



AUTONOMOUS SOLAR THERMAL SYSTEM DESIGN FOR INDIRECT DEHYDRATION OF AGUAYMANTO (*Physalis Peruviana L.*), JUNÍN

DISEÑO AUTÓNOMO DEL SISTEMA SOLAR TÉRMICO PARA LA DESHIDRATACIÓN INDIRECTA DE AGUAYMANTO (*Physalis Peruviana L.*), JUNÍN

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Abstract

This paper aimed to design an autonomous indirect solar dryer, which can dehydrate the aguaymanto in a cost-effective manner, yielding a quality product suitable for export from the central part highland of Peru. To complete this task, it was proposed to design a prototype of autonomous solar dryer of 100 kg per batch of aguaymanto, equipped with flat reflectors and forced air feed, and powered with photovoltaic energy. This system allows to dry aguaymanto fruit at the requirements needed for its exportation. The fryer has the following dimensions: inner dimensions of the drying chamber: bottom 0.60 m, width 1.40 m, and height 1.10 m, with additional 0.05 m for insulation. Hence, the outer measures are bottom 0.70 m, width 1.50 m, and height 1.20 m. Two solar collectors are proposed with the dimensions of each: 1.50 m wide, 2.40 m long, and 0.15 m height; 2 flat mirror reflectors are required. A 80 Wp photovoltaic panel was selected for the forced air system and process control. This solar dryer is expected to cope with the problem of post-harvest deterioration. Also, it will facilitate the export by improving product quality and providing a cost-effective technology.

Keywords: Agro-industrial, dehydration, solar collector, solar thermal system, aguaymanto.

Resumen

Con el propósito de tener un diseño de secador solar indirecto autónomo para deshidratar el aguaymanto, que sea económico y de calidad y que permita exportar de la parte alta central de nuestro país, se propuso el objetivo general: diseñar, un prototipo de autónomo secador solar de 100 kg por lote de aguaymanto, con reflectores planos y aire forzado alimentado con energía fotovoltaica que permita secar esta fruta con los requisitos para su exportación. Las dimensiones de la secadora son las siguientes: dimensiones interiores de la cámara de secado: fondo 0,60 m, ancho 1,40 m, altura 1,10 m, y 0,05 m para el aislamiento, por lo que las medidas exteriores son fondo 0,70 m, ancho 1,50 m, altura 1,20 m. Se proponen dos colectores solares con dimensiones cada una de: 1,50 m de ancho, 2,40 m de largo y 0,15 m de alto, de los cuales se requerirán 2 reflectores de espejo plano. Se seleccionó un panel fotovoltaico de 80 Wp para el sistema de aire forzado y el control del procesado. Este secador solar permitirá abordar el problema del deterioro posterior a la cosecha y facilitará la exportación, porque mejorará la calidad y el costo económico.

Palabras clave: Agroindustrial, deshidratación, colector solar, sistema solar térmico, aguaymanto.

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1 Introduction

Governmental institutions, organizations, international companies and academics all around the world are becoming more and more aware of the importance of natural resource management (Solangi et al., 2011; Sándor et al., 2020; Jakab, 2020) and the renewable energy transition (Reid et al., 2010; Solangi et al., 2011; Marcucci and Turton, 2015). The main objective of global energy sustainability is to replace the fossil fuel-generated energy by renewable energy (Lachuriya and Kulkarni, 2017; Lowy and Mátyás, 2020). With respect to policies on the planet, many North-American (USDE, 2010a,b; Liming et al., 2008; Smitherman, 2009; OPA, 2009; Branker and Pearce, 2010), European (BMU, 2008; Bhandari and Stadler, 2009; Dusonchet and Telaretti, 2010; Campoccia et al., 2009) and Asian (Wang and Qiu, 2009; Wang, 2010; Chaudhry et al., 2009) countries have passed solar energy policies in order not to depend on diesel and to increase national production of solar energy, as it has less impact on the environment (Solangi et al., 2011; Espinoza, 1991; Sommerfeld and Buys, 2014). As stated by Gamio, "Peru is an ideal place for renewable energy projects, because it has more resources and sources of green energy: such as sun, water, geothermal energy, wind or biomass" (Gamio, 2014).

