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Chapter 3

Sustainability in Solar Thermal Power Plants

Rafael Almanza and Iván Martínez

Additional information is available at the end of the chapter

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1. Introduction

In the last two decades, there has been growing interest in developing indicators to measure sustainability, which is currently seen as a delicate balance between the economic, environmental and social health of a community, a nation or even our planet. The current measure of sustainability tends to be an amalgam of economic, social and environmental aspects. Economic indicators have been used to measure the state of regional economies for over a century, and social indicators are largely a phenomenon of the postwar world. However, environmental indicators are relatively new and attempt to incorporate the ecosystem into the socio-economic indicators of a study site.

Any interest in defining these indicators primarily comes from the need to monitor performance and to indicate improvements resulting from specific actions. While economists have little difficulty in applying quantitative indicators, sociologists can have great difficulty in creating useful indicators for assessing the quality of life of a social group, as this is an issue that can be approached from different perspectives, many of them intangible. Scientists involved with the environment are considered less likely to have difficulty in establishing practical indicators with which to assess the ecological integrity of an ecosystem, either generally or in specific qualifying aspects.

However, sustainability is more than the interconnection of the economy, society and the environment. It may be something greater and more noble than a dynamic, collective state of grace, a theory such as Gaia (a set of scientific models of the biosphere in which life is postulated that fosters and maintains suitable conditions for itself, affecting the environment), or even the spirit. Instead of asking how can we measure sustainability, it may be more appropriate to ask what degree of sustainability is it?

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1.1. The concept of sustainability

The concept of sustainability has penetrated most life spheres, not only as a political requirement but also as something that clearly resonates deep within us, even if we have a poor understanding of what it is. The concept first emerged in the mid-1970s, but it exploded on the world stage in 1987 with the Brundtland Report (1987), in which sustainable development was defined as meeting present needs without compromising the ability of future generations to meet their own needs.

Even though this is a very noble goal, this definition challenges interpretation or operational implementation. Most of us would see our personal needs in the context of our circumstances and not as absolute entities. Therefore, our perception of the needs of future generations would impoverish the imagination. "How much is enough?" is a question we have to explore together, but it can only be answered separately. However, we rarely ask this key question individually, let alone collectively.

Once the Earth's ecological integrity is assured and our basic needs are met, how much is enough? The question should be considered in most developed countries, where in the midst of wealth there is still inequality. Increasing inequality is a necessary characteristic for the growth and advancement of an economy. Although it is desirable to achieve a high standard of living, there are finite limits. Our concern for the environment generally decreases with more prosperity, and we should not expect that our pursuit of sustainability should increase as our material wealth increases. Kerala, Cuba, Mennonite and Amish communities are all examples of small societies that practice sustainability, and they all exhibit traits of greater equity, justice and social cohesion.

There are other definitions that ignore human needs and express sustainability in terms of ecological integrity, diversity and limits. However, these definitions also challenge objective interpretation. Such deficiencies in the definitions can cause considerable frustration in a rational way of thinking, particularly for those trying to measure sustainability (Trzyna, 1995). Meanwhile, a reductionist mindset has the ability to link quantitative and productive activity, as in the case of sustainable agriculture, forestry, land management, fisheries, etc. Consequently, growth and sustainable development have been captured as the dominant paradigm. Sustainable development is held up as a new standard for those who really do not want to change the current model of development (Gligo, 1995), and sustainable development alone does not lead to sustainability. In fact, it is possible to support the longevity of an unsustainable path (Yanarella and Levine, 1992). However, the concept is still with us and is becoming stronger.

In general, we have a better understanding of what is unsustainable rather than what is sustainable. Unsustainability is commonly seen as the degradation of the environment (in its broadest sense), the strains of the human population, wealth and green technology in its global limits. Because these effects are entirely of our own construction, their control is, at least in theory, within our capabilities. Human nature tends to promote physical and biological limits towards survival rather than sustainability. We likely think of sustainability in terms of justice, interdependence, sufficiency, choice and above all, (if we were to think deeply about it) the meaning of life.

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Sustainability is also non-material life–the intuitive, emotional, and spiritual creativity for those who strive for all forms of learning. Perhaps some truths are really fundamental and universal, if their meaning and spirituality are components of sustainability. These morals and values, however, are not necessarily absolute and can be very difficult to define. For example, values are qualities that are derived from our experiences. If they confirm our default values, then we are more likely to adopt these values. When our experiences are continually at odds with implicit values, we are more prone to change our personal values with respect to the projected values.

Our inability to define sustainability means that we cannot prescribe it. The future may develop according to our vision and ability to always recognize global limits. Sachs (1996) presents three perspectives of sustainable development: the competition implies the prospect that infinite growth is possible over time; the astronaut perspective recognizes that development is poor over time; and the home accepts the prospect of finitude in development. These may be respectively considered as the dominant paradigm perspective, the precautionary principle and conservationist.

Accepting sustainability as a concept can create as many difficulties as the concept of evolution did 150 years ago. During this time, we have not addressed physical consequences involving the collective proficiency requirements for all companies; thus, in general, human awareness has created the concept of ecological crisis with little consequence. Therefore, any discussion of sustainability is essentially a debate about the meaning of what, who, why and how we believe individually and collectively. However, we are very reluctant to participate in the debate on a collective basis, even locally, let alone nationally or globally, in part because it is a messy and time-consuming proposition, i.e., there is a crisis of perception on which one side resides banality, while on the other side there is uncertainty and fear.

1.2. General indicators

Indicators and measurements are essential components in closed physical systems because they are an integral part of the scientific method. In this context, each indicator must be enclosed between target value limits to guide political and social action. Its usefulness for socio-biophysical closed systems (e.g., human welfare) and, in particular, to open physical systems (e.g., businesses, national economies, regional sustainability) is still unknown because knowledge of the full impact of external factors may not be possible. However, the Earth is ultimately a closed system, except for the flow of energy. In that sense, measures are needed that are theoretically possible globally, but local measures are potentially more meaningful and actionable. The impact of some issues can only be evident at the global level, for example, global warming and ozone depletion, even though the solutions may be local.

Henderson (1991) wrote extensively on indicators, and particularly on current paradigms. The proliferation of indicators is indicative of the confusion and uncertainty of what has been measured as well as the absence of debate and understanding.

1.2.1. Economic indicators

There is much discontent with economic indicators, as the majority states that they are indicators of something more than the economy. Some do not believe that there are significant economic measures of sustainability.

The most common indicator is the Gross National Product (GNP), now replaced by the Gross Domestic Product (GDP). Daly and Cobb (1994) developed the Index of Sustainable Economic Welfare (ISEW), which recently has been refined as the Genuine Progress Indicator (GPI) by Cobb, et al. (1995). Consumption remains the basis of the index, but instead of adding only negative or harmful consumption (e.g., environmental protection), positive beneficial consumption is also added (for example, voluntary work, child care, housework, etc.). It is difficult to conceive of an index where consumption is the basis for measuring sustainability.

GDP and GPI are aggregations of specific economic indicators, which can be equally sensitive in terms of time, or the actions of adjustment, but which do not apply to social or environmental concerns. Economic indicators are therefore not particularly useful as measures of sustainability, even though economic considerations must be taken into account.

