obtain. Although its efficiency is not so good. It is characterized because it can reach temperatures up to 150ºC, they are stable which does not cause risk for the users and can work even without the user's intervention, although they usually take a long time to heat up.

Figure 1 Box-type solar stove
Source: www.elmundo.es

Figure 2 Solar stove
Source: www.google.com

Its principle of operation is based on using optical concentration where most of the sun's rays are concentrated at the bottom of the pot, they use a reflective material to concentrate the radiation in a focal point.

Some of the main disadvantages of this type of stoves is the size, they take up a lot of space and they must be constantly oriented and because of the size is a bit difficult, the orientation of this can be confusing for people, plus the cost of this can be high for certain people, since they are mainly useful in low-income communities. The main advantage over any other type of solar stove is the high temperature it can reach. One of the main disadvantages is the high cost, due to the materials used, such as aluminum, stainless steel, eloxed aluminum, among others.

Figure 3 Parabolic solar stove, SK parabolic solar stove, Panel solar stove
Source: www.google.com

Figure 4 Parabolic solar stove
Source: www.google.com

Figure 5 Solar panel stove
Source: www.google.com

Panel solar stove

One of the simplest and cheapest, it is based on a cardboard surface covered with reflective material to focus the sunlight. The main advantage of this type of stove is its simplicity and the materials are so cheap that it is easy to build the stove following a simple plan. The attention for this one is really reduced since it is not necessary to be orienting. Generally the presence of moderate cloudiness does not affect the operation of this stove.

The disadvantages of this type of stove are that it is usually very unstable in moderate winds, and because it is made with materials made at home, its useful life is usually very short and it does not reach high temperatures.

3. Current situation of solar stoves

At present, solar stoves have been developed and perfected to improve their use and efficiency. Favorable results have been obtained for the use of solar cookers, indicating that they could be successfully used for cooking food in areas of medium and high insolation. However, the technical deficiencies and limitations, the influence of negative climates as well as the economy, personal use, culture and many other factors make the use of this type of alternatives become unrealistic solutions. But despite these factors, studies and improvements continue to be made to promote the use and dissemination.

The use of this type of stoves can only occur when users are willing to make different changes in their way of cooking, since the use of solar stoves involves cooking outdoors, which for many users or people could become annoying in addition to the fact that only one pot is used, which for many could be inconvenient. From another perspective, it can be seen as a cooking alternative. A considerable saving of money and help for the environment, taking into account the needs of people, it can be used for specific cooking of food and use your traditional cooking method for the rest of the food.

It has been characterized a solar stove made from two evacuated tubes that are used in solar water heaters to heat water for sanitary use, which are placed on supports, inside the tube has been introduced a tray made of food grade stainless steel, which is used to place the food to be cooked which have lids made with Nylomaq, these evacuated tubes are placed on an aluminum base in parabolic form, the values of the temperature inside the tray where the food is placed, were measured using an EXTECH® multimeter and a ThermaCAM E45® camera, the kitchen has a capacity to prepare food for two people, some foods have been cooked such as; mixiote, chicken in pipian sauce, chicken fajitas, beans, steak with potatoes, bread has been baked, among others, an analysis of their behavior has been made and the effectiveness of the proposed solar stove has been evaluated. (García Carrera Diana Lupian-Ugalde Valeria, 2016).

Solar stoves use clean and affordable solar energy for cooking food, however, currently available solar stoves have some weaknesses, such as being too large to transport, low heating temperature and too long cooking time, to achieve overcome these weaknesses a portable solar stove using a curved Fresnel lens as a concentrator was designed (Yunsheng Zhao. 2018). New ideas, fabrication techniques, and higher performance designs for a box-type solar stove were proposed. A good test standard is an important tool for the market and for user acceptance of stoves. This review is formulated keeping an important feature of existing proposals: simple and available instrumentation that allows taking these tests anywhere in the world, with minimal investment and/or laboratory conditions.(Collares-Pereira, Cavacoa, & Tavaresa, 2018).

The productivity of a phase change material (PCM) solar stove was investigated using a parabolic dish collector fabricated with two concentric cylinders with internal fins and kerosene wax. The average time to reach 90°C water with and without PCM is 120 min and 90 min, respectively (Senthil, 2020).

Solar stoves were evaluated according to ASAE (American Society of Agricultural Engineers) standard S580.1. The performance of the solar stove according to ASAE S580.1, reaches a temperature of 50 °C between ambient air and water temperature of the cooking vessel was 198° C for a parabolic type stove, 65° C for a box type stove and 25° C for a panel type stove (Ebersviller & Jettera, 2020).

The continuous increase in the level of greenhouse gas (GHG) emissions and rising fuel prices are the main driving force for using various renewable energy sources. Solar energy is recognized as one of the most promising options, as it is free of charge and provides clean and environmentally friendly energy. Two identical evacuated tube solar stoves have been designed and constructed to study the influence of inserting metal wires or nanographene particles on the thermal performance of the stove. The metal wires and nanographene particles are inserted inside the vacuum tube, which is filled with the heat exchanger oil. Steel, aluminum and copper wires have been examined, and the number of wires has been varied between 5, 10 and 15. It has been found that copper wires improve the heat transfer rate compared to steel wires, aluminum wires and nanographene particles. It has also been obtained that there is a critical number of wires, i.e. 10 wires, above which the natural convection heat transfer rate decreases and this is due to increased friction which resists natural convection currents. (Abd-Elhady, Abd-Elkerim, Ahmed, Halim, & Abu-Oqual, 2020).

This article demonstrates the importance of the parabolic solar stove. The main purpose of the stove is to concentrate solar radiation and convert it into heat using different effective materials. Some essential factors were considered such as the reflector surface which should be smooth and shiny, and the control variables (load, tracking, temperature sensing) and uncontrolled variables (wind, ambient temperature) should also be considered.

Several parabolic solar stoves use efficient reflector materials such as stainless steel, aluminum foil, and Mylar tape. Multiple tests were conducted with these parabolic solar stoves. In addition, different forms of temperature were measured in this research: concentration surface temperature, vessel temperature, and water temperature.(Masum Ahmeda, et al., 2020).

The performance of a portable vacuum tube solar stove together with a stainless steel tank was investigated. The presented model is validated by comparing the analytical results with those of experiments. The effect of important climatic and design parameters on the performance of the solar stove is evaluated. The parameters studied are the absolute pressure of the vacuum envelope, the absorptivity and emissivity of the absorber coating and the solar radiation (Hosseinzadeh, et al., 2021).

The feasibility of a stand-alone solar stove with heating plate, powered by renewable photovoltaic (PV) energy. The equipment is based on the sizing, design and construction of a PV system. It consists of photovoltaic panels, DC/DC power converters, thermal resistors and a digital block for the control, supervision, acquisition and visualization of meteorological, thermal and electrical quantities of the system (lighting, PWM signals, currents, voltages, powers, efficiency), temperatures, etc.

All the results obtained clearly show remarkable performances, the thermal efficiency of the cookstove is estimated at 86%, an improvement of 59.2% compared to conventional cookstoves (Atmane, Moussaoui, Kassmi, Deblecker, Bachiri, 2021).

To meet the Sustainable Development Goals (SDGs) of the United Nations, it was proposed as a goal to work with a solar stove where a new stove design equipped with internal reflectors and a lower parabolic tracking reflector (TBPR) is proposed that can help in achieving the SDGs. The cooker performance is determined using the cooker optothermal ratio (COR) as the thermal performance parameter (TPP) and glycerin as the test load. Actual cooking tests are conducted for a family of four describing the utility of the proposed solar stove.