In Latin America, there are proposals for the use of solar thermal energy in food processing, non-metallic, textile, construction, chemical, and even business-related industries (Mekhilef et al., 2011). Despite the enormous technical potential, the large-scale development and deployment of solar energy technologies around the world must yet overcome a number of technical, financial, regulatory, and institutional barriers. Therefore, it is necessary to expand the incentives of the Kyoto Protocol, which are insufficient (Timilsina et al., 2012). A practical, economic and environmental option is the use of solar thermal systems to preserve vegetables and other products. Heating systems using solar thermal energy can improve product quality, as well as reduce waste and the use of traditional fuels, improving people's quality of life (Roche-Delgado et al., 2017). With respect to food conservation techniques, one problem is the implementation of dehydration facilities for national export institutions.

According to Benavides (2014), one of the cons-

straints in the industry of dehydrated fruit and vegetables is the limited availability of dehydration machinery, therefore, plans are made to implement pilot dehydration plants in Ancash and Tarma. The basic objective is to use solar dryers with improved thermal performance and reduced environmental impact (AOAC International, 2000). In present, 10 to 40% of the harvested products do not get to the final consumer. Because intermediaries pay less than the cost of production, producers often leave their products on their farm. As a detrimental result, in developing countries decomposition and contamination of the products is frequent, particularly in the rural regions of Peru. In the agricultural practice several post-harvest technologies can be observed, with the goal of food preservation. Nevertheless, the oldest method used is solar drying, given that it maintains physical, chemical, and nutritional properties.

For drying food, farmers believe that 35% and 40% of the total cost of the processing is currently due to industrial machines of high cost. Such devices are difficult to use in small farms; therefore, technological alternatives are needed, such as the solar dryer, which is less expensive and does not pollute the environment. In present, in Peru solar drying outdoors are an alternative solution, but they do not offer the quality of products needed for export. Considering that most of the farmers are either in places of difficult access or at the borders of the country, solar dehydrator is an option for enabling to export their products and get out of poverty. In other countries, this technology is being used in tropical and subtropical areas. Unfortunately, solar drying will not be adopted by farmers if they cannot evidence significant differences relative to open air drying, impacting the quality of the products.

Therefore, it is important to improve the drying of products specifically aguaymanto, which can reduce losses, increase quality, efficiency of the processing, and can provide greater acceptance by the agricultural community. Hence, this investigation has the following goals: (a) to design an autonomous indirect solar dryer for dehydrating aguaymanto, in a cost-effective manner and at an outcome, which meets the export quality; (b) to equip with advanced technology producers from the central part of Peru's highland area, zone in which this

procedure is not yet available; (c) to build a prototype of autonomous solar dryer of 100 kg capacity by batch of aguaymanto, equipped with flat reflectors and forced air feed secured by photovoltaic energy; (d) this device should comply with dry fruit quality requirements for export.

To achieve the proposed objective, the area of the flat solar collector was reduced. Aguaymanto was chosen as the raw material to be dried, its morphology and drying rate were considered. Expected results were to design of a prototype for the indirect autonomous drying of a high quality aguaymanto, and devising plans for the local construction of the solar dryer according with the technological development of the local metal processing and machine construction companies. As recommendation, direct users of this innovative solar drying system should be small and medium farmers and agro-industrial plants that produce aguaymanto in Peru. So far, most of these facilities do not possess a cheap and efficient drying technology. To a significant extent, this system will solve the problem of post-harvest deterioration and will facilitate the exports. Climate change can also be mitigated.