The basis of modern economic theory has a political and a cultural component that addresses scarcity of resources. Affirming the need for a theory that goes beyond that and reflects the basic human needs would be very helpful.

1.2.2. Social indicators

Overall, there are five types of social indicators: informative, predictive, problem-oriented, program evaluation, and goal set. Several of them are partly economic, environmental and sustainable; they can be combined and compared, such as socio-economic indicators.

Indicators such as the standard of living, which is measured by analyzing time series data on observable phenomena, are called objective. Indicators such as quality of life, which measures the perceptions, feelings and responses through questionnaires with classified scales, are called subjective. The correlation between these conditions is very low, and there are considerable difficulties related to indicator aggregation and the design of weighting schemes.

1.2.3. Environmental / ecological indicators

Environmental indicators tend to relate most closely to human activity but may include economic, social and sustainability parameters. Measures may include the quality of living conditions and work environments, including air, land and water, as well as the productive use of resources.

Ecological indicators are more concerned with natural ecosystems; in some cases, human impact is not as obvious. The indicators for the integrity of ecosystems and biodiversity are prominent. The OECD produces a “pressure-state-response” model that many countries have used in the preparation of their "State of the Environment.”

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Most indicators have thresholds and targets. At present, there seems to be no drive to aggregate indicators or obtain a unique index. However, the Framework Convention on Climate Change (UNFCCC) and the Global Environment Facility (GEF) have very specific defined indicators for the problem of global climate change that may be adopted by all countries. Table 1 provides an overview of each topic in the UNFCCC so that each ecosystem could be described as the physical state of the substances found therein. As indicators for the GEF, they have a direct relationship with the strategic objectives defined by the same agency for action.

Topic	Sub-topic	Indicator	Unit of measurement
Atmosphere	Climate change	Emission of greenhouse gases	Gg or ton of CO_{2eq}
	Decreased ozone	Consumption of substances that deplete the ozone layer	Ton of CFC-11 or CFC-12 equivalent
	Air quality	Concentration of air pollutants in urban areas	$\mu g/m^3$, ppm, ‰
Land Use	Agriculture	Area of arable land under cultivation and permanent	ha
		Fertilizers	kg/m^2
		Pesticides	kg/m^2
	Forest	Forest area as a percentage of the total area	%
		Intensity of logging	%
	Desertification	Area affected by desertification	km^2 or %
	Urbanization	Area occupied by informal and formal settlements	km^2
Oceans, seas and coasts	Coastal areas	Concentration of algae in coastal waters	mg of chlorophyll/m^3
		Percentage of the total population that lives in coastal areas	%
	Fishing	Annual catch of target species	Ton/year
Fresh water	Water distribution	Annual withdrawals of ground and surface water as a percentage of total available water	%
	Water Quality	Biochemical Oxygen Demand (BOD) in water bodies	mg/L
		Concentration of fecal coliform in freshwater	mg/L
Biodiversity	Ecosystem	Area covering selected key ecosystems	km^2 o ha
		Protected area as a percent of total land area	%
	Species	Abundance of selected key species	# of individuals

Table 1. Outline of indicators proposed by the UNFCCC for global climate change.

1.2.4. Indicators of sustainability

Sustainability measures today tend to be an amalgam of economic, environmental and social indicators. The first two are susceptible to quantitative measurement because they can be expressed in biophysical terms, while the third is not easily quantified. Therefore, there is a tendency to only view biophysical sustainability.

Examples of sustainability indicators for a city are as follows:

- Per capita income.
- Solid waste generated/water consumption/energy consumption per capita.
- Proportion of workforce at the ten largest employers.
- Number of days of good air quality per year.
- Diversity and population size of particular urban wildlife (especially birds).
- Distance traveled on public transport and private transport per inhabitant.
- Residential density in relation to public space in city centers.
- Hospital admissions for certain types of childhood diseases.
- Percentage of children born with low birth weight.

Boswell (1995) proposed a theoretical basis for sustainable development indicators on a foundation of knowledge in sociology and ecology. Below, we present a set of attributes (energy use, community structure, life history, nutrient cycling, selection pressure and balance) in terms of objectives for the sustainable management of communities. The system lists 23 necessary conditions, but this may not be sufficient. The same author evaluates these goals with the selected sustainable development indicators. While a human ecology approach is clearly appropriate, Boswell (1995) does not recognize that the communities themselves should determine the strategy and indicators.

Whereas these are facets of sustainability, we must look beyond conventional measures to include a sense of quality of life, welfare, relevance, and harmony. We may have to be willing to accept semi-quantitative and qualitative indicators.

Environmental and social indicators are rarely expressed with a unique index. There is some interest in developing a single sustainability index based on a weighting of economic, environmental and social criteria, but this index cannot meet response times ranging from a few years (e.g., medical intervention) to a generation (e.g., global warming).

1.3. Criteria for the selection of sustainability indicators

The monitoring of sustainability is a long-term exercise so it must be flexible. The criteria for selecting appropriate indicators today could be expressed in a straight line with a slope and perhaps a long learning curve, and our ideas and preferences may change over time once complex criteria can achieve amenable results through statistical analysis. Perhaps someone

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can reduce a large set of indicators into a single sustainability index. Conversely, some communities may prefer or be willing to accept a few qualitative indicators for the sake of simplicity and direct relevance. Excluding qualitative criteria because they are not easily amenable to objective analysis would likely lead to the exclusion of essential characteristics of sustainability.

The numerous sets of criteria, e.g., Liverman (1988) and Seattle (1998), range from the simple (efficiency, fairness, integrity, management skills) to the complex. Hart (1995) believes that the best measures are not yet developed but suggests the following criteria:

- Multi-dimensional, linking two or more categories (e.g., economy and environment).
- Looking to the Future (range 20 to 50 years).
- Emphasis on local wealth, local resources and local needs.
- Emphasis on the levels and types of consumption.
- Measures and visualize changes that are easy to understand.
- Reliable, accurate and updated data available.
- Reflect local sustainability to improve global sustainability.

Social criteria (e.g., quality of life, sense of security, relationship with others) must reflect the degree of choice that a person has in an action. Many of us are locked into our own systems of collective construction within the dominant paradigm (many unsustainable) where the choice of being different can be socially, economically and practically difficult. Examples of this are the use of solar radiation and precipitation in dwellings and foregoing ownership of a car.

1.4. Risk analysis and comparative risk assessment

In all stages of information, including insufficient quality and quantity or vagueness and uncertainty, where much is at stake and there are several options for action, risk analysis can assist in selecting the most accurate values, lower costs, and/or the lower-risk option. The poorer the information, the greater the uncertainty, and risk analysis may be necessary. We suggest a preliminary stage of data analysis in order to confront a different set of issues and problems with inadequate resources. This technique classifies the problem issues according to the urgency, cost and likelihood of success.

It is frequently argued that there is insufficient or inadequate information to permit taking a rational action, including activities that affect sustainability. However, we know that there are systemic functional weaknesses in both ourselves and in our organizations. Research information actually adds to the uncertainty or controversy; we lose valuable time while more unnecessary work is undertaken. We know the direction that our action should take, but we do not know exactly what that action should be. Many of the problems and solutions are neither technically nor entirely rational. A new methodology for needs that arise may be required for sustainability. They should only be started through social action, where the general population as well as technical experts report on issues and decision-making recommendations.