An economic analysis using two indicators, Levelized Cost of Heat (LCOH) and Cooking a Meal (LCCM) and there is a reduction of 44% and 18% in LCOH and LCCM respectively (Tawfik, Sagade, Palma-Behnke, El-Shal, Allah, 2021).

The box-type solar stove is an easy-to-use solar energy harvesting system suitable for domestic cooking in tropical countries. It is proposed to add aluminum on the lids of cooking vessels in a solar stove. Four cylindrical aluminum cooking vessels with different lengths of 25 mm, 35 mm and 45 mm were used to heat water. Outdoor experiments are conducted for five days for each case. For the four configurations, it is observed that the water reaches a maximum temperature of 102º C in a closed system. The maximum temperature range maintained is between 90º C and 100º C for approximately 2 to 3 h during the outdoor tests (Vengadesan & Senthil, 2021).

In this paper, the objective is to design a zero-emission cooking device with reduced cooking time and low maintenance cost compared to other conventional solar stoves. The cooking pot consists of two hollow concentric cylinders made of stainless steel. The space between the cylinders will be filled with heat transfer fluid (HTF). Copper tubes filled with phase change material (PCM) are placed diametrically in the outer cooking pot, which allows cooking in sunless hours. The heat transfer fluid from the cooking pot is connected to the vacuum tubes via hoses. This arrangement adds heat to the heat transfer fluid inside the vacuum tube and the hot fluid will rise into the cooking pot from the vacuum tube through a thermosyphon cycle and transfer heat to the cooking pot and PCM (Hebbar, Hegde, Sanketh, Sanith, & Raghavendra, 2021).

A novel solar stove based on adaptive control via an online sequential extreme learning machine (OSELM) is presented and discussed. The solar stove represents a challenging scientific design. The use of a bar plate coated with nanocoating materials helps to stimulate and control the multifaceted performance of the cooking vessels. In addition, it was noted that traditional human methods are not able to stimulate an efficient design for thermal applications because the environment cannot adapt to the variable source.

To overcome these challenges, neural network-based adaptive controls approaches were used that further consider other parameters such as smallest family, measured conjunction, huge feeding period and lower yields (Thamizharasu, et al., 2021).

Contribution(s)

Adaptation of a solar stove made of recycled materials, adding a base for the mobile pot, which allows the readjustment of the parabola towards the sun without the need to touch the pot.

Hypothesis

The placement of a base for the solar stove will allow an easier and more efficient use of the solar stove.

Objective(s)

To test the cooking of food in a parabolic solar stove made from recycled materials. To measure the temperature inside the cooker under conditions of low solar irradiation. Plot temperature, wind speed, ambient temperature and solar irradiation profiles.

4. Materials and methods

Figure 6 UTSJR solar stove
Source: Own Elaboration

Base of the solar stove

A used BF Goodrich®, All-terrain T/A tire was used as a base, the smallest radius is 0.20 m and the largest radius is 0.35 m. The width of the tire is 0.25 m, the height of the tire is 0.18 m, rim diameter is 0.406 m (16 inches).

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Figure 7 Tire used as a base
Source: Own Elaboration

POT SUPPORT

A base made of metal, circular in shape with a diameter of 0.22 m and 0.025 m wide, three supports of 0.05 m long by 0.02 m wide, so that the pot rests on them, 0.10 m below the base has as counterweight 4 metal bars of 0.03 m x 0.2 m with a mass of 0.6 kg each, were used to support the pot. To hold the support inside the stove there is a ¾ inch threaded rod, 0.4 m long with two 3/8 inch nuts and two flat washers that serve to stop the support so that it does not slip.

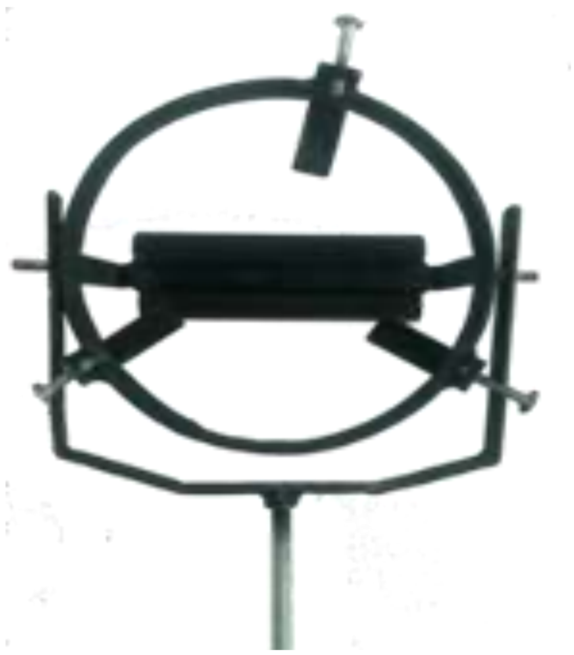


Figure 8 Pot support
Source: Own Elaboration

.
POT

An ODISEA® pot is used, number 20, with the following characteristics: diameter of the base 0.20 m, 0.14 m high, thickness 59 x 10^{-3} m.

To measure the temperatures reached by the pot, 12 reference points were used, 5 in front of the pot, 5 at the back, one at the bottom and one at the bottom of the pot. The pot was painted with Truper® matte black paint.

Figure 9 ODISEA® pot
Source: Own Elaboration

Thermometer

To measure the temperature reached by the pot, an Extech® infrared thermometer is used, with MIN/MAX readings that measure up to 650° C, distance to point ratio 12:1.

Figure 10 Infrared thermometer
Source: Own Elaboration

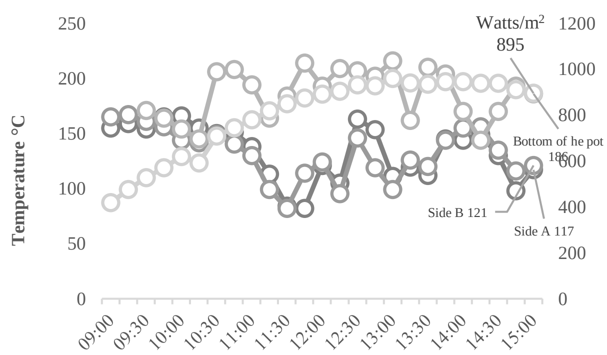
To orient the solar stove, a screw approximately 0.02m long should be placed on one of the sides of the stove.

Every hour the stove must be oriented, since for every hour that passes the sun moves 15 degrees, which means that the focal point is not maintained and changes every hour, to orient it the reference point is the screw that is placed, when this screw produces shadow, the stove must be tilted until it no longer produces shadow. Thus successively every hour.

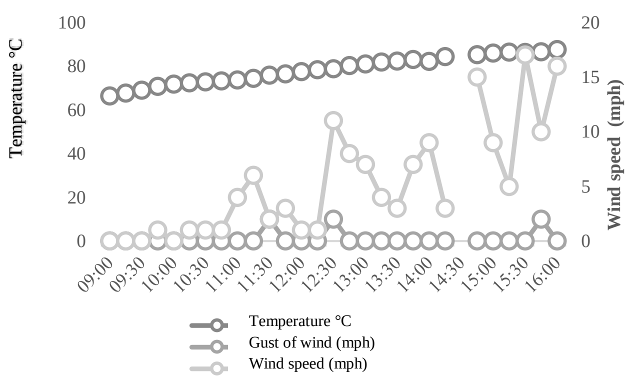
5. Results

Problem statement: To evaluate the performance of a solar stove made from recycled materials, which uses as a reflective surface self-adhesive contact paper with silver finish, placing in the focal point a pot of 0.2 m in diameter with a capacity of 4.3 liters of water, as an alternative for cooking food in urban areas of the city of San Juan del Río, Querétaro. Querétaro.