2 Materials and methods

The physical-chemical characteristics (pH, acidity and soluble solids), proximal chemical (humidity, fat, protein, fiber, ash, carbohydrates) and the drying parameters of aguaymanto were determined according to the standards established by AOAC International (2000). An autonomous solar drying system was designed by the authors considering the followings: (I) Morphology and drying conditions of the aguaymanto shall be considered. Calculation of drying chamber dimensions are based on quantity of raw material to be dried; area of the transversal section of the hot air flow; manual unloading of the products to be dried. (II) Design of flat solar collectors: Meteorological variables are considered: wind velocity, intensity of solar radiation, latitude, altitude, relative humidity and air temperature (information will be obtained from the test site). It will be proceeded with the followings: analysis of the thermal circuit in a flat plate collector; energy balance accounting for absorbed heat, useful heat, and losses at the top and bottom of the solar collector of flat plates; theoretical calculation of the efficiency

of solar collectors equipped with flat plates, determining the optimum collection area and the section area of air flow; in this process it is relied on the reflectors and photovoltaic system for forced flow, which can be optimized for dimensions of (length, width, and height the solar collector). (III) Design of forced air systems: control of temperatures inside the drying chamber will be implemented and the humidity of aguaymanto measured. (IV) Design of the control systems: stabilization and monitoring of temperatures, humidity and speed in the solar drying.

Considerations for the calculation and design of the solar drying system were encompassed into three categories: (1) Thermal, where the Sun was chosen as the source of energy. (2) Mechanical, which evaluated materials and construction details of the local technology. (3) Economic considerations referred to the cost of the system and was addressed for both the economic and cultural conditions of the farmers living in the area. Collecting the above data allowed to calculate the dimensions of the solar dryer and to select the right materials for making it. Also, in some cases, experimental data was used to figure some of the design parameters.

Characteristics of the forced-air-dryer's location: altitude: 3000 m.a.s.l.; typical climatic conditions of the highland; within cities, electric power is available, but in the field no electricity is accessible, therefore, both thermal and photovoltaic solar energy should be used.

3 Results and discussion

3.1 Chemical characteristics of dehydrated aguaymanto

In this experimental trial performed with an indirect dehydrator, results were obtained on the immediate chemical composition. Out of the measured parameters, listed in Table 1, humidity of aguaymanto fruit is of greatest interest. It has an average value of 15%.

Table 1. Approximate chemical composition of the dehydrated aguaymanto (100 g) obtained in an indirect dehydrator.

Analysis	Results
Humidity	15.06 ± 0.03
Fat	1.32 ± 0.18
Protein	5.58 ± 0.32
Fiber	4.36 ± 0.28
Ash	1.72 ± 0.03
Carbohydrates	71.96 ± 0.35

3.2 Physical-chemical composition of dehydrated aguaymanto

In experimental trials conducted in an indirect dehydrator, results listed in Table 2 were obtained on the physicochemical composition of dehydrated aguaymanto, where the percentage of soluble solids represents the greatest interest. Its value averaged at 85%.

Table 2. Physical-chemical composition of dehydrated aguaymanto, obtained in an indirect dehydrator.

Analysis	Results
pH	4.05 ± 0.01
Acidity (Citric Acid Exp.)	1.02 ± 0.18
Soluble Solids	84.94 ± 0.03

3.3 Conceptual design of solar dryer

Obtained results allowed to determine the technology and define the geometric shape of the solar dryer and it has the following characteristics:

1. Characteristics of aguaymanto:
 - Manually manageable size.
 - Geometry of similar spheres, in the size range from 2.0 to 2.5 cm.
 - It is a delicate fruit, sensitive to the incidence of direct solar radiation.
 - Initial moisture content is in the narrow range of 79-82%.
2. Drying conditions and requirements:

- Hot air drying at 60°C.
- Preferably uninterrupted drying in batches of 100 kg.
- Final humidity should be of 12%.

