2015

Learning by Doing - Energy Systems Management

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Proceedings of the American Society for Engineering Management 2015 International Annual Conference
S. Long, E-H. Ng, and A. Squires eds.

LEARNING BY DOING - ENERGY SYSTEMS MANAGEMENT

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Abstract
Climate change concerns have confronted energy policy makers by unprecedented challenges in the 21st century. Revolution of renewable energy technologies, as well as more efficient energy systems, has been promising in the context of global warming. However, these technologies are not maturing and chaning. Consequently planning for development of these resources requires dealing with various multidisciplinary research questions such as financial feasibility of renewable energy projects. Nevertheless, there is considerable lack of education programs offering multidisciplinary approach for addressing the current energy challenges. Based on the 21st evolving energy landscape, an interdisciplinary graduate certificate course work was designed at Old Dominion University (ODU) in the Engineering Management & Systems Engineering Department. Likewise other engineering departments at ODU, this course was conducted through a hands on approach, by teaching updated decision making and project management tools and encouraging students use them in the real world problem. RETScreen software, which is a clean energy decision-making tool, was taught to the students and a photovoltaic project which was done at ODU, analyzed as students final project work. In this paper, we are going to summarize the results and conclusion of that project as learning by doing approach in our educational system.

Keywords
Energy Systems, Engineering Management, Phoovoltaic, RETScreen

Introduction
The debate on energy consumption and its consequences has been constantly evolving and spread over as one of the most important debates of our time (Bryant & Olson, 2009). Energy policy makers are confronted by unprecedented paradox, the negative consequences of fossil fuel combustion have never been clearer but oil and gas extraction is experiencing a technological revolution. Rapid growth of renewable technologies and on the other hand, long-term implications of fracking and carbon capture and sequestration (CCS) technologies that extent fossil fuel use has made practical limit of fossil fuel supplies under serious questions (Howarth, Santoro, & Ingraffea, 2011; Kriegler et al., 2014; Smith & Ferguson, 2013). These questions are important and at the same time so challenging to be answered. Multidisciplinary nature of current energy challenges requires combination of complex scientific, economic, and sociopolitical considerations (T. C. Kandpal & Garg, 1999).

The 21st energy challenges is evolving very fast into much more multidisciplinary issues while there is considerable lack of competent educational coursework in this regard (Tara C. Kandpal & Broman, 2014). An interdisciplinary graduate certificate course work was designed at Old Dominion University (ODU) in the Engineering Management & Systems Engineering Department. This course was designed to provide a big picture of energy issues covering cradle to grave of energy systems, including production options, distribution technologies, and consumption environmental consequences.

Discussions in this course started from energy policy issues, and gradually continued toward energy management and engineering tools. The goal of policy discussion was to enhancing systems thinking capability towards complex energy problems. Improving the understanding how technologies changes reality; energy supplies and energy use in energy uses have evolved in parallel throughout history, and dominancy of each energy technology continuously changes the rules of the energy market. More importantly, any energy system scale to the magnitude of future energy demand will bring its own unintended consequences; in other words, there is no free lunch.

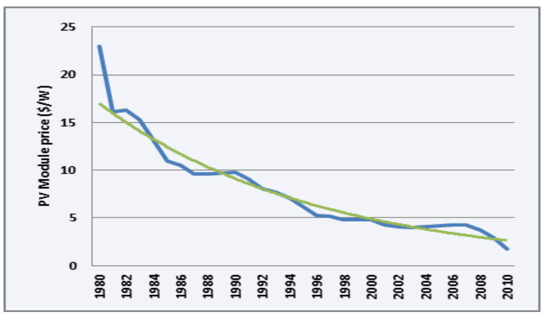
On the engineering discussions, new revolutionary technologies such as smart grids and hydraulic fracturing (fracking), were discussed. Interdependency of energy infrastructure was highlighted by reviewing some real cases such as blackout/brownout as well as cyber security issues. The ultimate aim of this course was to help students make better informed energy decisions, whether as a citizen, policy maker or energy professional. This course was offered both options of on- campus or online study to the students. By adopting learning by doing concept, we introduce students with two update software for managing energy projects. The Project Kickstart software were taught for project management issues and RETScreen was taught for analyzing feasibility of clean energy projects as well as greenhouse gas savings. Due to common hands on approach in our engineering school, we asked students to assess a real energy project using the tools as the course final project. An interesting case of installing 250 kilowatt of photovoltaic solar panels on the campus was assessed. In the following sections, we are going to present the tool, results and implications of our approach in energy education systems.

