IAC-06-E5.1.6

RENEWABLE ENERGY SYSTEMS: HOW CAN SPACE HELP?

Ozgur Gurtuna
Turquoise Technology Solutions Inc., Canada
Teknosfer Space and Energy Ltd., Turkey
gurtuna@turquoisetech.com

ABSTRACT

The current economic and political landscape creates a very favorable environment for renewable energy investments. This environment, together with the increasing maturity of renewable energy technologies, makes a compelling case for the prospects of renewable energy. The premise of this paper is that there are many synergies between space and renewable energy, creating a significant potential for future applications across the whole energy supply chain. This paper focuses specifically on renewable energy and space, and presents a phased approach for planning and executing renewable energy projects. The role of space technologies and applications during the project phases are highlighted. Some specific examples about ongoing efforts to use space-based resources to help develop new renewable energy projects are also discussed.

1.Introduction

It is becoming increasingly clear that there is a widening gap between our current energy supply and our ever increasing demand for energy. Beyond the issue of this demand/supply balance, there is also mounting scientific evidence on the negative environmental impacts of our over-reliance on fossil fuels.

Despite this rather pessimistic energy picture, there are also some good news. The current economic and political landscape creates a very favorable environment for renewable energy investments. This environment, together with the increasing maturity of renewable energy technologies, makes a compelling case for the prospects of renewable energy. However, those who envision renewable energy systems emerging as a substitute to fossil fuels and replacing them may prefer to move their bets to the next century: most indicators and forecasts point to a continued dominance of fossil fuels in the global energy mix for the foreseeable future.

Therefore, at this stage it is premature for renewable energy systems to compete directly with oil, natural gas and coal. Rather, renewable energy systems can be seen as part of the global energy “portfolio”. Compared to fossil fuels, renewable energy constitutes a very small part of this portfolio today, but it has a significant upside potential in the long-run.

At first glance, the intersection of space and renewable energy looks a rather limited, “niche” area. Apart from some past studies on Solar Power Satellites and conventional Earth Observation (EO) projects, not too many space related projects come to mind which are linked to renewable energy.

The premise of this paper is that there are many synergies between space and renewable energy, creating a significant potential for future applications across the whole energy supply chain.

An earlier work focused on the concept of the energy supply chain[1] and how space applications and technologies can provide a variety of benefits for renewable energy projects as well as traditional energy systems running on fossil fuel (Gurtuna, 2005).

Building on this framework, this paper will focus specifically on renewables, and present a phased approach for planning and executing renewable energy projects[2]. The role of space technologies and applications during the project phases will be highlighted. Some specific examples about ongoing efforts to use space-based resources to help develop new renewable energy projects will also be discussed. The paper concludes with some recommendations and specific areas identified for future research.

2.Renewable Energy: An Overview

In today's energy mix, renewable energy sources and technologies play a very modest role. With the exception of hydro (which supplies 16% of the world's total electricity), renewable energy sources provide only 2% of the total energy supply for electricity generation (Figure 1). This figure includes almost all types of renewable energy sources, including geothermal, solar, wind, marine (wave and tidal), heat as well as combustible renewables and waste.

However, renewable energy technologies have been rapidly evolving in the past few decades. As it can be seen in Figure 2, the installed capacity for wind and solar energy systems has been increasing on an exponential rate since the mid-1990s.

[1] Energy supply chain includes each step (or link) that connects primary energy sources to the end users; energy is generated, stored, transmitted and distributed through the energy supply chain.

[2] Although there are no universally accepted definitions of renewable energy, the consensus is that it includes energy obtained from natural processes that do not require the use of exhaustible resources such as fossil fuels.

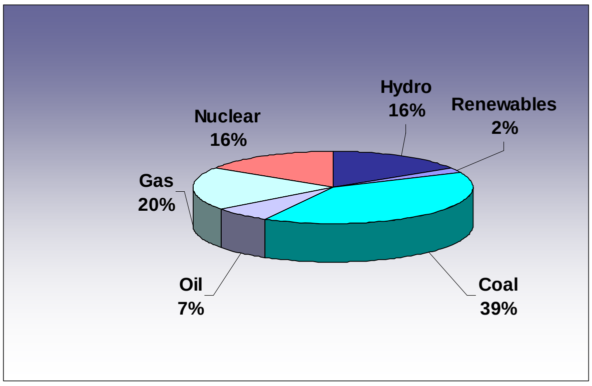

Fig. 1: The share of different energy sources in electricity generation for the year 2004 (worldwide). The total is 17,450 TWh. Renewables include geothermal, solar, wind, heat as well as combustible renewables and waste. Data source: International Energy Agency Key World Energy Statistics 2006.