3. Selected technology: An indirect solar forced-air-drying is preferred, where a solar collector can be used to reach a drying temperature of 60°C. Ventilation is also regulated with forced air, using photovoltaic energy, according to the schematic displayed in Figure 1.

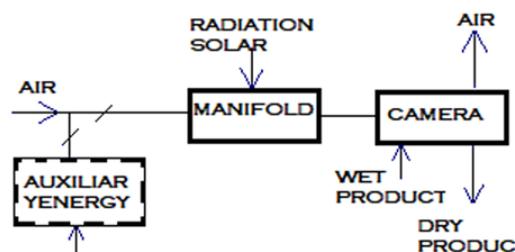


Figure 1. Schematic of an indirect dryer. Taken from Espinoza (1991).

3.3.1 Drying chamber

Given that aguaymanto is fragile but easy to manipulate, the fruit was placed in trays. Trays of 11 kgm⁻² have been procured. The proposed chamber is of the shape of a parallelepiped (Figure 2), with the following characteristics:

- Flow form: parallel.
- Simple frame tray with millimeter mesh.
- Chamber bottom dimension: 0.60 m.
- Collector width: 1.40 m.
- Chamber height: 1.10 m (which corresponds to 22 trays, with 2 trays per row and 11 trays per holder level. Spaces between tray holders is of 6.50 cm.

Consequently, dimensions of the drying chamber are the ones listed in Table 3.

Table 3. Drying chamber dimensions in [m].

	Inside interior	Outside exterior	Observation
Depth	0.60	0.70	Size difference between inside and outside arise from the insulation
Width	1.40	1.50	
Height	1.10	1.20	

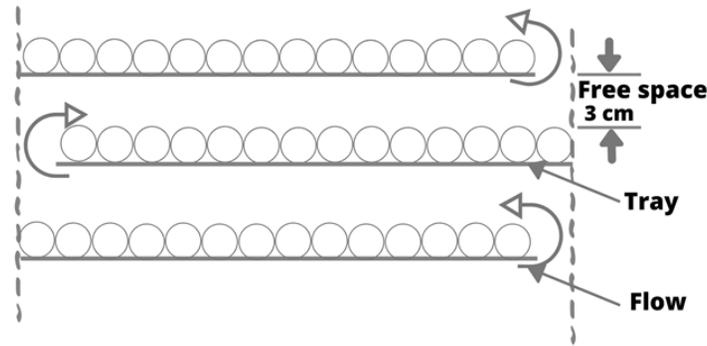


Figure 2. Parallel arrangement of fruit to be dried. Taken from Espinoza (1991)

Flat solar collectors: These are devices that allow to transform radiant solar energy into thermal energy in the form of hot air (Espinoza, 1991).

Size: In this part it can be approximated by a drying factor of $1.0 \text{ kg water}/(\text{m}^2 \cdot \text{day})$ (Espinoza, 1991). According to the humidity conditions of the aguaymanto, it is necessary to evaporate approximately 70 kg of water.

Estimated area: per day 70 m^2 . The result obtained would mean that 70 m^2 of flat collector is needed to dry in one day and therefore in three days $23,3 \text{ m}^2$

. Hence, the most exact calculations will be done later. For the moment for the conceptual design, the alternative for the collector of 20 m^2 and drying in three days is used; besides it is assumed for the width 1.4 m, the length is 16.6 m, which would result in the shape of the solar dryer as shown in Figure 3.

3.3.2 Design calculations for drying 100 kg of aguaymanto

In the design process, it is necessary to carry out some reference or checking calculations (Espinoza, 1991).