Analysis and data collection: The following are the results obtained during the food cooking process, on different days during the month of June. On Monday, June 7, only the temperatures reached by the pot were measured, without food. It was measured in three different points of the pot.

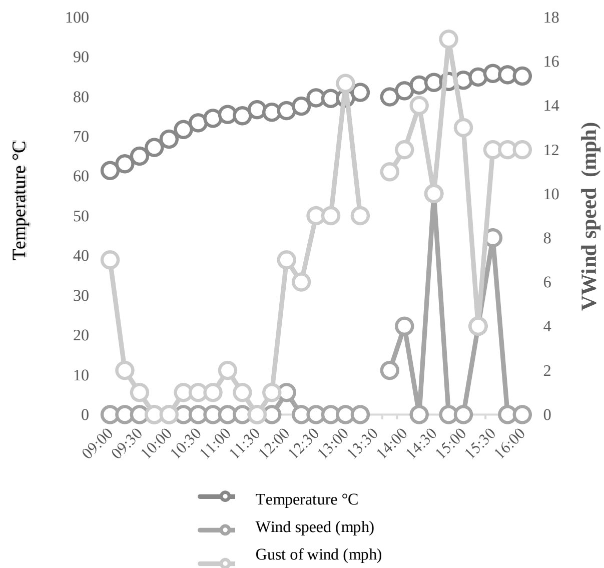


Graph 1 Temperature reached by the pot on June 7, 2022 on June 07, 2022
Source: Own Elaboration



Graph 2 Meteorological variables obtained from the weather station
Source:https://www.wunderground.com/dashboard/pws/IQUERETA29

Tuesday, June 08



Graph 3 Temperature and wind speed for June 8, 2022

Recipe 1: Chicken with achiote

Ingredients:

- 250g ranch chicken cut into small pieces,
- 3 cloves of garlic (10g).
- 20g white onion
- 50g of one Lol-Tun® achiote cube
- 50 ml white cane alcohol vinegar, Clemente Jacques®.

Procedure:

Dissolve the achiote tablet in the vinegar to make a thick creamy paste. Add the crushed garlic cloves. Coat the chicken pieces with the paste and place in the pot with the onion slices.

Figure 11 Chicken in achiote
Source: Own Elaboration

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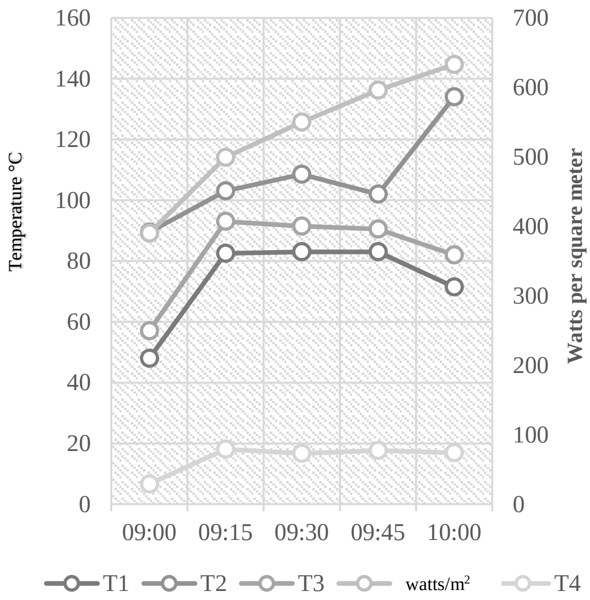
This recipe was ready in approximately one hour, with the following temperatures reached by the pot.



Graph 4 Irradiance
Source: Own Elaboration

Recipe 2: Boiled Potatoes

Ingredients:

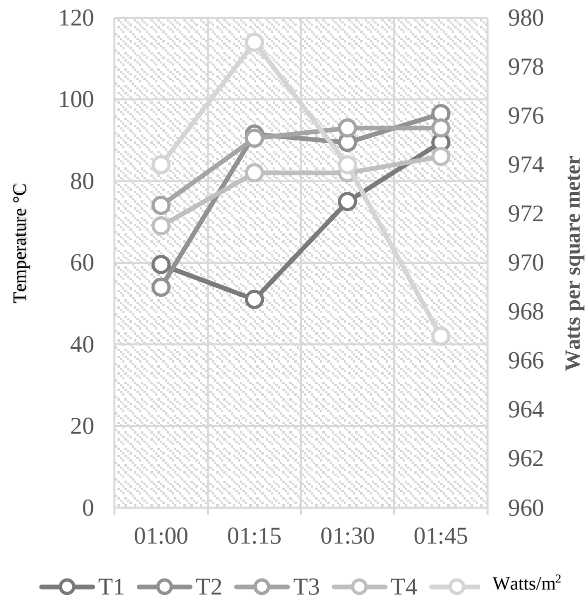
– 300 g of potatoes purchased at the market.
– 250 ml of water

Procedure:

Put water in the pot along with the previously washed potatoes.

Figure 12 Cooked potatoes
Source: Own Elaboration

The potatoes were cooked for 45 minutes, the temperatures reached by the pot were as follows.



Graph 5 Temperature in the pot and solar irradiance for recipe 2
Source: Own Elaboration

Recipe 3: Hard boiled eggs

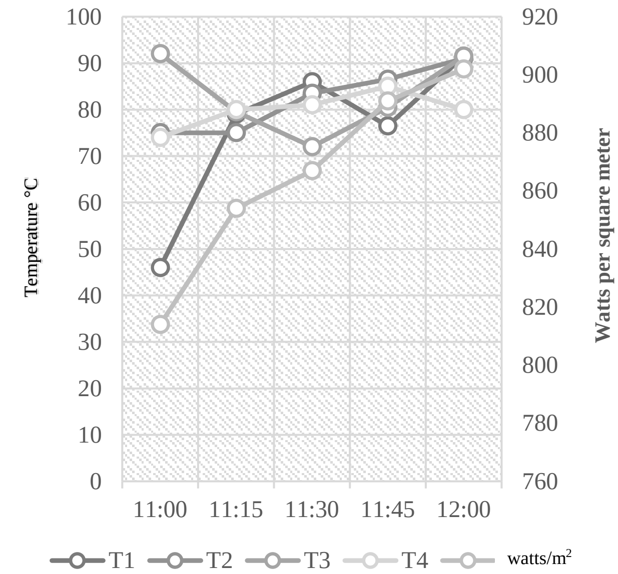
Ingredients:

– 3 pieces of white eggs
– 250 ml of water

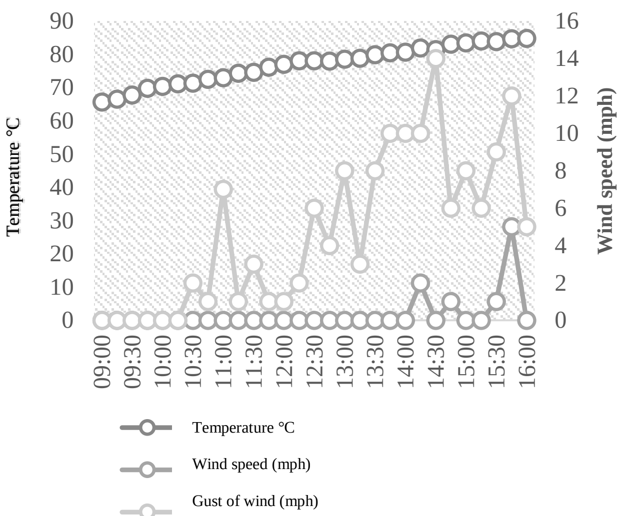
Procedure:

Put the eggs in the solar cooker along with the water.