This trend clearly demonstrates that these technologies have reached the stage of mass adoption.

Today, the cost of electricity produced by solar cells ranges between 20 to 25 U.S. cents per kWh. Wind turbines, on the other hand, generate electricity for about 5 cents per kWh. For comparison, the cost of electricity generated from coal is 4-6 cents per kWh and the cost for natural gas generated electricity is 5-7 cents per kWh (Kammen, 2006; Roberts, 2005)[3].

Although the cost of electricity generated from solar cells is much higher than the conventional alternatives today, as demonstrated by the wind energy sector achieving cost competitiveness is feasible. In fact, since the beginning of 1980s, many renewable energy technologies demonstrated very significant improvements in cost-efficiency. In addition to advances in technology, the consistent decline in cost of such systems is a result of mass production.
Especially in view of the recent surge in the prices of fossil fuels (especially oil and natural gas), this decline can create a very interesting dynamic in the energy market and shift the balances in the long-run.

[3] These figures are for the U.S., however the situation is similar in other countries.

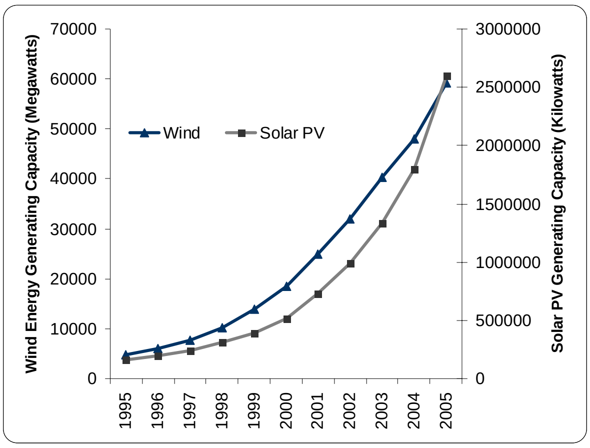

Fig. 2: The installed capacity of wind energy turbines and solar photovoltaic systems over time (cumulative). Note that the wind energy capacity is given in megawatts and it is actually much higher than the solar PV capacity (here given in kilowatts) Data source: BP Statistical Review of World Energy 2006.

Although most experts believe that it will take many years for renewable energy systems to be competitive with fossil fuel alternatives on a purely cost basis, the picture changes significantly when we consider two major "externalities": environmental impact and energy security. The prices of fossil fuels in today's energy markets largely ignore the environmental cost of such fuels and energy security issues.

The environmental impact of fossil fuels is becoming increasingly clear, and there is a growing public awareness that connects our current consumption rates of fossil fuels to climate change. A more detailed discussion of this connection is beyond the scope of this paper. It is suffice to say that, both from carbon emission and long-term sustainability perspectives, renewable energy has a natural advantage over fossil fuels in terms of its environmental footprint.

Energy security issue creates another layer of complexity in the energy sector. Energy security refers to the ability of a country to maintain a steady stream of energy supply. Renewable energy systems arguably have an advantage over fossil fuels in this respect as well, since almost all countries in the world have access to one or more types of renewable energy sources. Therefore, solely by investing in renewable energy systems and starting domestic projects, countries can have more control on their energy supply. Compared to the current oligopolistic structure of the energy markets (especially oil), where very few can control so much, the geographic distribution of renewable energy sources are far more dispersed.

One other major security advantage of renewables is the potential for a distributed architecture. This concept is also referred to as the "Energy Internet" (Vaitheeswaran, 2003). By distributing the generation and storage of energy to multiple points ("micropower"), and linking the generators and consumers using a hybrid energy/telecommunications network, a distributed architecture can be created. This network architecture decreases the probability of a catastrophic failure in the overall energy supply chain. Therefore, compared to the current paradigm of centralized, concentrated production of fossil fuels, this distributed architecture can create a more secure energy network in the long run (Rifkin, 2002).