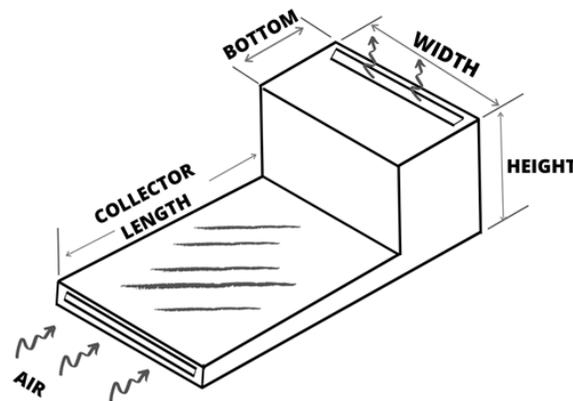


Figure 3. Diagram of the conceptual design of an indirect hybrid solar dryer according to Espinoza (1991).

Amount of energy required: If wanting to dry 100 kg of a product like the aguaymanto from 80% of initial humidity up to 12% of final humidity, there is:

- Initial water quantity: $100 \times 0,80 = 80$ kg
- Final water quantity: $100 \times 0,12 = 12$ kg
- Amount of water to evaporate: $80 - 12 = 68$ kg
- Latent heat of water evaporation at solar drying temperature = 2440 kJ/kg water
- Necessary energy : 68 kg water \times 2440 kJ/(kg water) = 165920 kJ.

Necessary sunny days: The average annual radiation in Tarma is $5,61 \text{ kWh/m}^2$ of solar radiation (Camayo-Lapa et al., 2017).

- Equivalent energy: $5,61 \times 3600 = 20196$ kJ/(m^2 -day)
- Assuming 20 m^2 of collector: 20196 kJ/(m^2 -day) \times $20 \text{ m}^2 = 403920$ kJ/day.

Assuming a total efficiency of 40% one has:

- Available energy: 403920 kJ/day $\times 0,4 = 161568$ kJ/day.
- Drying days: 165920 kJ / 161568 kJ/day = 1,03 days.

Therefore, 1.03 days of drying are needed. Hence, by having collectors of 1.40 wide \times 2.40 long then 6 collectors are needed, and if placing reflectors like flat mirrors, only 3 solar collectors are needed to dry the product in one day approximately. Checking the solar collector length: Equation 1 is used (Espinoza, 1991); with ΔT the warming of the air through the collector [$^{\circ}\text{C}$], H solar radiation [W/m^2], L the collector length [m] and v velocity of air through the collector [m/s]:

$$\Delta T = (0,131H) \left(1 - e^{-\frac{0,12L}{v}} \right) \quad (1)$$

Given as radiation data of 900 W/m^2 , a length of $2,40 \text{ m}$, velocity of 1 m/s the collector can increase by $56,2^{\circ}\text{C}$.

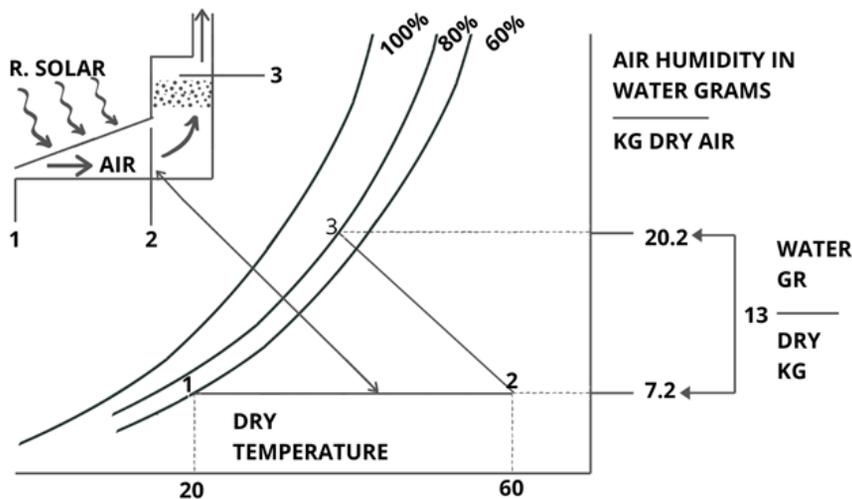


Figure 4. Diagram of the conceptual design of an indirect hybrid solar dryer (according to Espinoza (1991)).