This recipe was ready in approximately one hour, the temperatures reached by the pan were as follows



Graph 6 Temperature in the pot and solar irradiance for recipe 3
Source: Own Elaboration



Graph 7 Meteorological variables obtained from the meteorological station.
Source: Own Elaboration, https://www.wunderground.com/dashboard/pws/IQUERETA29

Recipe 4: Chicken broth with vegetables

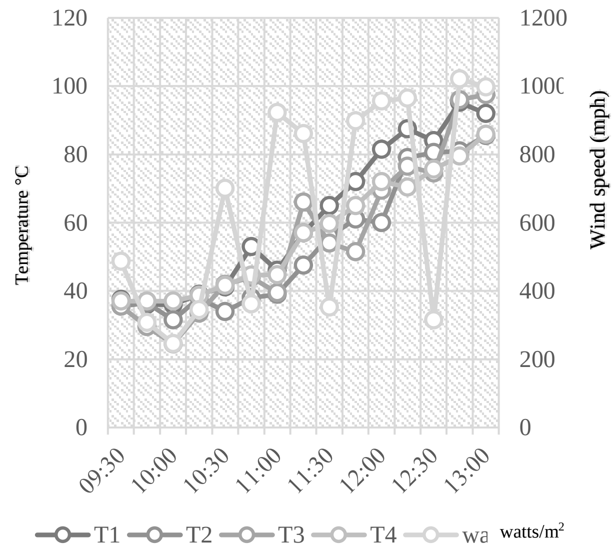
Ingredients:

- 300g washed ranch chicken.
- 30g green chayote
- 40g white onion
- 45g potato
- 20g of pumpkin

Procedure:

Put water to heat, add the chicken and the other previously chopped ingredients and season.

This recipe was ready in approximately three and a half hours, the temperatures reached by the pot were as follows.



Graph 8 Temperature in the pot and solar irradiance for recipe 4
Source: Own Elaboration

Recipe 5: Lentils

Ingredients:

- 100 g of Lentejas sol campestre®, product of the field.
- 30g white onion
- 1 tablespoon of olive oil

Procedure:

Clean the lentil, add in the pot with the other ingredients.

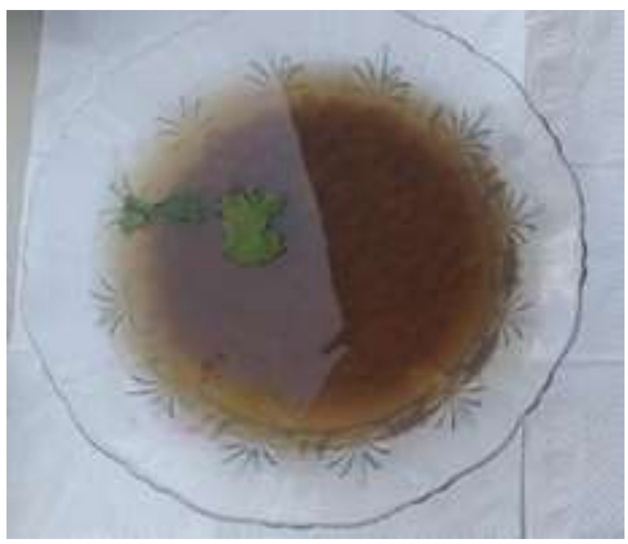


Figure 13 Boiled lentils
Source: Own Elaboration

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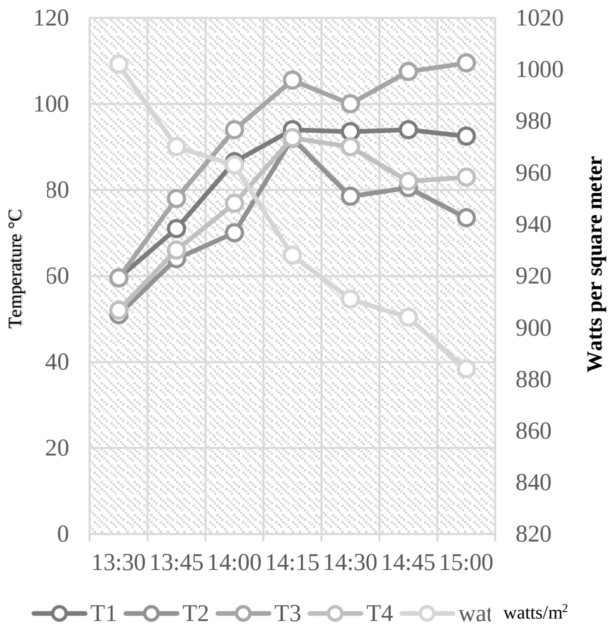
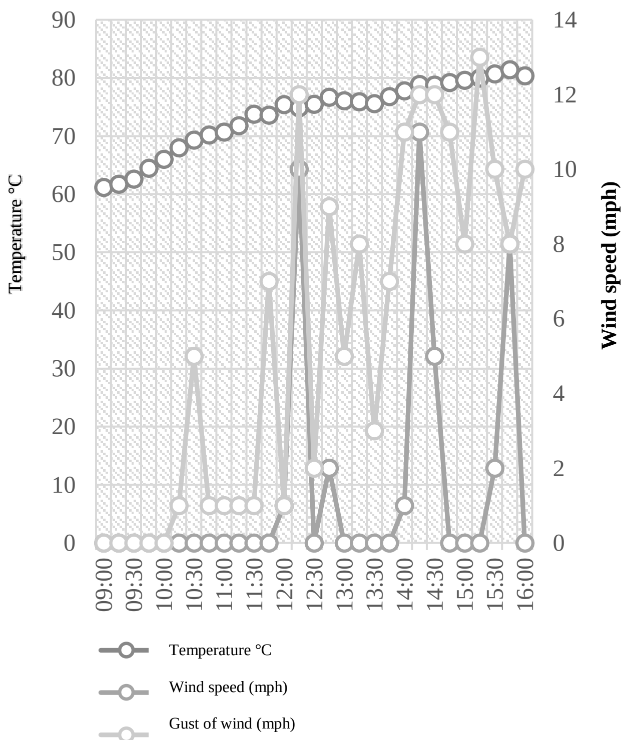
This recipe was ready in approximately one hour and a half, the temperatures reached by the pot were as follows.



Graph 9 Temperature in the pot and solar irradiance for recipe 5
Source: Own Elaboration



Graph 10 Meteorological variables, obtained from the meteorological station
Source: https://www.wunderground.com/dashboard/pws/IQUERETA29

Recipe 6: Mexican style soybeans

Ingredients:

– 100 g Nutricasa® cottura type soybeans.
– 1 clove of garlic (6g)
– 30 g white onion
– 200g of red tomato from the field
– 2 tbsp Nutrioli® Oli Olive Oil, Extra-virgin
– 5g cilantro
– 2 lemons

Procedure:

Hydrate the soybeans with seasonings and water, when ready remove the water and add the remaining ingredients.