This is not to say that renewable energy will unlock a very "democratic" energy system. In all likelihood, control of advanced renewable energy technologies will determine the leaders and followers of the future energy market. In other words, given that "raw" renewable energy sources (e.g., solar radiation, wind, biomass, etc.) are present in almost any country, the race will be for harvesting these raw sources in the most economically efficient way.

3. The Role for Space

Given this key role of technology in the emerging renewable energy market, space technologies and applications have the potential to make a significant contribution.

In the past, many space mission concepts were proposed with the aim of solving the energy problems on Earth. These concepts, such as Solar Power Satellites and Helium-3 extraction from the Moon, require enormous resources as well as significant advances in space technologies and decades of investment.

Contrary to these visions based on radical innovation, this paper proposes a more modest approach based on incremental innovation. Specifically, I argue that:

- We can start developing renewable energy projects today by using the space assets which are already in place.
- In the short- to medium-run, rather than striving to create energy from space, we should focus on creating energy here on Earth with assistance from space applications and technologies.
- Instead of trying to replace fossil fuel systems by creating a “silver bullet” technology, we need to adopt a portfolio approach in which each energy generation system has its own advantages and disadvantages. Space can help us to better manage almost all energy sources in this portfolio.

4. Investing in Renewables: A Phased Approach

Energy markets are notorious for their volatility and the relative occurrence of large price swings. Introducing technological uncertainty on top of this high level of market uncertainty is a big challenge, yet this is precisely what many renewable energy projects are facing, since associated technologies are still maturing. Therefore, on top of the market uncertainty, renewable energy projects have to deal with various technological uncertainties as well.

One particular investment method useful in an environment characterized by a high level of uncertainty is the “stage-gate approach” (Cooper and Edgett, 1999). When applied to renewable energy projects, this approach consists of four main stages for bringing a renewable energy project from concept to realization (Fig 3).

Each stage of a renewable energy project is linked and the project stakeholders have to make a go/no go decision based on the future expectations of market, technology and other factors (such as the policy environment). In other words, completion of each phase gives the stakeholders the option, but not the obligation to proceed with the next phase. This is also referred to as “options thinking” in the economics/finance literature, and it enables controlling project risks without being overly-conservative.

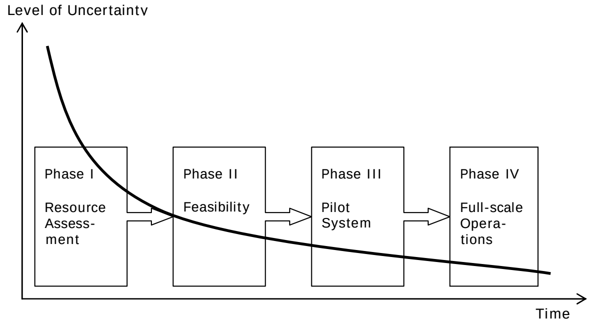

Fig. 3: The four phases of renewable energy projects, and decreasing uncertainty over time.

During all of these phases, project stakeholders actively strive to collect more information, so that better decisions can be made. This discovery process decreases the overall uncertainty of the project over time[4].

This reduction in uncertainty is precisely where space technologies and applications can make a significant contribution: by helping decision-makers to obtain and analyze the relevant data with a very quick turnaround. During all four phases, space can play an important role.

4.1 Phase I: Resource Assessment

This stage is mostly devoted to the assessment of the existing natural resources within a specific country or region using Earth Observation and Geographical Information Systems capabilities. In addition to the information that can be gathered from satellites, ground measurements can also be used. Moreover, other layers of information related to renewable energy systems such as demographics and the status of the existing electricity grid should be used in conjunction with EO data.

The ideal outcome from this phase is an inventory of renewable energy resources that are promising based on the geography and natural resources of the selected region. The obvious advantage of using satellite data during this phase is the ability to cover wide geographical regions in a quick and efficient

[4] Figure 3 is simplistic and it is only intended to demonstrate the overall decrease in uncertainty as the phases are completed. In reality, the decrease in uncertainty would not be as smooth, and in the long-run there can still be “jumps” in uncertainty due to market interactions, natural disasters, etc.

manner. Access to historical satellite data is another advantage since this data can enable time series analysis of various factors (e.g., wind speed, cloud cover, etc.) which can impact renewable energy systems and also the demand for energy.