3.3.3 Design of forced air systems

Calculation of the air flow required to dry: For the drying of 100 kg of wet product, from initial humidity of 80% to 12% of final humidity, such as aguaymanto, 24 h. If the average drying speed

is $\frac{x_i - x_f}{t} = 7,87 \times 10^{-6}$ kg water/((kg dry) s). And if the 100 kg wet product consists of 80 kg water and 12 kg dry matter. The average evaporation rate would be: $7,87 \times 10^{-6}$ kg water/(kg dry-s) \times 12 kg dry = $9,4 \times 10^{-5}$ water/s.

This amount of water will have to be evaporated in an air stream with a certain flow rate and drying capacity, which is obtained from the psychrometric chart for the air pressure and temperature conditions of the place where the drying will take place. According to the diagram Figure 4, 20 kg of forced-

air-drying can evaporate 13 g of water, which corresponds to $9,4 \times 10^{-5}$ water/s. Thus, the air flow required is $9,4 \times 10^{-5}$ kg water/s $\times 1 / (13 \text{ g water} / \text{kg air} \times 1 \text{ kg} / 1000 \text{ g}) = 0,00723 \text{ kg air/s} = 7,23 \text{ g air/s}$. An airflow equal to $m = 7,23 \text{ g air/s}$ is needed.

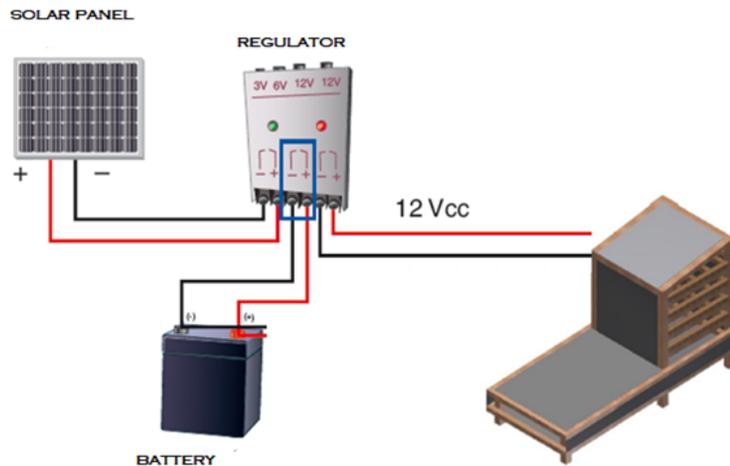


Figure 5. Diagram of the photovoltaic system for use in solar dryers.

Calculation of flow rate (Q) and velocity (v) of the air: The flow rate is calculated from Equation (2) with $\rho = 1,2 \text{ kg/m}^3$ the air density.

$$Q = \frac{m}{\rho} \quad (2)$$

Therefore, $Q = \frac{0,0072 \text{ kg air/s}}{1,2 \text{ kgm}^3} = 0,36 \text{ m}^3/\text{s}$ is the air flow needed. Recommended air velocity is from 1 to 2 m/s (Espinoza, 1991).

3.3.4 Final dimensions of the solar dryer

Drying chamber: The interior dimensions are 0.60 m, width 1.40 and height 1.10 m and it is expected 0.05 m for the insulation, so the exterior measurements are 0.70 m wide, 1.50 m deep, and 1.20 m high, as it is shown in Table 3.

Solar collector: It needs to be taken into account the dimensions of 1.50 wide, 2.40 long and 0.15 high, which will need 2 reflectors of flat mirrors for each collector, so that in the end it will need 2 units of solar collectors with their respective reflectors of flat mirrors. Likewise, the solar thermal dryer will

consist of a photovoltaic system (Figure 5).

Solar panel dimensioning:

- Energy requirement = 404.8 Wh-day.
- Panel Power = Daily Energy Requirement / Daily Solar Incidence Hours.
- Hours of solar incidence in Tarma 5, 6 h-day.
- Panel power = 404.8 Wh-día / 5.6 h-day.
- Panel power = 72.29 W.
- The panel will be 1 module of 80 Wp.