Case Study

Solar Energy

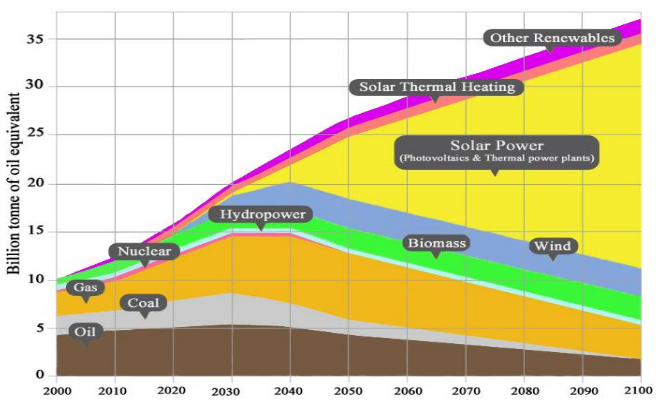
Over the last decade, solar energy as a clean energy recourse has experienced a drastic development followed by a considerable growth in quality and a sharp decline in the price (see Exhibit. 1). This prosperity was achieved by R&D investments of developed countries and simultaneous supportive policies such as feed-in-tariff (FIT) and renewable portfolio standards (RPS) (Kumar, 2015). Solar energy is the fastest growing source of renewable energy in the world and based on some scenarios, it would be the largest source of energy by the end of 21st century (see Exhibit. 2).

Exhibit 1 PV module price trend from 1980 to 2010 (Candelise, Winskel, & Gross, 2013).



Despite the rapid growth, these technologies are changing and maturing fast which makes investors wait for better technology in the market. Moreover, due to different geographical and economical situations, these technologies still cannot be economically competitive in the market in some cases. Consequently, a detail assessment, based on the solar radiation, costs, possible support, and right technology is necessary before investing on solar energy projects.

Exhibit 2. Long term forecast for solar portion of the global annual primary usage of energy (Wbgu, 2003)



Lesson Learned From ODU Photovoltaic Projects

Over the last 3 years, photovoltaic panels started to takeover Old Dominion University's rooftops by an innovative partnership with Dominion Virginia Power. These projects started as a smaller project on the roof of engineering building (Kaufman Hall) in 2012 and continued on the roof of Students' recreation center in 2014 with installation of 600 solar panels, which will generate approximately 125 kilowatts. That is enough to power 31 homes.

Exhibit 3. Views of the photovoltaic panels on the roof of Student Rec Centre at ODU.

The practical aspect of installing photovoltaic panels in public buildings such as university buildings is that, solar energy is being prodyced during the day and these public building mainly consume electricity during the day as well, mainly for airconditioning purposes. These projects I ODU were done as a demonstration that how solar energy can fit into electricity grid in the State of Virginia. However, due to existence of different types of solar panels (see Exhibit 4) and different way of installing them. In this project different type were analyzed for the Student Web Center at ODU using the RETScreen software.

Exhibit 4. PV technology improvement trends up to 2020 (Wbgu, 2003).