1.5. Limitations of the measures of sustainability

Although we cannot objectively and unambiguously define sustainability, we must not abandon or postpone attempts to measure it. Even if we recognize that there are other equally valid ways of learning, we must begin where we are, even though that may be reductionist, rational or materialistic. We can define the limiting aspects (for example, the sustainable productive capacity of a specific area of the Earth) and trends in the direction of sustainability (for example, increased use of public transport, a more equitable distribution of revenues) and choose indicators that are appropriate and meaningful. The former must be below the threshold of unsustainability. The latter must give directions that require us to act. Many, in fact, are actually indicators of unsustainability. Many discussions and studies on the measurement of sustainability are not defined, nor do they even provide a common understanding of what is measured. The context of sustainability cannot be separated from the measurement.

We recognize at the outset the limitations of quantitative measures. However, we must be on guard to keep the threshold clear. Although sustainability is about quality and other intangible non-physical aspects of life, this does not mean that we are unable to obtain measurements for them. Just as biological indicators (e.g., health of trouts) are now used to measure the quality of industrial effluents alongside conventional physical-chemical indicators, we must be able to obtain parameters that serve us and the Earth.

1.6. Some indicators to measure sustainability

If we know that we are becoming more sustainable without having to measure the "sustainability discourse" as part of the process that then leads to a sustainable lifestyle and measures of it, some of which are relatively easy to measure and some of which are roughly quantified to preset limits. However, if it is consistent, then we can say that achieving sustainability has begun. Therein lay the success of initiatives such as Seattle.

The initial challenge of this discourse is communicating the environmental and social change that is underway within organizations, as groups cannot yet see their particular success as part of the combined progress towards sustainability. The dialogue should be extended to the wider community to open the discussion for a more effective participation on the big issues ahead. Local communities need to renegotiate their sense of community in the modern world and discover new modes of expression.

2. Evaluation of sustainability between combined cycle power plant production and a hybrid solar-combined cycle system

A discussion on sustainable development must create a process-oriented dialogue and therefore a dynamic concept that establishes priorities; the generic concept of sustainable development must be able to determine its specificity and concreteness at a local and regional level.

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This section presents a biophysical, social and economic need for high available renewable resources within our country. As a primary energy source for the generation of electricity in a combined cycle solar energy plant, the sustainability is measured in physical terms, while also taking social, economic and environmental interactions into account.

2.1. Overview

We consider the following questions: What is to be held, for how long, and at what spatial scale? These questions involve social concepts and economic and biophysical factors that should be evaluated as deeply as the scope of this study can allow. This project should also be evaluated superficially, viewing sustainability as a multivariate feature in a socio-environmental system that involves answering additional questions such as: Sustainability for whom, who will carry it out, and how can it be done? Only then can we understand and integrate the plurality of preferences, priorities, perceptions and joint inequalities in the objectives of what is to be held in an appropriate application to the different scales of analysis.

This section requires the evaluation of sustainability between two electrical generation systems: a combined cycle (conventional) and a hybrid solar-combined cycle.

Energy is essential for economic, social and global welfare, but unfortunately, most of it is produced and consumed in unsustainable ways (Yuksel, 2008). The primary source is fossil fuels (oil, coal and natural gas), with more than 90% of global production used to meet commercial energy needs. OPEC forecasts foresee further growth into 2030, both in developed and developing countries. Consequently, energy poverty is a crucial variable for the foreseeable future (OPEC, 2007), while the control of gases and other substances emitted into the atmosphere will become a more urgent matter to be resolved. This condition implies that further improvements must be achieved in the production, transmission, distribution and consumption of electricity (Yuksel, 2008).

In this context, renewable energy sources such as solar, wind, hydro, geothermal and biogas are potential candidates to meet global energy requirements in a sustainable manner. Renewable energy sources have some advantages when compared with fossil fuels (Demirbas, 2000). As a result, the increased use of renewable energy can have a significant environmental effect.

Among renewable sources, solar technologies are attracting worldwide attention (Patlitzianas et al., 2005, Hang et al., 2007); their application in new structures and their adoption in existing ones is currently one of the more common approaches with respect to electricity and heating supply. For example, solar photovoltaic technology worldwide in 2004 reached a production level of 1256 MWp, a 67% increase in production from 2003 (Flamant et al., 2006). Photothermal technology has reached over 430 MW (Morse, 2008).

This trend is expected to continue in the coming years, requiring the creation of specific tools for evaluating the efficiency of solar technology. Classical methods essentially provide tools for the assessment of energy and economy. However, placing these assessments in the broader context of sustainability of the environment require more integrated analyses. From this perspective, one must quantify both environmental and economic costs.

To this end, "emergy" has recently been identified as a valid analysis approach. Emergy can be defined as "useful energy (exergy) of a certain type, which has been used both directly and indirectly in the process of developing a particular product or service" (Odum, 1988; Scienceman and El-Youssef, 1993). Emergy expresses the cost of process-equivalent units of energy, such as solar power. The basic idea is that solar energy becomes the primary unit of energy that expresses the value of any other unit of energy so that it is possible to compare completely different systems, such as Emjoule (emergy joule), also called the emjoule solar, which is designated by the symbol (sej). "Emergy calculations have the same purpose as the Exergy: to capture the energy hidden in the organization and construction of living organisms." It is beyond words to define emerging as "exergy built."

2.2. Definitions

The means used to achieve the desired objectives will be varied, so emphasis should be placed on long-term ecological sustainability. All methods should promote the efficient use of energy and resources, encourage the use of renewable energy sources (and thereby reduce fossil fuel use), reduce costs and increase the efficiency and economic viability of alternative energy sources.

From the environmental point of view, the sustainability of a hybrid solar-combined cycle power generation system will essentially depend on the management and optimization of the following processes:

- Reduction in natural gas consumption; this will also reduce greenhouse gas emissions into the atmosphere.
- Preservation and integration of biodiversity; the use of parabolic trough concentrators requires a large area, so it is important to locate the hub area while affecting as little regional flora and fauna as possible.

Socially, electric power generation should benefit all communities in the area no matter where they are located, thus providing people with energy that can be used to increase productive capacities, self-management and local cooperative mechanisms. One can say that the process is a socially driven activator, improving conditions for all those who receive that energy as well as future generations.

2.3. Systemic attributes and operational definitions of a sustainable management system

The following primary schematic characteristics of a sustainable system must be analyzed:

- Productivity: the system's ability to provide the required level of goods and services. Represents the attribute value over a period of time.
- Equity: the system's ability to deliver productivity (benefits and costs) in a fair manner. This implies a distribution of productivity among affected beneficiaries in the present and the future.