Figure 14 Stewed soybean tostadas
Source: Own Elaboration

This recipe was ready in approximately two hours and 15 minutes, the temperatures reached by the pan were as follows.

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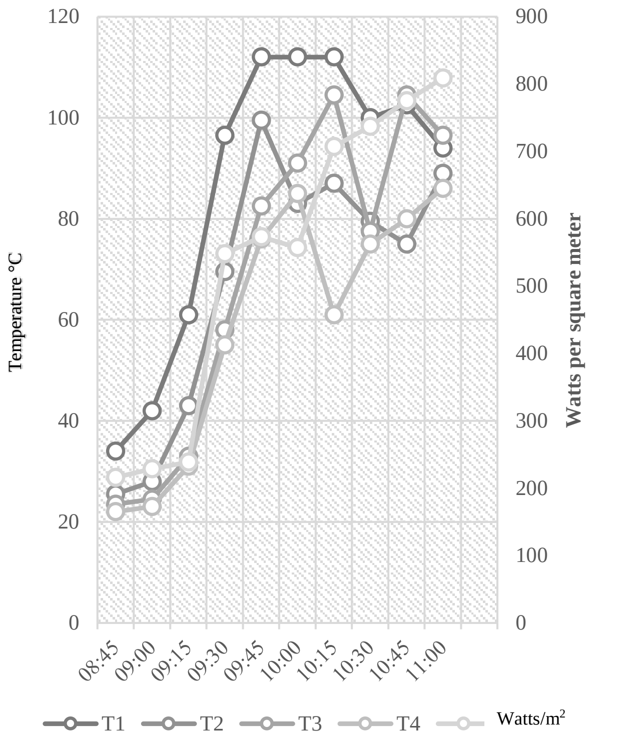


Graph 11 Temperature in the pot and solar irradiance for recipe 6
Source: Own Elaboration

Recipe 7: Beans

Ingredients:

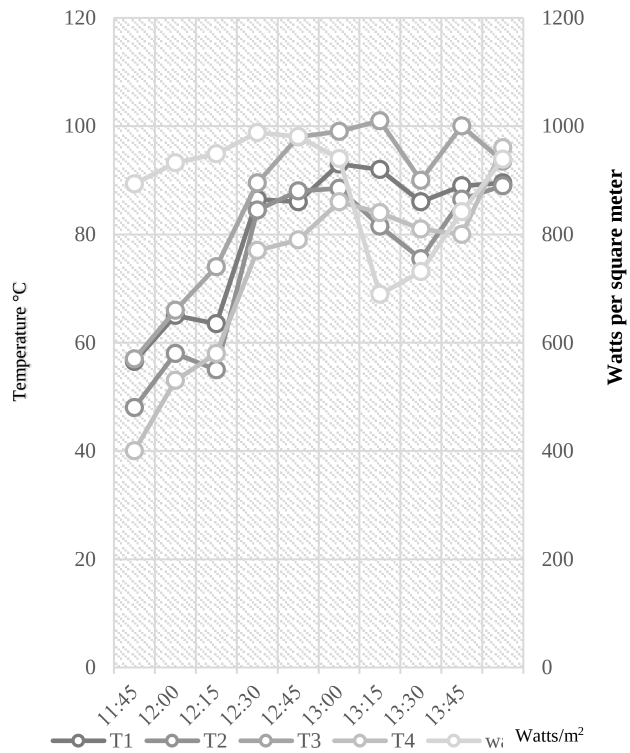
– 300g of green black beans valle®.
– 40g of onion

Procedure:

In the pot place the onion and beans previously cleaned along with water to achieve its cooking.

Figure 15 Black beans served over Sabritas® sabritones
Source: Own Elaboration

This recipe was ready in approximately two hours and 15 minutes. The temperatures reached by the pot were as follows.



Graph 12 Temperature in the pot and solar irradiance for recipe 7
Source: Own Elaboration

Recipe 8: Mexican Steak

Ingredients:

– 110g red ball tomato.
– 30g white onion
– 6g green serrano chile bell pepper
– 1 clove garlic (6g)
– 250g steak, beef for grilling Res selecta.

Procedure:

Chop the steak into fine pieces, add to the pot with the other ingredients and wait for it to be ready.

This recipe was ready in approximately one hour 45 minutes, The temperatures reached by the pot were as follows.

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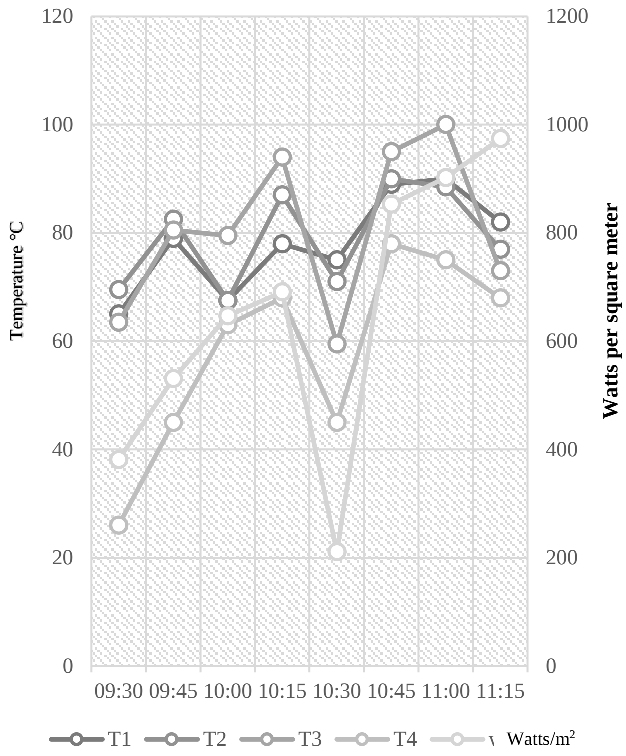


Graph 13 Temperature in the pot and solar irradiance for recipe 8
Source: Own Elaboration

Recipe 9: Egg Mexican style

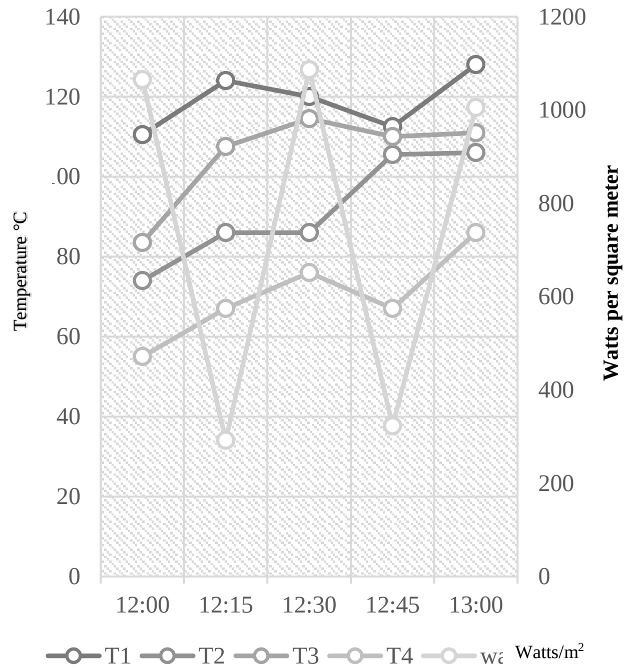
Ingredients

– 120g of white egg
– 30g of red ball tomato
– 2g chili bell pepper
2 tablespoons of olive oil

Procedure:

Let the pot with the oil heat up, when hot add the scrambled egg with the other ingredients.