Criterion	PV technology	2007	2010	2015	2020
PV module efficiency range (%)	Concentrators	20	20-25	25-30	30-35
	Crystalline Si Cells	13-18	15-20	16-21	18-23
	Thin Films	5-11	6-12	8-14	10-16
	Organic Cells	4	7	13	18
Inverter lifetime (years)	Overall	10	15	20	>25
Module lifetime(years)	Overall	20-25	20-25	25-40	35-40
Energy pay-back time (years)	Overall	2-3	1-2	1	0.5

RETScreen

RETScreen is a very useful tool for analyzing the impact of the resource characteristics and financial conditions. It also allows the end user to determine the greenhouse gas (GHG) emissions of the proposed renewable energy project and the change in GHG emissions between the proposed project and another conventional source of power generation. The tool is very user friendly with many built-in renewable energy scenarios, allowing the user to determine impacts to equity payback, risk, and generation capacity in real time with minimal effort.

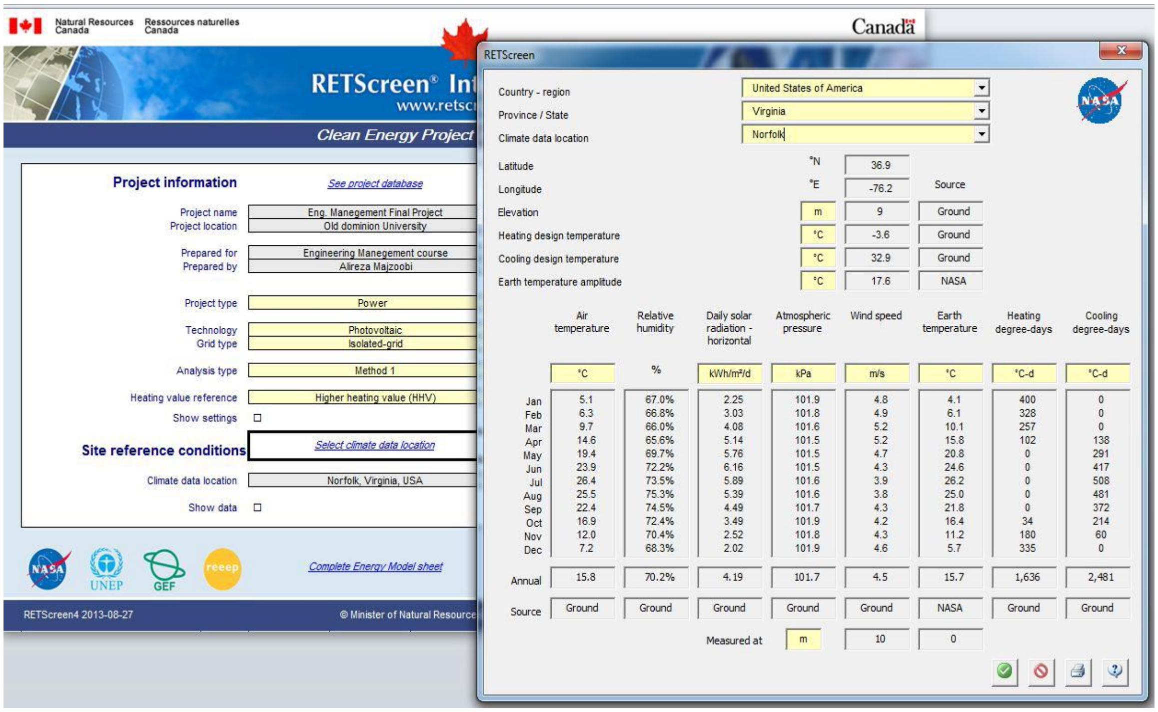
This software is being developed by Natural Resources Canada with aim of helping engineers to evaluate clean energy projects such as renewable energies and energy efficiency projects. RETScreen software has been used for educational purposes as well as professional ones (Tara C. Kandpal & Broman, 2014).

One of the main benefit of using RETScreen software is comparing different possible technologies with each other. For instane, there are different types of solar panels with difefferent performance in efficiency, however the more efficient ones are more expensive as well. So choosing the technology type depends on our usage. But, always there are some options that we can not easily compare, in those cases, RETScreen software clearly shows different financial specifications of each project.