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- Stability: refers to ownership of the system having a dynamic state of equilibrium. It can maintain the productivity of the system at a level not decreasing over time under normal conditions.
- Resilience: the ability to return to equilibrium or maintain productive potential after the system has suffered major disturbances.
- Reliability: the ability of the system to be maintained at levels close to the usual equilibrium, i.e., temperature shocks.
- Adaptability and flexibility: the ability to find new equilibrium levels to long-term changes in the environment. It is also the ability to actively seek new levels of productivity.
- Self-reliance or self-management: the ability to regulate and control the system through outside interactions. Includes organizational processes and mechanisms of socio-environmental systems to endogenously define their own goals, priorities, identities and values.

It also emphasizes that the sustainability of a system depends on endogenous properties and their external linkages with other systems and structural relationships. These attributes are designed to apply to systems management as a whole, including social, economic, environmental and technological attributes. Focusing on the abovementioned attributes allows for the development of sustainability indicators fundamental to systemic priorities, thereby avoiding long lists of purely descriptive factors and variables.

In operational terms, a sustainable management system will be one that simultaneously allows the following:

- A high level of productivity through efficient and synergistic use of natural and economic resources.
- Reliable production, stable and resilient to major disturbances in the course of time, ensuring access and availability of productive renewable resources; the use, restoration and protection of local resources, proper temporal and spatial diversity of the natural environment and economic activities and risk-sharing mechanisms.
- Adaptability or flexibility to adjust to new conditions of economic and biophysical environment through innovation and learning processes and the use of multiple options.
- Fair and equitable distribution of costs and benefits to the different affected groups, ensuring economic access and cultural acceptance of the proposed systems.
- An acceptable level of self-reliance to respond and externally manage induced changes, maintaining its identity and values.

These five general attributes of sustainability are the basis for the design of indicators:

- Productivity, which can be evaluated by measuring efficiency, achieved average returns and availability of resources.

- Stability, reliability and resilience, which can be evaluated with the trend and variation in the average return, with the quality, conservation and protection of resources, renewability in the use of resources, spatial and temporal diversity systems with a relationship between income and opportunity cost system, and an evolution of jobs created and risk-sharing mechanisms.
- Adaptability, which can assess the range of technically and economically available options, with the ability to change and innovate, strengthening the relationship between the process of learning and training.
- Equity, which can assess the distribution of costs and benefits to participants and target groups, and the degree of "democratization" in the decision-making process.
- Self-reliance, where one can evaluate the forms of participation, organization and control over the system and decision-making.

This project follows the methodology proposed by Masera (1996), which consists of the following:

1. Determining the objectives of the evaluation and defining the management systems to assess their characteristics and the socio-environmental assessment.
2. Selecting the indicators that define the critical points for the sustainability of the system, the diagnostic criteria and the derived sustainability indicators.
3. Measuring and monitoring indicators, including the design of analytical instruments and the procedure used to obtain the desired information.
4. Obtaining and submitting results that compare the sustainability of the analyzed management systems, identify the main obstacles to sustainability, and provide suggestions for improving the system of innovative management.

2.4. Objective of the assessment: Definition of management system

Planning to meet the nation's future electricity demand is an issue of paramount importance, considering the urgent need for economic development, the projected population growth and the allocation of capital to finance that growth.

The Mexican Federal Electricity Commission (CFE) forecasts that the demand for electricity will grow 5 to 6% annually in coming years, requiring a dramatic increase in production capacity along with new schematic development. A primary objective for the electricity sector should be a transition from a centralized power system to a geographically distributed and decentralized system, allowing for a wide availability of natural resources in order to focus on the use of renewable energy. In this scheme, we propose a reduction in plant size and geographical dispersion.

In this paper, we carry out a sustainability assessment by comparing a traditional production of electricity through a 316 MW combined cycle plant using natural gas as the primary energy source as well as an innovative system of electricity production through a solar-hybrid combined cycle plant that employs an 80 MW thermal and a 236 MW natural gas energy source.

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The large capacity 80 MW solar plant was chosen because of economy of scale (a larger capacity involves occupying a land area of over one million square meters). This capacity is not arbitrary; it is based on an example presented by PURPA (Public Utility Regulatory Policies Act) in the United States of America, which arose from limits for small producers. We selected this capacity to generate the parabolic trough based on the experience and cost information at our disposal. ABB GT24 combined cycle turbines of 236 MW and 316 MW were selected for use in the different alternatives.

The following are the main determinants used to characterize the proposed systems:

2.4.1. Bio-physical components of the system

For solar thermal technologies to be effective, the proposed systems must be located in an area with high solar irradiance during most of the year. Sonora State (Northwest of Mexico) was proposed as the construction site of the north plant, as shown in Figure 1.

Sonora is located within the North West Coastal Plain, which forms a belt 1400 km long, bounded on the east by the Sierra Madre Occidental and on the west by the Gulf of California. It is 250 km wide to the north (Sonora) and 75 km wide to the south (Sinaloa State), with an average elevation of 100 m. The region is mostly flat with a gentle slope towards the sea, interrupted by deeply eroded hills and low mountains or hills surrounded by low lying alluvial plains. From the northern border to the Rio Yaqui, there are large areas of typical desert plains, arreicas and criptorreicas where one can find sand dunes in a half moon.



Figure 1. State of Sonora (source: IMADES)

1. *Climate of the State of Sonora*: The State of Sonora has a dry climate (Figure 2), with an average temperature of 20 °C in the valleys and along the coast, while in the mountain region is 16 °C, with highs of 56 °C and minimum of -10 °C. The northern part of Sonora is characterized by a dry desert climate in the plains near the coast, a temperate rainforest in the mountainous region and the remaining dry steppe. The annual precipitation is 50 to 350 mm in the northwest and 400 to 600 mm in the rest of the state. In the southern desert, the climate is dry and very warm, with a rainfall of 266 mm in the summer.

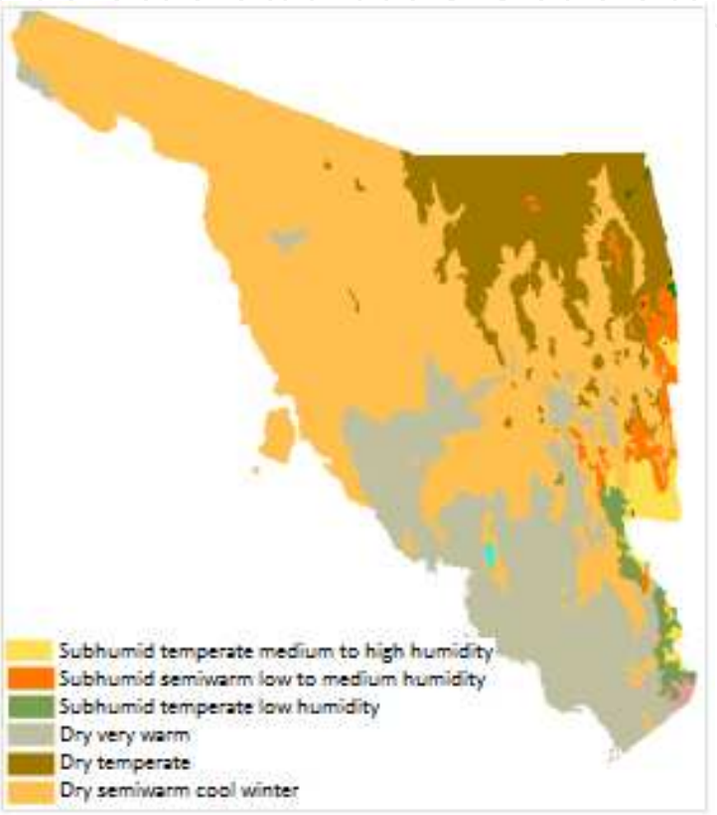


Figure 2. Schematic with different climates in the state of Sonora. (Source: IMADES)