This recipe was ready in approximately one hour. The temperatures reached by the pot were as follows.



Graph 14 Pot temperature and solar irradiance for recipe 9
Source: Own Elaboration

6. Acknowledgments

The authors wish to express their gratitude to the members of the renewable energy academic team of the Universidad Tecnológica de San Juan del Río, for all their comments that allowed the improvement of this work, and to Mr. Apolinar Rodríguez Torres, for his support in the assembly of the solar stove, pot supports and preliminary food cooking tests.

7. Conclusions

The results have been shown by conducting practical sessions with students of the Renewable Energy Engineering career, in each experimentation tasting tests were conducted by students and professor advisor of the ES01SM-20 group, of the Technological University of San Juan del Rio, all concluded that the food had reached the proper cooking and had a good flavor, the solar stove has been used for cooking various foods, which allowed to verify the effectiveness of the device and that it can go from practice to commercialization. The temperatures are adequate for cooking the food, the process takes a little longer compared to a gas-burning stove. The results obtained in cooking food are satisfactory; the solar stove made from recycled materials is an alternative for cooking food in urban areas.

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Dimensioning of a hybrid system boiler - solar collector of evacuated tubes, for the defrosting of fish

Dimensionamiento de un sistema híbrido caldera - colector solar de tubos evacuados, para el descongelamiento de pescado

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Abstract

The fishing sector, better known as the fishing industry, is part of the primary sector, which is why it is an important economic activity in the world, as it is part of the human diet and industrial processes. The processing of fish in industries requires defrosting, this is achieved by superheated steam produced in a boiler which uses fuel oil as primary energy, this increases production costs. This work aims to design a hybrid defrost system that is efficient, reduces costs and takes advantage of solar energy for water preheating. The purpose of the system is to reduce fuel oil consumption by taking advantage of solar thermal energy through evacuated tubes, for which the system is analyzed using the first law of thermodynamics. From the reduction of fuel oil consumption, the amount of CO_2 emitted into the environment will decrease, as well as production costs.

Fish, Hybrid, Thermodynamic

Resumen

El sector pesquero, más conocido como industria pesquera, forma parte del sector primario, por lo que es una actividad económica importante en el mundo, al ser parte de la dieta del ser humano y de procesos industriales. El procesamiento del pescado en las industrias requiere descongelarlo, esto se logra por medio de vapor sobrecalentado que se produce en una caldera la cual utiliza combustóleo como energía primaria, esto hace que aumente los costos de producción. Este trabajo tiene la finalidad de diseñar un sistema de descongelamiento híbrido que sea eficiente, que reduzca los costos y aproveche la energía solar para el precalentamiento del agua. La finalidad del sistema es reducir el consumo de combustóleo aprovechando la energía térmica solar mediante tubos evacuados, para ello se analiza el sistema mediante la primera ley de la termodinámica. A partir de la reducción de consumo de combustóleo disminuirá la cantidad de CO_2 emitida al medio y a su vez los costos de producción.

Pescado, Híbrido, Termodinámica

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Introduction

For many years, food freezing has been used as part of the preservation process that industries have opted for to guarantee the regular and standardized supply of fish, more specifically the quality and quantity of the product, as well as the economic value.

Freezing is an excellent procedure for food preservation and only generates minimal changes in the qualitative and organoleptic properties of seafood products. However, during thawing, abundant exudation occurs, which can be detrimental to food quality (Fabre, Perlo, Bonato and Teira, 2022).

Thawing has become a real challenge for organizations and companies, so that in the industry there are several alternatives for thawing the product such as water immersion, climatic chamber, radiofrequency, microwave, and even combinations of some of these processes mentioned (Xargayó et al, 2021). A popular alternative is the use of boilers, so that the energy contained in the fuel oil is transformed into thermal energy to defrost the product; however, this implies a considerable impact on the environment due to the exhaust gases, which are the product of combustion.

In view of this, a hybrid system with solar energy is an option to reduce the impact on the environment. Its operation consists of preheating the water to be used by the boiler with solar thermal energy and thus reducing the amount of fuel oil burned.

1. Problem statement

The industrial fish thawing process is a challenge for companies and organizations because the product requires a large amount of thermal energy at low temperatures. The operating costs and energy consumption of fish processing are very high due to the energy used for preservation/freezing, thawing, washing and other processes. In addition, carbon emissions from the fishing industry are increasing due to the continuous use of fossil fuels, which continues to be an environmental problem, so organizations have established air quality and energy consumption reduction as a priority in their policies.

A viable option is the use of renewable energies and it has been found that solar thermal energy is used in different countries in the industrial fishing sector in applications of drying processes and water heating, using different types of solar collectors depending on the thermal power capacity and temperature range.
In Mexico, the fishing industry is of great importance, therefore, this work proposes the performance analysis of a hybrid solar thermal system to optimize the continuous supply of hot water that is integrated to the defrosting process, in order to enhance energy savings in the freezing-thawing processes.

2. Calculation of the thermal load

It is necessary to calculate the amount of heat for defrosting, according to the transformation of the product when it is defrosted. For this case we have 20 tons of fish for 24 hours for thawing, with an inlet temperature of -20 °C and an outlet temperature of 5 °C. The fish has three processes during thawing, first the thawing below the freezing point in this case the freezing point of the fish is -2.2 °C, then there is a phase change in the thawing that considers the latent heat of vaporization and finally there is the heat generated above the thawing point.

By applying Equation 1, the amount of heat in the three fish processes is calculated, considering the specific heats above (Cp↑) and below (Cp↓) the freezing point, as well as the latent heat of vaporization hfg.

Cp↑= 1.776 kJ/kg K
Cp↓= 0.953 kJ/kg K
hfg = 234.92 kJ/kg

With these data, the amount of heat required is determined using Equation 1 (Çengel and Ghajar, 2011) for the thawing process as shown in Table 1.

$$Q = m\, C_p\, \Delta T \qquad (1)$$

Q_1	256454.4 kJ
Q_2	33888.8 kJ
Q_3	4698400 kJ

Table 1 Amount of heat in the fish processes Prepared by the company

Applying equation 2, the total heat of the 20 tons of fish to be thawed is calculated.

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$$Q_{total} = Q_1 + Q_2 + Q_3 \quad (2)$$

$$Q_{total} = \frac{256454.4\ kJ + 338886.8\ kJ + 4698400\ kJ}{24\ h}$$

$$Q_{total} = 220{,}572.55\ \text{kJ/h}$$

Therefore, 220,572.55 kJ/h of heat is required to thaw the fish and have the proper conditions.