In the following assessment, we have used RETScreen software as well as knowledge we learned from the former photovoltaic projects done before at ODU. We will illustrate the priocess of assessment, step by step through RETScreen softare.

Using the lessons learned from former projects at ODU, RETScreen also contains template for many renewable projects and additional case studies to allow the user to compare the proposed renewable project to other projects templates or actual projects completed. The initial project type is selected, "power," "heating," "cooling," etc (Government of Canada, n.d.).

Exhibit 5. Uploading site conditions in RETScreen.



The first step for energy modeling in RETScreen software is uploading specification of project. The project type is "power" and the technology is "photovoltaic". Considering that the generated power will not be connected to the grid, "isolatedgrid" has been considered for grid type. Also the site conditions should be uploaded in this step. RETScreen has a very powerful climate database and by clicking on "select climate data location", and searching and selecting of project location, site conditions are uploaded in our file. As Figure 4 depicts, Norfolk (where ODU located), has been selected as the location of project.

The next step is selection of photovoltaic type and vendor from RETScreen database. As Table 1 shows, there are different types of photovoltaic such as, mono-Si, poly-Si, a-Si and CIS which could be selected by user. In this project mono-Si technology has been considered for panels. By clicking on "See product database" panel manufacturer which exist in RETScreen database were selected, considering the range of efficiency is from about 6 percent till about 20 percent.

Exhibit 6. Some of solar panels manufacturers from RETScreen database.

Manufacturer	Capacity per unit	Frame area (m^2)	Efficiency
Aleo Solar	165	1.38	12 %
BP solar	220	2.12	10.39 %
Canadian Solar	150	1.28	13.09 %
Centennial Solar	10	0.13	7.81 %
China Sunenergy	300	1.94	15.49 %
Sharp	70	1.15	6.07 %
Suntech	240	1.65	14.55 %
Sunpower	320	1.62	19.6 %

The selection of PV module type depends on a number of factors, such as price from suppliers, product availability, warranties, efficiencies, etc. Sunpower has been selected for this project with 19.6 percent efficiency. Also another option which should be filled in by the user is the number of panels based on the required output power. 785 unit solar panels have been considered in this project to supply 250kW output power. Also the estimated cost of project is about 1250000 dollar.

After selection of manufacturer, "miscellaneous losses" is another parameter which should be filled in by user. The user enters array losses from miscellaneous sources not taken into account elsewhere in the model. This includes, for example, losses due to the presence of dirt or snow on the modules, or mismatch and wiring losses. Typical values range from a few percent to 15%. In some exceptional circumstances (e.g. very harsh environment) this value could be as high as 20%. Based on site condition, 2 percent has been considered for miscellaneous losses.

The next step is important data for inverter which should be completed by the user. Solar inverter (PV inverter) is an electrical equipment which converts the direct current (DC) output of photovoltaic (PV) solar panel into a alternating current (AC) that can be fed into a commercial electrical grid or used by a consumer. Efficiency of inverters are between 80% and 95%, although for modern types of inverters it hass been boosted till about 98 percent. Efficiency of inverter has been considered 95 percent in this project. Capacity factor is another parameter which represents the ratio of average power produced by the photovoltaic system over a year to its rated power capacity. Typical value for photovoltaic system capacity factor is from 15% to 20%. In this project 16.9 percent has been considered by RETScreen.

Emission analysis

As part of the RETScreen Clean Energy Project Analysis Software, an Emission Analysis section is provided to help the user estimate the greenhouse gas emission reduction potential of the proposed case. Results are calculated as equivalent tonnes of CO2 avoided per annum. In order to emission analysis the user should enter Greenhouse Gas (GHG) emission factor.