2. *Vegetation of the State of Sonora*: Bushes occupy the largest area of the state (38.07%), dominated by ranching and the removal of wildlife for commercial purposes (mesquite, oregano, chiltepin) and crafts (ironwood, etc.). The areas with no apparent use in extension are next in prominence (17.29%). Pastures are predominantly livestock areas and occupy 13.06%. Forests cover 12.57% of the state and are located in the Sierra Madre Occidental; they are characterized as pine-oak, oak-pine and pine, and although there is infrastructure, the forestry operations remain mostly artisanal. Value-mining areas are well distributed in the state (6.28%) and dominated by gold and copper deposits. Approximately 6.01% is suitable for livestock, and the agricultural areas of the state (4.89%) are mostly irrigated. Intensive livestock (poultry, swine, dairy farms and feedlots) occupies a small area (1.15%), although it is economically important.

3. *Soil salinity in the State of Sonora*: Although 90.77% of the territory has no saline problem, approximately 10% is affected by salts at different levels. While 62.3% of the agricultural soils are normal, the rest are either saline-sodic (15.9%), have problems of salinity (12.4%), are strongly saline (3.2%), are strongly saline-sodic (2.3%), have only sodicity problems (1.7%) and are strongly sodic, are moderately saline (0.8%), or are strongly saline (1.4%). Salinity problems primarily exist in the Irrigation Districts of Caborca and the Hermosillo Coast and in the Yaqui and Mayo Valleys. The most important and difficult to eradicate are the saline-sodic soils found in the Yaqui Valley and in the saline delta plain (plains of San Luis Rio, Colorado).
4. *Stationary sources of air pollution*: Using the Information System Rapid Environmental Impact Assessment (SYRIA) simulation model, pig farms, landfills, urban centers, mines, mining and industry emissions were analyzed. In some cases, emission factors were used. The nine municipalities in the State of Sonora comprise nearly 85% of the population and nearly 65% of the productive activities, propagating a proportional burden of pollutants in the atmosphere, which presumably generate 251.2 Mg/year of total particulate matter, 48,037.8 Mg/year of hydrocarbons, and 399.5 Mg/year of carbon oxides in different composition.
5. *Watershed*: The State of Sonora has 12 watersheds, with most domestic consumption taking place in the Sonora River Basin, which passes through the state capital and crosses some of the oldest villages. Next in order of importance are the Yaqui River and Mayo River Basins; they have larger concentrations of people due to an agricultural boom resulting from the construction of hydraulic works. This assertion is reflected in the consumption of water for agricultural activities; water consumption from the Rio Yaqui and Mayo has increased since the construction of the Alvaro Obregon and Adolfo Ruiz Cortines dams. From the point of view of industrial development, these three hydrologic regions also contribute to the increased water consumption and increased demands on the service sector.

2.4.2. Socioeconomic and cultural components

The demand for services and natural resources is determined by the quality of life, which translates to economic growth. To evaluate this demand, we analyzed data on the growth of different economic sectors. The employed population has remained constant over the past three decades. Although the EAP has increased from 25.9% in 1970 to 45% in 1990, the unemployment rate increased from 0.75% in 1980 to 2.5% in 1990. The tertiary sector is the most dynamic in the state, occupying 49%, while 23% are in the primary sector, down from 1970 to 1990. Among the major indigenous groups are the Opata, Yaqui, Papago, Pimas and Seris.

Productive activities (Figure 3) were analyzed based on natural resources, particularly vegetation, as resources show the utilization of the soil. This enables the observation of impacts or consequences of productive activities on the environment.

As mentioned above, the vegetative plane incorporated activities such as aquaculture and was derived from recent satellite imagery. Human settlements and industries were added based on INEGI corrected plans for the 72 largest settlements in the state. Intensive livestock dairies, feedlots, poultry and swine were charted by obtaining the coordinates of each of those registered in the Ministry of Livestock Development, the State Delegation of the Ministry of Agriculture or livestock associations. The mining districts were mapped on the basis of records provided by the Mining Development Division of the Ministry of Economic Development and Productivity.

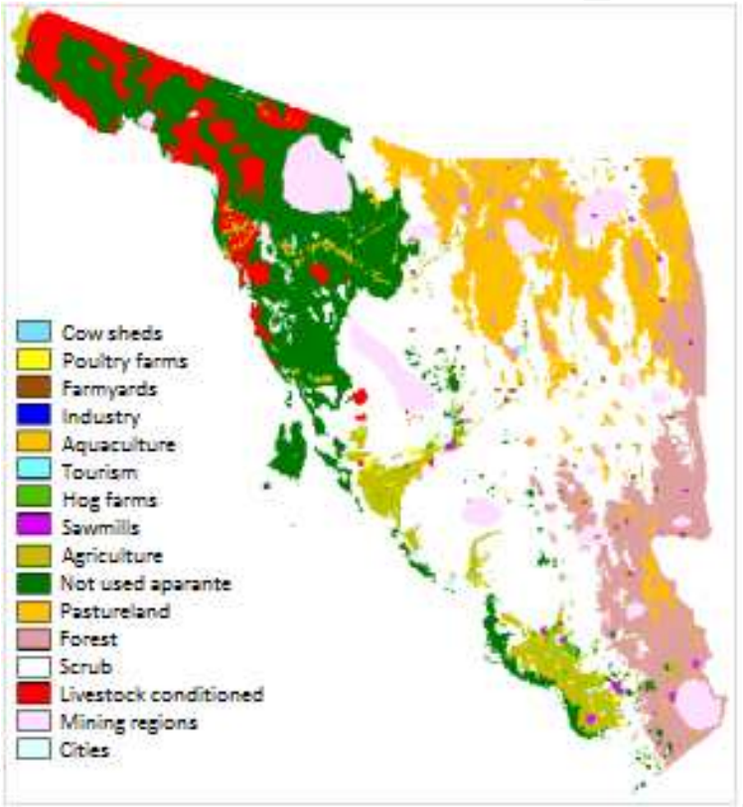


Figure 3. Distribution of land use in the State of Sonora. (Source: IMADES)

2.4.3. Technology and management components

The state of Sonora has a series of dirt roads, paved roads, highways and railroads linking major cities. As a border state, the highway goes straight to the border in Nogales. There is a pipeline that runs through much of the center of the state, which originates in the U.S., passes by Naco, Cananea, and reaches Hermosillo following the route of the highway. This is a great advantage because this is the area that receives the largest amount of solar radiation in the country. Table 2 compares the proposed systems.