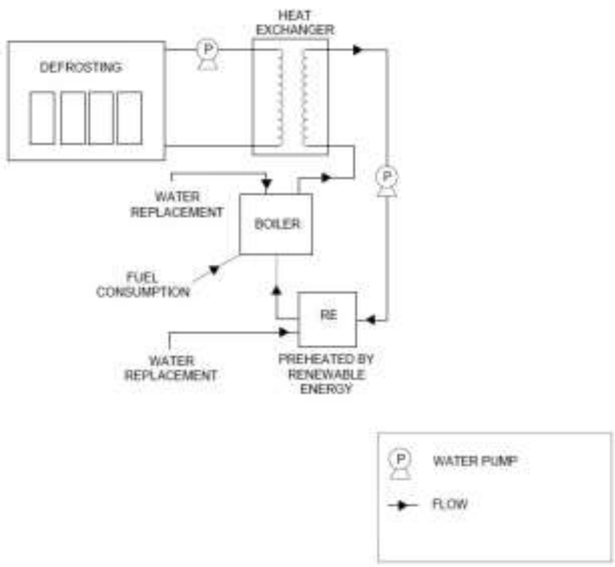

Figure 1 Components in the thawing process
Ovando, Huchin, Castillo and Estrada, 2016

Figure 1 graphically represents the components involved in the thawing process. The thawing room contains the frozen product, which is sprayed with hot water through sprinklers that conduct water at 30 °C. The water returns to the tank by decanting at a temperature of 10 °C and is then reheated in the heat exchanger through contact with steam pipes coming from the boiler.

The heat exchanger serves as a support to maintain the water flow and to have the correct defrosting temperatures, so that the water temperature at the outlet is 30 °C, is sent to the frozen fish and returns to the heat exchanger tank at 10 °C.

Reheating the water requires a steam flow from the boiler at 250 °C as superheated steam and will have an outlet of 40 °C as saturated steam.

3. Heat exchanger design

The thermodynamic analysis of the heat exchanger is shown below.

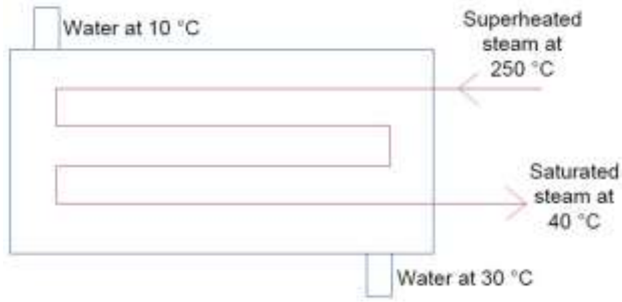

Figure 2 Heat exchanger
Prepared by the author

The heat exchanger is of the open type. The tubes are immersed in water to heat it with the steam coming from the boiler. The design of the heat exchanger was made from equations 3, 4 and 5.

Equation 3, 4 and 5 are used to calculate the Reynolds number (Re), Nusselt number (Nu) and convective coefficient (h_o) respectively for the outer side of the tank, so the convective coefficient of the air over the flat area surface is calculated.

ρ	1.225 kg/m^3
v	10800 m/hr
μ	6.26E-2 kg/m*hr
k	0.072 kJ/hr*m*K
Pr	0.7

Table 2 Properties of air Coopeland, G. n.d..

$$Re = \frac{\rho * v * L}{\mu} = 2.11x10^6 \quad (3)$$

$$Nu = 0.664 * Re^{\frac{1}{2}} * Pr^{\frac{1}{3}} = 856.82 \quad (4)$$

$$h_o = \frac{Nu * k}{L} = 6.169\ \frac{kJ}{hr * m^2 * K} \quad (5)$$

To calculate the convective coefficient of water, the Reynolds number (Re), Prandtl number (Pr) and Nusselt number (Nu) are determined using equations 6, 7 and 8, respectively, using the data in Table 3. The result is shown in equation 9.

ρ	997 kg/m^3
v	18000 m/hr
μ	3.6172 kg/m*hr
k	2.1528 kJ/hr*m*K
Cp	4.182 kJ/kg*k

Table 3 Properties of water Coopeland, G. n.d.

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$$Re = \frac{\rho * v * L}{\mu} = 49750499 \quad (6)$$

$$Pr = \frac{C_p * \mu}{k} = 7.007 \quad (7)$$

$$Nu = 0.0296 * Re^{\frac{4}{5}} * Pr^{\frac{1}{3}} = 81391.650 \quad (8)$$

$$h_i = \frac{Nu * k}{L} = 17522 \ \frac{kJ}{hr * m^2 * k} \quad (9)$$

The purpose of determining the convective coefficients of air and water is to calculate the overall heat transfer coefficient U (Equation 11) and from Equation 10 determine the resistance per flat plate area (thickness=0.3048 m, k=5.04 kJ/m*K).

$$R_T = \frac{1}{h_o} + \frac{x}{k} + \frac{1}{h_i} = 0.223 \ \frac{hr * m^2 * K}{kJ} \quad (10)$$

$$U = \frac{1}{R_T} = 4.492 \ \frac{kJ}{hr * m^2 * K} \quad (11)$$

Considering a U-tube heat exchanger, for steam at 250 °C with a latent heat of steam h_{fg} =1716.2 kJ/kg, the mass of steam will be (equation 12):

$$m = \frac{Q_{total}}{hfg} = 128.524 \ \frac{kg}{hr} \quad (12)$$

From equation 13 we calculate the steam quantity as a function of the mass flow rate (V_{esp}=0.2327 m^3/kg)

$$\dot{m} = m * Vol_{esp} = 29.9 \ \frac{m^3}{hr} \quad (13)$$

The flow velocity is calculated from equation 14. (D_{int}=0.0254 m)

$$v = \frac{\dot{m}}{A} = \frac{\dot{m}}{\pi \frac{d^2}{4}} = 59023.046 \ \frac{m}{hr} \quad (14)$$

The convective coefficient (*hl*) for steam at 250 °C is determined with equations 15,16,17,18 and 19 from the data in Table 4.

ρ	4.2966 kg/m³
V_{esp}	0.2327 m³/kg
μ	6.50E-2 kg/m*hr
k	0.108 kJ/hr*m*K
Cp	1.98 kJ/kg*K

Table 4 Properties of steam 250 °C Coopeland, G. n.d.

$$Re = \frac{\rho * v * d}{\mu} = 9.92x10^4 \quad (15)$$

$$Pr = \frac{\mu * C_p}{k} = 1.191 \quad (16)$$

$$Jh = \frac{0.491}{Re^{0.49}} = 0.001749 \quad (17)$$

$$Gr = \frac{Re * \mu}{d} == 253598.42 \ \frac{kg}{hr} \quad (18)$$

$$hl = \frac{Jh * Cp * Gr}{Pr^{\frac{2}{3}} * (\mu / \mu m)^{0.14}} = 781.792 \ \frac{kJ}{hr * K} \quad (19)$$

The convective coefficient for steam at 40 °C is determined by equations 20,21,22,23 and 24.

ρ	0.08314 kg/m³
V_{esp}	12.027 m³/kg
μ	3.58E-2 kg/m*hr
k	0.072 kJ/hr*m*K
Cp	1.94 kJ/kg*K

Table 5 Properties of steam at 40 °C Coopeland, G. n.d.

$$Re = \frac{\rho * v * d}{\mu} = 3.27x10^3 \quad (20)$$

$$Pr = \frac{\mu * C_p}{k} = 1.0282 \quad (21)$$

$$Jh = \frac{0.027}{Re^{0.2}} = 0.005352 \quad (22)$$

$$Gr = \frac{Re * \mu}{d} = 4907.176 \ \frac{kg}{hr} \quad (23)$$

$$hl = \frac{Jh * Cp * Gr}{Pr^{\frac{2}{3}} * (\mu / \mu m)^{0.14}} = 50.019 \ \frac{kJ}{hr * K} \quad (24)$$

With the results of Equation 19 and 24, the total interior coefficient is determined by Equation 25

$$hit = \frac{2}{3}(h_{40°C}) + \frac{1}{3}(h_{250°C}) = 293.943 \ \frac{kJ}{hr * K} \quad (25)$$