However, by selecting "the country – region" from the drop-down list, the user can use the RETScreen database for GHG emission factors. Transmission and Distribution (T&D) losses are not included in these factors and it is another parameter which should be entered by the user. The transmission and distribution (T&D) losses (%) includes all energy losses between the power plant and end user. This value will vary based on the transmission voltage, the distance from power plant to load, ambient temperature, peak energy demand and electricity theft. Also transmission and distribution system and quality of equipment may also influence losses. "T&D losses" which is asked in RETScreen software is percentage of all electricity losses to electricity generated. It is reasonable to assume 8 to 10% in modern countries and 10 to 20 percent in developing countries. As this project is located in the modern country as well as distance between generation and consumption is too short, 5 percent has been considered for the transmission and distribution (T&D) losses in this project.

As it was mentioned, by selecting country and region in the software, the software gives the amount of GHG emission factor excluding transmission and distribution (T&D) losses. Also the software calculates the GHG emission factor for the selected project based on GHG emission factor (excl. T&D) and the T&D losses entered by user. The result of emission analysis for this project shows annual Greenhouse gas emission reduction is equal to 203 tCO2, which is equal to:

- 37.1 cars and light trucks not used.
- 87125 litres of gasoline not consumed.
- 472 barrels of crude oil not consumed.
- 203 people reducing energy use by 20%.
- 46.1 acres (18.6 hectares) of forest absorbing carbon.
- 69.9 tonnes of waste recycled.

Financial analysis

One of the primary benefits of using the RETScreen software is its financial analysis part which facilitates the project evaluation process for decision-makers. RETScreen required some financial parameters as input such as, inflation rate, debt ratio, debt interest rate, etc. Then the software calculate financial viability output items such as, internal rate of return, simple payback, equity payback, etc. which allows the project decision-maker to have a better view and decision about the project. The inflation rate, which is the projected annual average rate of inflation over the life of the project, should be entered by the user. The inflation rate estimation for the next 25 years in North America is between 2 and 3%. Thus in this project 2.5 percent has been considered for inflation rate. The user enters the project life, which is the duration over which the financial viability of the project is evaluated. Project life of this project has been considered 25 years. In addition, 50 percent debt ratio with 2.5 percent interest rate and 15 years debt term have been considered for the project.

Financial incentives are the other parameter which should be entered by the user in this section. Feed-in tariff (FIT) is the incentive program for renewable energy which has been applied in this project. Feed-in tariff (FIT) is policy mechanism designed to accelerate investment in renewable energy technologies. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. In Virginia, state pay 15 cents/kWh for a contract term of five years for all PV-generated electricity provided to the grid, and will continue to pay the retail rate for all electricity that they consume. Based on U.S. Energy

Information Administration (eia), the retail rate for electricity in Virginia is 12.08 cent in 2014 (“EIA - Electricity Data,” n.d.). In continue financial analysis has been done for three cases with different conditions to consideration effect of different panel technology and various financial input parameters in financial output parameters.

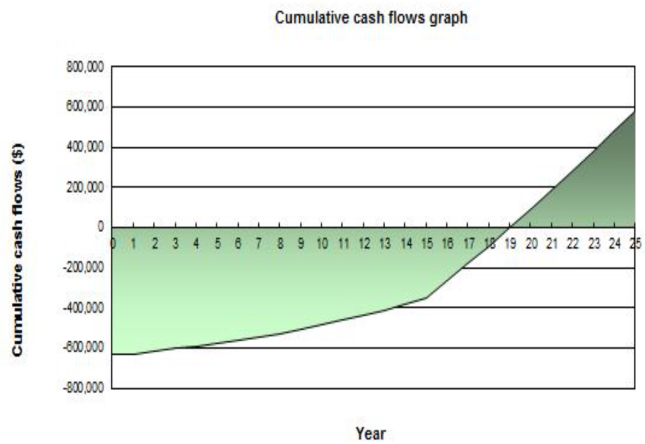
Case one

In the first case we analyze fixed solar panel as the type of installation. The most efficient degree for fixed installation in the determined geographical location for the project which is Old dominion University is 30 degree. Inflation rate is determined in average of 2.5% and project life for 25 years. The following are the input parameters based on the state of Virginia over the period of the project:

- Installation type of panels: Fixed (30degree)
- Inflation rate: 2.5 %
- Project life: 25 years
- Debt ratio: 40%
- Debt interest rate: 2.5 %
- Debt term: 15 years
- Incentives: 15 cents/kWh, Electricity export rate

The financial output of the RETScreen software for case one determines 19 years as the equity payback period for this case. In this case, the pre-tax-IRR-equity would be 3.8% and pre-tax-IRR-assets would be -0.2%.
Exhibit 7 depict the financial payback period of the case one.