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System Determinants	Traditional System	Hybrid System
Generation Capacity	300 MW combined cycle	50 MW solar thermal (PT) 250 MW combined cycle
Primary energy used	natural gas (imported)	solar energy and natural gas (imported)
Gross efficiency of c.c. Net efficiency of c.c.	46.79% 45.38%	46.79% 45.38%
DSG system net efficiency with Parabolic trough	-----	23%
Generation time with natural gas	5694 h/year (p.f.= 0.65)	5694 h/year (p.f.= 0.65 for c.c.) 13.2 h/day (85.3%)
Generation time with solar power	-----	2445 h/year* 6.7 h/day (14.7%)
Solar radiation design	-----	2772 kWh/m^2
Maximum solar radiation	-----	3122 kWh/m^2
Natural gas heat value	9200.14 kcal/m^3	9200.14 kcal/m^3
Solar concentration area	-----	570 265 m^2
Required total area	846 476 m^2	1 316 741 m^2
Life	30 years	30 years
Domestics inputs Imported inputs	37.4% 62.6%	53.7% 46.3%
Funding	CFE and private investment	CFE, World Bank,private investment and GEF

* The combined cycle always works and the plant is at full capacity for only 6.7 hours per day.

Where: c.c. --- Combined cycle p.f. --- Plant factor (taken from COPAR) P.T. --- Parabolic trough

Table 2. Comparison of the characteristics of each system.

The plant can be located in any area close to the west of the Hermosillo highway linking the city of Santa Ana south of Nogales. The area around the pipeline from the United States also spans a river, and the amount of solar radiation is the highest in the country. Furthermore, the ground is flat and semiarid.

2.4.4. Identification of critical points in the system

To identify the critical points in the system we ask the following question: What are the environmental factors or processes–technical, social and economic–that individually or in combination may have a crucial effect on the survival of the management system?

a. Environmental aspects: From this point of view, factors that can influence the sustainability of the management system include the following: air pollution from natural gas leaks; the large land area required for the installation of parabolic trough concentrators; large loss of cooling water for weather at certain times of year; low yields from cloudy weather; emissions from burning natural gas; change of land use; erosion; etc.

b. Socioeconomic aspects: These aspects are highly dependent on electricity prices because instability will affect the entire future of a plant using imported natural gas. Though this natural gas pipeline is national, it remains very sensitive to the unit price. International borrowing may be required to finance the construction of any system, and the construction may entail in a high migration of population for the construction of the plant, resulting in an imbalance in the surrounding communities. Combined cycle technology requires a great deal of imported equipment and will be subject to prices quoted in dollars or euros. The cost of labor will be slightly higher compared to the rest of the country, as this is a region near the border. Additionally, the use of an alternate source of energy can create suspicion among investors. Recently, CFE tender-type parabolic trough plants have been deserted both in Agua Prieta and Puerto Libertad (Sonora) due to administrative –not technical– reasons.

2.5. Selection of indicators

To define the indicators used in this evaluation, we must select those that are inclusive, i.e., those that describe rather than analyze processes. The indicators must be easy to measure, easy to obtain and be appropriate for the system under analysis. They must be applicable in a defined range of ecological, socioeconomic and cultural conditions and have a high level of reliability. These indicators should be easy to understand for most readers and be able to measure changes in system characteristics over time in a practical and clear manner. Finally, the measurements must be repeatable over time.

For this paper, we will consider three areas of evaluation: economic, social and technical/environmental, placing the general attributes of sustainability in each of the areas proposed by their own diagnostic criteria.

2.5.1. Economic indicators

To select these indicators, we must first state the diagnostic criteria to follow and then the indicator to use for defining the general attributes of sustainability.

- Productivity: You can assess profitability and efficiency indicators by using Net Present Value, Internal Rate of Return and Cost/Benefit. Other indicators may include the investment cost, turnaround time, etc.
- Stability, Resilience and Reliability: We can assess the diversification of fuel use and risk measurement mechanisms, using indicators for credit, insurance, leverage, percentage of income derived from the use of different primary energies, price of natural gas, etc.

- Adaptability: We can evaluate the options of primary energy use and technology options by indicating of number and type of primary energy options and technologies available, the cost at low loads, cost of generation on cloudy days, low demands, etc.
- Equity: The diagnostic criterion is the adaptability of technology and employment trends using indicators such as the cost of investment/production revenue, number of jobs created (temporary and permanent), access to fire insurance, etc.
- Self-Reliance: The indicators measure the level of self-financing, the degree of indebtedness, domestic savings, percentage of self-produced energy use, etc.

2.5.2. Technical and environmental indicators

These indicators give us information about the ability of the proposed systems to be environmentally "productive." Sustainability must sometimes include indicators describing the state of the environment or the processes of prevention and protection of environmental degradation.

- Stability, Resilience and Reliability: Can be used as an indicator of land use patterns, number of species in the area, soil quality and water, soil degradation, disasters, climate change, soil chemical properties, physical soil properties, distribution of natural capital in each region, and so on.
- Self-Reliance: This requires indicators of energy subsidy, energy efficiency and degrees of external dependence.

2.5.3. Social indicators

This type of indicator is very difficult to quantify, especially for a production plant that will supply power to the communities and surrounding cities in Sonora. A much larger study is required to determine the exact number of beneficiaries and the investment schemes to be used for construction and operation. Some of the indicators suggested in the literature (Masera, 1996) are as follows:

- Equity: The distribution of benefits can be used as an indicator of the number and type of benefits by gender, social sector, age, ethnicity, etc. The factors influencing decision-making may include policies, group's resistance, lobbyists and others.
- Stability, Resilience and Reliability: The ability to overcome serious events can affect the survival of the project after conflicts, problems or lack of financing. The processes of learning and training can reference the type and frequency of training, knowledge sharing mechanisms between members, etc.
- Adaptability: Human resource development can be evaluated using indicators such as concepts, methodology and ownership by the community as a capacity for change. We can assess changes in objectives, projects, personnel, and adaptation to changes in the different aspects of production, etc.

- Self-Reliance: Participation is evaluated by the number and frequency of the different phases of the project. We measure the power control that decides on critical aspects of the organization with respect to the type, structure and permanence of the organization.

2.6. Measurement and monitoring indicators

The above indicators will be evaluated quantitatively or qualitatively, depending on the question, because some of them will be justified by arguments or theoretical reasons, partly due to the difficulty in assigning a number to an assessment of non-numeric type. First, we will present the economic indicators, followed by the technical-environmental indicators and then social indicators.

2.6.1. Economic indicators

Regardless of the general attributes of evaluating sustainability indicators, they are calculated individually to reach a conclusion. Table 3 shows the results of these calculations (Geyer, et al., 2004).

Indicator	Conventional System	Hybrid System
Generation [GWh]	1,708	1,708
Investment cost [USD]	$ 135,000,000.00	$ 237,316,931.13
Fuel cost [USD]	$ 68,505,647.32	$ 57,088,039.43
Operation and Maintenance Cost [USD]	$ 8,634,951.00	$ 8,334,592.50
Unit Cost of Generation [USD/kWh]	$ 0.045	$ 0.038
Unit Cost of Investment [USD/kWh]	$ 0.079	$ 0.139
Internal Rate of Recovery	26.90%	19.60%
Net Present Value [USD]	$ 38,943,485.89	$ 33,155,291.46
Annuity equivalent [USD]	$ 7,821,505.70	$ 6,659,196.56
Benefit/Cost	4.11	2.61
Recovery period	4.8 years	3.1 years

Table 3. Economic variables of each model (Source: own data).