The overall heat transfer coefficient is determined (equation 29).

$$Nu = 0.036(Re^{0.8} * Pr^{0.43} - 17400) + 297 * Pr^{\frac{2}{3}} = 119949.968 \quad (26)$$

$$h_{sal} = \frac{Nu * k}{l} = 25822.829 \ \frac{kJ}{hr * K} \quad (27)$$

$$R = \frac{1}{hit} + \frac{x}{k} + \frac{1}{h_{sal}} = 0.003 \ \frac{hr * m^2 * k}{kJ} \quad (28)$$

$$U = \frac{1}{R} = 2878.282 \ \frac{kJ}{hr * m^2 * K} \quad (29)$$

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The logarithmic mean temperature LMTD is determined:

$$LMTD = \frac{\Delta T1 - \Delta T2}{Ln(\frac{\Delta T1}{\Delta T2})} = 95.361\ °C \quad (30)$$

The heat transfer area will be (equation 31):

$$A = \frac{Q}{U * LMTD} = 8.0235\ m^2 \quad (31)$$

The length of the exchanger tubes is determined from equation 32:

$$L = \frac{A}{\pi * d} = 100.60\ m \quad (32)$$

The pressure drop is determined using equation 34:

$$jf = \frac{0.05573}{Re^{0.261}} = 6.74x10^{-3} \quad (33)$$

$$\Delta P = 8 * jf * (\frac{\mu}{\mu m})^{0.14} \left(\frac{L}{d}\right) \left(\frac{\rho * V^2}{2}\right) = 2387.78\ \frac{kg}{m * s^2} \quad (34)$$

4. Fuel consumption calculation

In this analysis, the amount of fuel required to defrost 20 tons of product is determined in order to compare what will be saved if heat production with renewable energies is implemented. For this purpose, the data in Table 6 applied to Equations 35, 36, 37, 38, 39 and 40 will be used.

T_{ent}	40 °C
T_{sal}	250 °C
Efficiency	90 %
ρ fuel oil	920 kg/m^3
Calorific Power (LHV)	40,1664 kJ/kg
P_{ent}	120 kPa
P_{sal}	1176 kPa
h_1	2573.5 kJ/kg
h_2	2935 kJ/kg

Table 6 Boiler steam and fuel characteristics. Coopeland, G. n.d.

Calculation of steam mass and heat

$$m_{vapor} = 128.524\ kg/hr \quad (35)$$

$$Q_{vapor} = m_{vapor}\,(h_2 - h_1) = 46461.35\,\frac{kJ}{hr} \quad (36)$$

Calculation of fuel mass

$$m_{fuel} = \frac{Q_{vapor}}{\text{Efficiency} * LHV} = 1285.25\ \frac{kg}{hr} \quad (37)$$

$$\dot{m}_{fuel} = \frac{m_{fuel}}{\rho_{fuel}} * 1000 = 1397\ \frac{liters}{hr} \quad (38)$$

Considering a fuel cost of $13 MNX and a 12-hour production, the cost can be determined from equation 39 and 40.

$$Cost = \dot{m}_{fuel} * fuel\ cost = 18161.09\ \frac{MXN}{hr} \quad (39)$$

$$Cost_{daily} = Cost * production = 217{,}933.11\,\frac{MXN}{day} \quad (40)$$

5. Sizing of the system

The city of Tapachula is located at a latitude of 14.9 °N and a longitude of 92.3 °E, at an average altitude of 171 meters above sea level. It has a minimum irradiation level of 5.46 kWh/m2 day in the month of September and a maximum of 7.21 kWh/m^2 day in the month of March (INEGI,2017).

Design parameters	Values
Desired water temperature	30 °C
Ambient temperature	29.2 °C
Relative humidity	66 %
Wind speed	4.7 m/s
Water to be heated	18 m^3

Table 7 Design parameters of the solar collector
Prepared by the authors

The solar collector used is model SCSPV-15, its characteristics are shown in Table 8.

Solar collector	
Nominal size (cm)	181x210
No. of tubes	15
Integral system	
Empty weight (kg)	61.5
Full weight (kg)	211.2
Actual collection area (m^2)	2

Table 8 Solar collector characteristics
Own Elaboration with data from technical data sheet

The sizing of the system requires estimating the average energy that each collector can provide in the critical month based on the catchment area (Ovando, Huchin, Castillo and Estrada, 2016), for this case an average efficiency for evacuated tubes of 89% was considered (Albizzati, 2016)

Although other parameters such as optical efficiency and removal factor must be taken into account (Venegas, Jaramillo, Rodríguez, Sosa and Domínguez, 2015), in addition to the minimum irradiation value of 5. 46 kWh/m^2 day (19656 kJ/m^2 day) so the average energy delivered by each equipment will be:

$$E = 19656 \text{ kJ/m2} * 2\, m^2 * 0.89 = 34{,}988\, kJ \quad (42)$$

Therefore, the total number of collectors that will make up the system must consider the energy requirement so that:

$$m^2 = \frac{Necesidad\ energetica}{Energia\ de\ colector} = \frac{4{,}988{,}742\, kJ}{34{,}988\, kJ} \quad (43)$$

This gives us a total of 143 evacuated tube solar collectors to meet the energy requirement.

We use a procedure for the minimum number of collectors needed to meet the energy requirement.

Collector unit price	$ 9,335.00
Cost of 143 collectors	$ 1,334,905.00
Pumping equipment	$ 187,645.00
Piping and fittings	$ 90,000.00
Estimated installation cost	$ 258.967.00
Project cost	$ 1,796,837.00

Table 9 Capital required
Own Elaboration

6. Acknowledgements

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7. Conclusions

Fish thawing is still using a traditional steam boiler system that uses fuel oil and in turn affects the environment, so that operating costs are high. In view of this, a viable option is the use of renewable energies such as solar-hybrid thermal energy to reduce the operating costs of the system, reduce the burning of fossil fuels, mitigate greenhouse gases and whose payback period is no more than 7 years.

It is of great importance that organizations begin to implement renewable energies such as photothermal and be aware that although the return on investment is not favorable, it favors the environment due to a lower production of CO_2.

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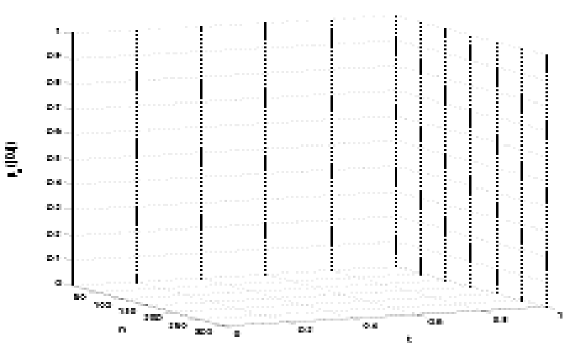

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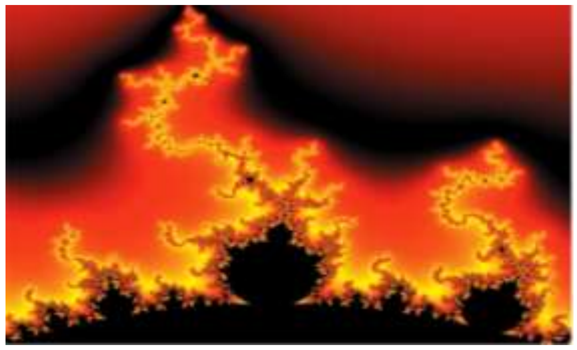

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