4 Conclusions

Under the drying conditions carried out with an autonomous solar thermal system for indirect dehydrating in aguaymanto, these have nutritional characteristics that show the nutritional quality of the product and that the moisture content obtained guarantees its useful life. Due to the physicochemical characteristics of the aguaymanto, an indirect solar dryer with forced air was selected, where the

energy source for the fans and the controls of temperature, humidity and air speed is from a photovoltaic system. The components of the autonomous drying system of 100 kg of aguaymanto per process designed for an average drying time of two days consists of: a collector with the dimensions: bottom of 1.50 m, width 2.40 m and height 0.05 m and 0.05 m is expected for the insulation, which increases its efficiency and reduces the collector area, it will have a reflector of flat mirrors of bottom 1.50 m wide 2.40 m on each side, in a drying chamber whose proposed interior dimensions are bottom of 1.50 m wide 2.40 m; the forced air system and controls is a photovoltaic panel of 80 Wp.

This drying proposal is expected to face the problem of post-harvest deterioration and facilitate the export because it will improve the quality, cost and clean of the aguaymanto. According to the technological development of the metal-mechanic companies of the town, the proposed construction of the solar dryer will allow its local construction. It is also expected that the direct users of this innovative solar drying system will be the small and the medium farmers and agro-industrial of the aguaymanto in our country.

References

- AOAC International (2000). *Official Methods of Analysis*. Number #3. Online: http://sutlib2.sut.ac.th/sut_contents/H125800.pdf. 18th edition.
- Benavides, L. (2014). Project: Industrial innovation dehydration of berries-aguaymanto 2014-2015. Website.
- Bhandari, R. and Stadler, I. (2009). Grid parity analysis of solar photovoltaic systems in germany using experience curves. *Solar Energy*, 83(9):1634–1644. Online: <https://bit.ly/3nTAJHP>.
- BMU (2008). *Electricity from renewable energy sources—what does it cost Us?* Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin, Germany.
- Branker, K. and Pearce, J. (2010). Financial return for government support of large-scale thin-film solar photovoltaic manufacturing in Canada. *Energy Policy*, 38(8):4291–4303. Online: <https://bit.ly/3iWc9m4>.
- Camayo-Lapa, B., Pomachagua-Paucar, J., Massipe-Hernández, J., Quispe-Flores, M., and Torres-Ten, A. (2017). Validación y aplicación del modelo bristow campbell para estimar la radiación solar global de la región de junin. *Tecnología Química*, 37:574 – 590. Online: <https://bit.ly/33cJZON>.
- Campoccia, A., Dusonchet, L., Telaretti, E., and Zizzo, G. (2009). Comparative analysis of different supporting measures for the production of electrical energy by solar pv and wind systems: Four representative european cases. *Solar Energy*, 83(3):287–297. Online: <https://bit.ly/34YNdpe>.
- Chaudhry, M., Raza, R., and Hayat, S. (2009). Renewable energy technologies in pakistan: prospects and challenges. *Renewable and Sustainable Energy Reviews*, 13(6-7):1657–1662. Online: <https://bit.ly/3lQvpTX>.
- Dusonchet, L. and Telaretti, E. (2010). Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in western european union countries. *Energy Policy*, 38(7):3297–3308. Online: <https://bit.ly/2SYKgza>.
- Espinoza, R. (1991). *Teoría y práctica del secado solar*. Google Libros. Online: <https://bit.ly/3k36hJa>.
- Gamio, P. (2014). *Renewable Energies and Climate Change*, chapter Demonstrating projects sustainable development. Konrad Adenauer Stiftung.
- Jakab, A. (2020). The ammonium lactate soluble potassium and phosphorus content of the soils of north-east hungary region: a quantifying study. *DRC Sustainable Future*, 1(1):7–13. Online: <https://bit.ly/3j54oKy>.
- Lachuriya, A. and Kulkarni, R. (2017). Stationary electrical energy storage technology for global energy sustainability. In *2017 International Conference on Nascent Technologies in Engineering (ICNTE)*, pages 1–6, Navi Mumbai, India. IEEE.
- Liming, H., Haque, E., and Barg, S. (2008). Public policy discourse, planning and measures toward sustainable energy strategies in canada. *Renewable and Sustainable Energy Reviews*, 12(1):91–115. Online: <https://bit.ly/3dxjFm8>.