The economic and financial analysis necessary to reach these results was performed on a spreadsheet, considering each year of construction, testing, operational development and economic variables.

For economic indicators, we used data from the Costs and Benchmarks for Formulation of Investment Projects in the Electricity Sector - Generation (CFE, 2007) for the combined cycle units, while the thermal data were taken from Hertlein et al. (1990) and Franz Trieb (2009).

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2.6.2. Technical and environmental indicators

The location of the proposed plant is 73 km northwest of City of Caborca, off Highway 37 (60 km in a straight line). The vegetation of the area consists of scrub and grassland as non-endemic species. The fauna consists primarily of rodents, reptiles and insects. No crops are grown in the area.

The degradation phenomena studied consisted of erosion, salinity and pollution (soil, water and air). In most cases, estimates were made in the absence of available information by using mathematical models with the aid of GIS and satellite imagery to update information. The erosion in the area lies between 4 and 10 ton/ha. In terms of salinity, the area is within the affected soils. There are no landfills in the vicinity.

The selected region has few clouds for most of the year. However, as the present electricity generation derives from natural gas, the combined cycle plant will operate continuously and the total capacity of the plant will be operational within the CSP.

The energy subsidy should be completely designated as external and not just for the region but also for the nation, as the pipeline that feeds the plant comes from the United States. The energy efficiency is the highest in Mexico. The total conversion efficiency of the solar thermal power plant varies from 21 to 23%, and it can be significantly improved if a Direct Steam Generation solar field is used to deliver steam at 550 °C and 100 bar (Zarza, 2004). The CO_2 emissions from each of the proposed systems are shown in Table 4.

Indicator	Conventional System	Hybrid System
Amount of fuel	386 181 018 m^3/year	337 125 816 m^3/year
Amount of CO_2 emitted	275 844 ton/year	240 804 ton/year

Table 4. Atmosphere emissions for each model.

2.6.3. Social indicators

The indigenous groups in Sonora who live around the area proposed for the construction of the plant (the Opata, Yaqui, Papago and Pimas) subsist primarily through activities such as the manufacture of handicrafts, animal husbandry and subsistence farming. The construction of the plant would mean a source of temporary employment for them, bringing benefits in both economy and quality of life.

The primary operator will be CFE, although it is very likely that contractors will decide less important aspects that may have a major impact on the region.

In the event of any social conflict in the area, the construction phase will have to stop for security reasons. However, if the pipeline continues to provide natural gas, then the plant will continue producing. There is sufficient security in the area to guard against rebel groups tampering with transmission towers or the pipeline.

Staff at the plant must be local people who receive sufficient training in all aspects of the plant; this can provide a continuity of (very general) knowledge to the community.

The organization of the plant will likely come from CFE because it is the institution that controls and manages the production of electricity. They already have defined organizational schemes in place for the initial production of a new power plant.

The beneficiary communities surrounding the hybrid plant, including the cities of Hermosillo and Santa Ana, are not intended to affect social stability during the construction period (1 to 3 years) and afterwards during operation.

2.7. Evaluation results

The objective of the proposed hybrid system is the generation of electricity for the area by installing the latest technology, meaning that the technology used has the highest possible conversion efficiency of primary energy, that the solid and liquid waste emissions are minimized, and that the system incorporates the additional use of a renewable energy source. According to calculations above, the obtained results show that the amount of generated CO_2 is less than that emitted by the conventional system; hence, the risk for environmental pollution is reduced for future generations. The plant is also adapted to an area with poor socio-ecological circumstances, which will dramatically improve the benefits for future generations.

Production structures for generation, distribution and consumption will provide electrification services and reliable energy necessary for the progress of the region, which facilitates total employment and meaningful work, thereby improving human capabilities for the inhabitants of the region.

With the launch of a hybrid power plant (solar combined cycle), low resource consumption technology is developed that adapts to local socio-ecological circumstances. Because the primary energy sources are low-polluting solar energy and natural gas, there are still significant risks for the present and future. Increasing the electrical infrastructure in the region by consuming imported gas will not preserve this resource for future generations for other uses. It will, however, conserve resources in the zone if outside resources are used.

We must ensure the satisfaction of some of the most basic human needs, such as the provision of high-quality energy. By implementing an innovative system of this type, we promote cultural diversity and pluralism; by using new commercial technology, we can share experiences with other international institutions on the construction of field parabolic trough concentrators and on the development of the plant and its operation.

This should help to reduce the aspects that make it less sustainable to allow the use of more solar energy as renewable primary energy.

In terms of economic indicators such as initial investment, it is slightly more expensive to implement a hybrid plant. However, costs would be absorbed by international organizations and the CFE, whose resources are governmental and therefore contributed by people from across the country. Despite this, the remaining features and sustainability objectives

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are met; therefore, it can be said that a sustainable system has a very promising future. The advantages outweigh the disadvantages, and thus it is worth implementing a solar power plant for generating electricity under the study conditions. It is a sustainable project from a technical, ecological and social standpoint, but from an economic point of view, it is not entirely sustainable because it requires external resources, which does not comply with the characteristics of self-sufficiency.

As a complement to the results of this analysis, there is an internal report from the Institute of Engineering (Almanza, et al. 1990) that offers a more formal and technical evaluation of the climatic conditions of the proposed area.

3. Conclusions

The amount of CO_2 emission from the hybrid system is less than the conventional system. Production structures are generated, and the plant develops hybrid technology with a low consumption of resources, which are adapted to local socio-ecological circumstances.

Since there is a wide acceptance in all social sectors of the concept of sustainability, the proposal made in this paper aims to ensure a sustainable supply of high quality electricity to a region where one of its main natural resource is the Sun spite that, today, still we can not objectively define that term and therefore implement it.

It is very important to make clear that sustainability goes beyond ensuring the environmental integrity of a site and the standard of living of a population, should address the concept of "quality of life" and a form of collective life.

Sustainability is now in a further process of discourse, and efforts to measure it should become a state priority. Institutional initiatives and debates about the measurement of sustainability in general show resistance in committing to this concept. Therefore, there is no common shared understanding of what has been measured.

Sustainability indicators are often an amalgam of economic, social and environmental indicators, but recently, they are showing signs of maturity with better measures of sustainability. These indicators, however, are limited and may reflect unsustainable measures. Their primary value is to indicate the direction of change rather than a swing state.

The indicators are just the initial map and not what could be called the territory. The difficult task of achieving sustainability is another issue.

In consulting references, it follows that the most successful initiatives in measuring sustainability are those initiated and controlled by autonomous public groups (e.g., Sustainable Seattle 1998), where the process is more important than the indicators.

The greater the public involvement in the execution of a community role (for example, consensus conferences, citizen juries, etc.), the more likely we are to achieve sustainability.

We need to address the fundamental existential questions and find meaning in life if we are to achieve sustainability.

The emergy evaluation assigns a value to products and services through their conversion into an equivalent form of energy: solar energy (Odum, 1983, 1996).