4.2 Phase II: Feasibility

Based on the inventory study done during Phase I, the second phase is concentrated on choosing one or more of the renewable energy sources and conducting a detailed feasibility analysis. It is critical to adopt a multidisciplinary approach at this stage, and examine the feasibility of renewable energy systems from multiple angles, including:

- Technology (maturity, reliability, availability, cost, etc.)
- Market (labor cost, demographics of the market, etc.)
- Environmental impact assessment
- Policy analysis (incentives for renewable energy, political stability of regions, etc.)

Another important step in Phase II is determining the availability of potential investors and securing financing. Together with the feasibility analysis, financing possibilities will inevitably eliminate some of the candidate renewable energy systems from further consideration. If one or more concepts are deemed feasible, then a pilot project can follow.

During this phase, Earth Observation can play an important role, since a more detailed analysis of the selected energy source is needed. In terms of project requirements, this can mean higher resolution imagery, and temporal as well as spatial analysis.

4.3 Phase III: Pilot System

In the preceding phases, most of the work consists of "paper studies". However, in order to prove that the chosen renewable energy concept can function in the candidate geographic region, actual hardware integration is needed.

This stage not only involves constructing an energy generation system, but also installing the corresponding energy storage solution (if any), connection to the main grid, performance measurements, and operational planning.

A successful pilot project proves that the chosen concept can function in a real-life setting in a cost-efficient manner. Only by actually operating the plant that more accurate information can be obtained about the life-cycle cost of similar projects.

This demonstration further reduces the uncertainty discussed earlier and makes a compelling case for potential investors to get involved in the next phase.

4.4 Phase IV: Full-scale Operations

The final phase of renewable energy investments involves building multiple systems and ensuring long-term environmental and economic sustainability. In parallel to the "portfolio" concept outlined earlier, during full-scale operations, one country or region does not necessarily have to pick only one type of renewable energy. In fact, in order to increase the redundancy in the system and to create incentives for more innovations, a hybrid system would present certain advantages.

During Phase IV, one of the most valuable skills is to gain in-depth expertise in the operations of renewable energy systems. Demand forecasting is an area particularly important for operations.

5. Demand Forecasting

Another relevant space capability to renewable energy generation is forecasting the changes in electricity demand on an operational basis. Weather and environmental conditions have a direct impact on the variations on electricity demand over time, and these conditions can be readily observed from space.

In recent years, with the deregulation of the energy industry (especially in North America), sophisticated energy markets have emerged. As discussed by Hertzfeld at al. (2003) and Mathurin and Peter (2004), space technologies and applications have the potential to play an important role in this new market environment.

Currently, trading takes place both in the spot market, where buy/sell transactions are instant, and in the day-ahead market, which gives a 24-hour horizon for buyers and sellers. It is likely that the day-ahead market will transform into a derivatives market (including forward/futures and options) with a much longer time horizon.

As in any financial market where future expectations and the flow of information play a critical role in determining the prices, energy markets are also very sensitive to new information. Therefore, any additional advantage one can get in collecting and analyzing information pertinent to electricity demand has a significant financial value.

Moreover, having more accurate weather forecasts in the 5-day period, and pushing the forecasting horizon to 7-10 days can also help plant operators to make better operational decisions, such as scheduling maintenance and adjusting generating capacity.

Using satellite data for forecasting demand for electricity is a relatively new research area, and there are many questions that need to be answered before reliable models can be developed and gain wide acceptance in the energy industry.

6.Project Examples

In this section, in order to illustrate some of the points discussed above, some ongoing efforts will be highlighted.

At the Agency level, one of the most relevant programs to renewable energy is ESA's Earth Observation Market Development (EOMD) program[5]. EOMD includes a number of projects focusing on EO and energy, with a specific focus on renewable energy since 2004. As part of EOMD, many different types of satellite measurements which are relevant for renewable energy projects have been examined, including wind speed, snow cover monitoring, ground irradiance, and cloud cover.

Some of the EOMD projects are dedicated to estimating the energy yield of prospective offshore wind farm sites. Compared to traditional methods (e.g., using an offshore meteorological mast to take wind measurements), using satellite data not only provides cost-efficiency, but it also enables analyzing multiple sites in a relatively short amount of time. In the phased approach discussed above, this capability can be especially useful for Phases I and II. Similar methods have also been developed to measure topography and terrain roughness, important determinants of yield for onshore wind farms (Nielsen et al., 2004, Mathieu, 2005).