- Lowy, D. and Mátyás, B. (2020). Sea water activated magnesium-air reserve batteries: Calculation of specific energy and energy density for various geometries. *DRC Sustainable Future*, 1(1):1–6. Online: <https://bit.ly/3lUrEg3>.
- Marcucci, A. and Turton, H. (2015). Induced technological change in moderate and fragmented climate change mitigation regimes. *Technological Forecasting and Social Change*, 90:230–242. Online: <https://bit.ly/31c7QNN>.
- Mekhilef, S., Saidur, R., and Safari, A. (2011). A review on solar energy use in industries. *Renewable and sustainable energy reviews*, 15(4):1777–1790. Online: <https://bit.ly/2IADca9>.
- OPA (2009). Ontario power authority: Feed-in-tariff program development. Web page.
- Reid, W., Chen, D., Goldfarb, L., Hackmann, H., Lee, Y., Mokhele, K., Ostrom, E., Raivio, K., Rockström, J., Schellnhuber, H., and Whyte, A. (2010). Earth system science for global sustainability: grand challenges. *Science*, 330(6006):916–917. Online: <https://bit.ly/2IAfVVR>.
- Roche-Delgado, L., Hernández-Touset, J. P., and García-a Rodríguez, A. (2017). Diseño conceptual de secador solar a escala piloto para algas marinas. *Tecnología Química*, 37:184 – 200. Online: <https://bit.ly/3nOENID>.
- Sándor, Z., Tállai, M., Kincses, I., László, Z., Káttai, J., and Vágó, I. (2020). Effect of various soil cultivation methods on some microbial soil properties. *DRC Sustainable Future*, 1(1):14–20. Online: <https://bit.ly/318aPX2>.
- Smitherman, G. (2009). An act to enact the green energy act, 2009 and to build a green economy, to repeal the energy conservation leadership act, 2006 and the energy efficiency act and to amend other statutes 2009.
- Solangi, K., Islam, M., Saidur, R., Rahim, N., and Fayaz, H. (2011). A review on global solar energy policy. *Renewable and sustainable energy reviews*, 15(4):2149–2163. Online: <https://bit.ly/3lPEsEx>.
- Sommerfeld, J. and Buys, L. (2014). Australian consumer attitudes and decision making on renewable energy technology and its impact on the transformation of the energy sector. *Open Journal of Energy Efficiency*, 3(3):85–91. Online: <https://bit.ly/3j9mbR6>.
- Timilsina, G., Kurdgelashvili, L., and Narbel, P. (2012). Solar energy: Markets, economics and policies. *Renewable and sustainable energy reviews*, 16(1):449–465. Online: <https://bit.ly/2Hec9Aw>.
- USDE (2010a). Solar energy grew at a record pace in 2008. Web page.
- USDE (2010b). Study: Solar power could provide 10 Web page.
- Wang, Q. (2010). Effective policies for renewable energy—the example of china’s wind power—lessons for china’s photovoltaic power. *Renewable and Sustainable Energy Reviews*, 14(2):702–712. Online: <https://bit.ly/355RpDq>.
- Wang, Q. and Qiu, H. (2009). Situation and outlook of solar energy utilization in tibet, china. *Renewable and Sustainable Energy Reviews*, 13(8):2181–2186. Online: <https://bit.ly/3j63L3s>.