Exhibit 7. Financial payback period of the case one.



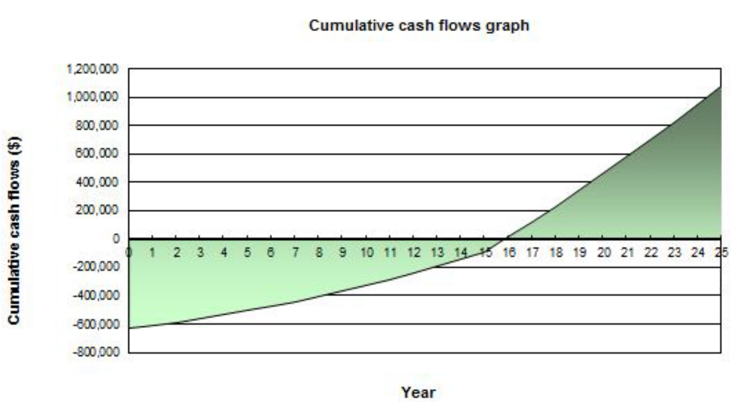
Case two

In the seccond case we analyze one axis solar panel as the type of installation. One axis solar panels have the capability of following the sun during different hours of the day. Obviously this technology is more efficient in terms of producing more electricity per each panel but more expensive installation type that the fixed solar panel. The only difference between these three cases is the installation type which affect cost and efficiency. Thus other input parameters are the same as following:

- Installation type of panels: one-axis
- Inflation rate: 2.5 %
- Project life: 25 years
- Debt ratio: 40%
- Debt interest rate: 2.5 %
- Debt term: 15 years
- Incentives: 15 cents/kWh, Electricity export rate

The financial output of the RETScreen software for case two determines 15.9 years of equity payback period. In this case, the pre-tax-IRR-equity would be 6.6 % and pre-tax-IRR-assets would be 1.9%. Comparing with the first case. Case two is financially better project to invest on. However, two axis technology is the most efficient one which is analyzed in the case three. Exhibit 8 depict the financial payback period of the case two.

Exhibit 8 Financial payback period of the case two.



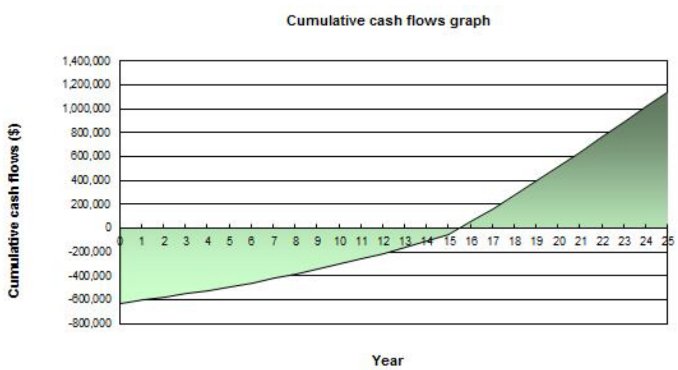
Case three

In the third case we analyze two axis solar panel as the type of installation. Two axis solar panels have capability of following sun in every possible directions. Needless to say when the solar radiation hits directly the solar panel surface, the maximum amount of electricity is being produced. Thus two axis type of installation has the capability of producing the maximum amont of electricity that a solar panel can produce. Other input parameters of the case three, is similar to previous two cases as the following:

- Installation type of panels: two-axis
- Inflation rate: 2.5 %
- Project life: 25 years
- Debt ratio: 40%
- Debt interest rate: 2.5 %
- Debt term: 15 years
- Incentives: 15 cents/kWh, Electricity export rate

The financial output of the RETScreen software for case three determines 15.5 years of equity payback period for this project. In this case, the pre-tax-IRR-equity would be 7% and pre-tax-IRR-assets would be 2.1%. Results of financial analysis demonstrate that two axis solar panel has a shorter payback period but require higher initial investment. On the other hand Fixed solar panel is cheaper to start but require longer time to get paid back. Exhibit 9 depict the financial payback period of the case three.

Exhibit 9. Financial payback period of the case three.



Conclusion

Energy education is a certain need dealing with current evolving energy landscape, especially dealing with diversification of renewable energy technologies. More importantly, having learning by doing approach in teaching energy issues and avoid of just discussing at the class, can help students enhance their learning capabilities. Photovoltaic energy is a stepping-stone for powering the United States of America for its energy needs in long time. However, dealing with variety types of panels, economic and geographic situation has made decision making on feasibility of these project a very hard task to accomplish. RETScreen as a very user-friendly software were introduced in this paper and highly recommended for analyzing renewable energy projects. This software can pave a way to make decision making for renewable energies an easier task, which can facilitate development of these technologies in feasible geographic and economic situation. Three cases for Old Dominion University analyzed by students as final project of the course using RETScreen software. Based on the three cases studied done for Old Dominion University, two axis solar panel is recomended for the type of installation.

References

Bryant, S., & Olson, J. (2009). Training carbon management engineers: why new educational capacity is the single biggest hurdle for geologic CO2 storage. *Energy Procedia*, *1*(1), 4741–4748. http://doi.org/10.1016/j.egypro.2009.02.299

Candelise, C., Winskel, M., & Gross, R. J. K. (2013). The dynamics of solar PV costs and prices as a challenge for technology forecasting. *Renewable and Sustainable Energy Reviews*, *26*, 96–107. http://doi.org/10.1016/j.rser.2013.05.012

EIA - Electricity Data. (n.d.). Retrieved June 7, 2015, from http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

Government of Canada, N. R. C. E. S. C. E. T. C. – V. Rets. I. (n.d.). RETScreen International What is RETScreen? Retrieved from http://www.retscreen.net/ang/what_is_retscreen.php

Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change*, *106*(4), 679–690. http://doi.org/10.1007/s10584-011-0061-5

Kandpal, T. C., & Broman, L. (2014). Renewable energy education: A global status review. *Renewable and Sustainable Energy Reviews*, *34*, 300–324. http://doi.org/10.1016/j.rser.2014.02.039

Kandpal, T. C., & Garg, H. P. (1999). Energy education. *Applied Energy*, *64*(1-4), 71–78. http://doi.org/10.1016/S0306-2619(99)00076-8

Kriegler, E., Weyant, J. P., Blanford, G. J., Krey, V., Clarke, L., Edmonds, J., … van Vuuren, D. P. (2014). The role of technology for achieving climate policy objectives: Overview of the EMF 27 study on global technology and climate policy strategies. *Climatic Change*, *123*(3-4), 353–367. http://doi.org/10.1007/s10584-013-0953-7

Kumar, B. (2015). A study on global solar PV energy developments and policies with special focus on the top ten solar PV power producing countries. *Renewable and Sustainable Energy Reviews*, *43*, 621–634. http://doi.org/10.1016/j.rser.2014.11.058

Smith, M. F., & Ferguson, D. P. (2013). "Fracking democracy": Issue management and locus of policy decision-making in the Marcellus Shale gas drilling debate. *Public Relations Review*, *39*(4), 377–386. http://doi.org/10.1016/j.pubrev.2013.08.003

Wbgu. (2003). *Climate Protection Strategies for the 21st Century. Kyoto and Beyond*.

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