Another EOMD project related to renewable energy generation is estimation of ground irradiance for terrestrial solar energy plants. For this particular purpose, meteorological satellite data for solar irradiance is used in combination with other EO capabilities such as Digital Elevation Models and cloud cover measurements. Similar to the wind farm yield assessment projects, this capability is also relevant for Phases I and II of renewable energy projects. In addition, solar energy yield estimation can also help with Phases III and IV during the management of plant operations. Plant managers can compare the actual energy production with the estimates from satellites. A wide spread among these two values can help them identify potential problems with the performance of solar plants (Mathieu, 2005).

7. A Note on Space Technology Spin-offs

For some experts, storing the renewable energy in the form of hydrogen is the ultimate target. This will enable reaching the consumers not only in the electricity market, but also supplying energy to the transportation market and powering the next generation vehicles running on fuel-cells (Dunn, 2001).

Energy storage technologies are becoming increasingly important for terrestrial applications, and there are many energy storage technologies developed for space applications that can be used on Earth.

One of the biggest drawbacks of renewable energy systems is their intermittent nature: the energy output can vary significantly over the course of a single day or even come to a halt. Storage technologies are critical to surmount these reliability and continuity of service issues.

Currently, among the various storage technologies considered for renewable energy systems, batteries and hydrogen

[5] http://www.eomd.esa.int

conversion are forerunners (Roberts, 2004)[6]. Space companies and agencies have significant heritage in both of these storage technologies and experience ranging from building storage systems to safely operating hydrogen facilities.

Moreover, energy generation and storage will be on the agenda of space agencies as part of future space exploration missions which envision sustained human presence on other planetary bodies.

These needs create a window of opportunity for closer cooperation between space and energy sectors. Space agencies and companies can create value in the energy industry by transferring some of the existing know-how, and also seek ways to involve the energy industry in future space missions.

8. Conclusion

Renewable energy industry is a very dynamic and innovative sector of economic activity, and it is poised to play a more central role in the coming decades.

Some of our current capabilities in the space industry are directly relevant to the needs of the renewable energy sector, and a closer cooperation between these two sectors can create many synergies.

Although there are some examples of space projects related to renewable energy initiatives, there is still a lot of room for more involvement. Especially in the fields of energy storage and energy demand forecasting tools space can play a much more significant role.

References

Cooper, R.G. and Edgett, S. J., Product Development for the Service Sector: Lessons from market Leaders, Perseus Books, Cambridge, MA, 1999

Dunn, S., “Hydrogen Futures: Toward a Sustainable Energy System”, Worldwatch paper 157, Worldwatch Institute, Washington, D.C., 2001

Gurtuna, O., “New Energy Regime: Possible Roles for Space Technologies and Applications”, Proceedings of RAST 2005 Conference, Istanbul, Turkey, 2005

Hertzfeld, H., Williamson, R.A. and Sen, A., “Weather Satellites And The Economic Value Of Forecasts: Evidence From The Electric Power Industry”, Proceedings of the 54th International Astronautical Congress, Bremen, Germany, 2003.

Kammen, D. M., “The Rise of Renewable Energy”, Scientific American, September 2006

Mathieu, P.-P., “Eye in the Sky: Earth Observation from Space in Support of the Renewable Energy Sector”, reFocus, July/August 2005

Mathurin, J. and Peter, N., “Space Weather Information: Opportunity for Alternative Investments in Electricity Trading”, Proceedings of the 55th International Astronautical Congress, Vancouver, Canada, 2004

Nielsen, M., Astrup, P., Hasager, C. B., Barthelmie, R., and Pryor, S., “Satellite Information for Wind Energy Applications”, Research Report, R Risø National Laboratory, Risø-R-1479, 2004

Rifkin, J. The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth, Tarcher/Putnam, New York, NY, 2002

Riis, T., Hagen, E. F., Vie, P. J. S. and Ulleberg, Ø., “Hydrogen Production R&D: Priorities And Gaps”, International Energy Agency Publication, 2006

Roberts, P., The End of Oil: The Decline of the Petroleum Economy and the Rise of a New Energy Order, Bloomsbury Publishing Plc, London, 2004

Vaitheeswaran, V.V., Power to the People: How the Coming Energy Revolution Will Transform an Industry, Change Our Lives and Maybe Even Save the Planet, Farrar, Straus and Giroux, New York, 2003

[6] For more information on hydrogen production and storage, see Riis et al. (2006)