Solar energy is used as the common denominator through which different types of resources, whether energy or material, can be measured and compared with others.

Author details

Rafael Almanza and Iván Martínez

Universidad Nacional Autónoma de México / Universidad Autónoma del Estado de México, México

References

[1] Almanza, R, Valdés, A, Lugo, R, Zamora, J M, Sandoval, C y Estrada Cajigal, V. (1990). *Estudio del comportamiento de sistemas solares térmicos para generar electricidad en 5 comunidades de Sonora o Baja California*. Proyecto 0102 Instituto de Ingeniería, UNAM. Patrocinado por CFE. (abril 1990) pp. (1-254)

[2] Boswell, M.R. (1995). Establishing indicators of sustainable development. *Proceedings of the Annual Conference of the Association of Collegiate Schools of Planning*. Detroit, Michigan, USA. October 1995.

[3] Brundtland, G. (Chairman). (March, 1987). Report of the World Commission on Environment and Development: *Our Common Future*. Available in: http://www.un-documents.net/wced-ocf.htm

[4] Cobb, C., Halstead, T. and Rowe, J. (1995). If the GDP is up, why is America down?, In: *Atlantic Monthly digital edition*, Available from: http://www.theatlantic.com/past / politics/ecbig/gdp.htm

[5] Comisión Federal de Electricidad (CFE). (2007). Costos y Parámetros de Referencia para la Formulación de Proyectos de Inversión en el Sector Eléctrico – Generación. (April 2007), México.

[6] Daly, H. and Cobb, J. (1994) *For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future*. (2nd edition). Beacon Press. ISBN 9780807047057. USA.

[7] Demirbas, A. (2000). Biomass resources for energy and chemical industry. In: *Energy Education, Science and Technology*. Vol. 5, pp. (21–45)

[8] Flamant, G., Kurtcuoglu, V., Murray, J., Steinfeld, A. (2006). Purification of metallurgical grade silicon by a solar process. *Solar Energy Materials & Solar Cells*. Vol. 90, No. 14, (September 2006), pp. (2099–2106), ISSN 0927-0248.

[9] Gligo, N. (1995), Situación y perspectivas ambientales en AméricaLatina y el Caribe, *Revista de la CEPAL*, No 55 (LC/G.1858-P), Santiago de Chile.

[10] Griffin, J. (Ed.) (2007). *World oil outlook 2007*. Organization of t Petroleum Exporting Countries, ISBN: 9783200009653, Vienna, Austria.

[11] Hang, Q., Jun, Z., Xiao, Y., Junkui, C. (2008). Prospect of concentrating solar power in China the sustainable future. *Renewable & Sustainable Energy Reviews.* Vol. 12, No. 9, (December 2008), pp. (2505–2514), ISSN: 1364-0321.

[12] Hart, M. (1995). Guide to Sustainable Community Indicators. Ipswich, Maine. QLF/ Atlantic Center for the Environment.

[13] Henderson, H. (1995). The Indicators Crisis, In: *Paradigms in Progress: Life Beyond Economics,* pp. (147-192), Berrett-Koehler Publishers, ISBN 978-1881052746, USA.

[14] Henderzon, H. (1991). Paradigs in progress: Life beyond economics. (2nd Ed.). Knowledge Systems. ISBN 9780941705219. USA.

[15] Hertlein, Klaiss, and Nitsch. (1990). *Cost analysis of solar power plants*. American Solar Energy Society. USA.

[16] Holden, M. (2006). Sustainable Seattle 1998: The Case of the Prototype Sustainability Indicators Project. In: *Community Quality-of-Life Indicators Social Indicators Research Series.* (2006). Vol. 28, pp. (177-201), DOI: 10.1007/978-1-4020-4625-4_7

[17] Liverman, D, Hanson, M E, Brown, B J, y Meridith, R W. (1988). Global sustainability: towards measurement. In: *Journal of Environmental Management*. Vol. 12, No. 2, (1988), pp. 133-143, DOI: 10.1007/BF01873382

[18] Masera, O.; Astier, M. (1996). *Metodología para la Evaluación de Sistemas de Manejo Incorporando Indicadores de Sustentabilidad.* Grupo Interdisciplinario de Tecnología Rural Aplicada, México.

[19] Morse, F. (2008). Concentrating Solar Power (CSP) as an option to replace coal. In: Energy & Climate Mini-Workshop, Washington, DC. 14/05/2012. Available from: http://ossfoundation.us/projects/ energy/2008

[20] Odum, H.T. (1988). Self-Organization, Transformity, and Information. *Science*, Vol. 242, No. 4882, (November 1988), pp. (1132-1139), ISSN: 0036-8075 (print), 1095-9203 (online).

[21] Organization of the Petroleum Exporting Countries (OPEC). (2007). *World oil outlook 2007*. Technical Report OPEC. ISBN: 9783200009653, Vienna, Austria.

[22] Patlitzianas, K., Kagiannas, A., Askounis, D., Psarras, J. (2005). The policy perspective for RES development in the new member states of the EU. *Renewable Energy*. Vol. 30, No. 4, (April 2005), pp. (477–492), ISSN: 0960-1481.

[23] Rees, W., Wackernagel, M., and Testemale, P. (1998). *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers, ISBN 9780865713123, Canada.

[24] Sachs, W. (1996). What kind of sustainability?, *Resurgence*, No 180, (1996), pp. (20-22).

[25] Scienceman, D.M. and El-Youssef, B.M. (1993). The System of Emergy Units. *Proceedings of the XXXVII annual meeting of the International Society for the Systems Sciences*. New South Wales, Australia, July 1993.

[26] Trieb, F., Schillings, C., O'Sullivan, M., Pregger, T. and Hoyer, C. (2009). Global Potenctial of Concentrating Solar Power. *Proceeding of the 15th Solar PACES International Symposium on Concentrated Solar Power and Chemical Energy Technologies.* Berlin, Germany, September 2009.

[27] Trzyna, T. (1995). A Sustainable World; Definig and measuring Sustainable Development. IUCN. Earthscan.

[28] Trzyna, T. (Ed). (1996). *A Sustainable World: Defining and Measuring Sustainability*. International Union for Conservation of Nature, ISBN: 978-1880028025, Switzerland.

[29] World Commission on Environment and Development. (1987). *Our Common Future*. Oxford University Press. ISBN 9780192820808. Great Britain.

[30] Yanarella, E.J. and Levine, R.S. (1992). Does sustainable development lead to sustainability?, *Futures.* Vol. 24, No. 8, (October 1992), pp. (759-774), ISSN: 0016-3287.

[31] Yüksel, I. (2008). Global warming and renewable energy sources for sustainable development in Turkey. *Renewable Energy*. Vol. 33, No. 4, (April 2008), pp. (802–812), ISSN: 0960-1481.

[32] Zarza, E., Valenzuela, L., León, J., Hennecke, K., Eck, M., Weywers, H., Eickhoff, M. (2004) Direct Steam Generation in parabolic troughs, final results and of the DISS project. *Proceeding of the 12th Solar PACES International Symposium on Concentrated Solar Power and Chemical Energy Technologies.* Oaxaca, México, October 2004.