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Book Review: Renewable Energy and Energy Efficiency: Assessment of Projects and Policies

Duffy, A., Rogers, M. & Ayompe, L. (2015). Renewable Energy and Energy Efficiency: Assessment of Projects and Policies. West Sussex, UK: 261 pages. ISBN: 9781118631041.

This book provides the analytical tools, based on financial and non-financial criteria, to systematically evaluate the important renewable and efficient energy technologies. It is written as a practical textbook at the M.Sc level or final year B.Sc level to train economists and other analysts in both individual project appraisal and the larger scale assessment of energy policy. This book could be used as stepping stone for students whose ultimate objective is the pursuit of a Ph.D.

The accurate assessment of alternatives if essential to optimal decision making. This book summarizes the various renewable energy and energy efficiency technologies, modeling approaches, and financial and non-financial analyses that lead to optimal decisions. It constitutes a comprehensive approach to evaluation, essentially a step-by-step methodology that can and should be applied to energy related decisions. The book has six chapters, each focused on a specific part of the evaluation process.

Chapter 1: Introduction

In this chapter the authors offer the rationale for a systematic approach to evaluating renewable energy and energy efficiency projects and policies. A consistent, comprehensive assessment system is required because these types of projects/policies are becoming more important in the energy sector for two reasons. First, the high cost of traditional fuels, which the author's project to increase in price over time, and second, the need to reduce greenhouse gas (GHG) emissions.

Unfortunately, the authors failed to anticipate recent price reductions for many commodities. For example, the price of oil has declined from above $100/bbl ($100/barrel) in 2013 to below $30/bbl today (early 2016) while the price of natural gas has dropped approximately 75% in the last five years. Further, the general expectation is that traditional fuel prices will remain low for the foreseeable future. And as natural gas prices have fallen, natural gas has been substituted for coal in power production, resulting in a significant reduction in the emissions of greenhouse gases.

Chapter 2: Technologies

In this chapter the authors provide technical and economic details on every conceivable renewable energy system. The range of technologies examined is quite impressive. Direct generation of electricity using the traditional fossil fuels, hydropower, wind power, ocean energy, and photovoltaics is considered initially. Each technology is described, with historic usage levels and key financial and technical characteristics listed. Heat generation (fossil-fueled boilers, solar hot water), combined heat and power or CHP (Micro-CHP, CHP engines, CHP turbines), and energy storage (electrical, pumped hydroelectric, compressed air) options are also described in substantial detail. Finally, some energy efficiency options (thermal insulation, high efficiency lighting) are considered.

The work in this chapter is really well done and is essential in moving to the next step, which is the modeling of the alternative energy systems.

Relatively small concerns with this chapter include: (1) designating all monetary units in euros rather than US dollars; (2) the relative small energy efficiency section that omits many possible programs that could be summarized (e.g., commissioning, retro-commissioning, industrial processes, behavior changes related to energy use comparisons, etc.); and (3) the lack of consideration for potential interactive effects of policies (e.g., higher efficiency lighting might lead to increased use of heating).

Chapter 3: Modeling Energy Systems

In chapter three the authors focus on system analysis (inputs and system behavior is known), system design (determining components, configuration, sizing, and operation of a system that meets certain requirements), and system optimization. The systems analyzed are primarily deterministic, dynamic system models; thus, uncertainty analysis is minimized although some sensitivity analysis (i.e., the effects of changes in input variables and parameters) and scenario analysis (i.e., plausible future environments) are discussed. Note that more sophisticated analyses such as Monte Carlo analysis is excluded. System design examines alternative design solutions whereas system optimization is finding the best system performance with respect to desired objectives.

Energy modeling, developing a flow diagram, creating energy input/output data, analyzing model results, and optimization are summarized expertly in Example 3.3, which is concerned with the installation of attic insulation in a residential building.

The remainder of the chapter is devoted to the simulation of energy systems. The wind farm example is designed to both demonstrate simulation modeling and to illustrate various simulation errors. This example assumes readers have extensive knowledge and could be improved with a more detailed discussion of the relative importance of each measure of error and how these measures are used for decision-making.

Also, the discussion of simulation tools seems nearly irrelevant because the book does not include either an example or a case study using one of the simulation software programs.

The chapter concludes with three simulation examples (Office PV System[1] , gas heat pump, and compressed air energy system). These examples are basically well constructed and include all the elements for effective decision making. After working through the examples I offer the following two comments.

First, the office PV system graphs (3.17 and 3.18) do not seem to be a representative of the entire year long simulation. The graphs indicate that approximately one-quarter of demand is offset by the PV system where in reality the figure is closer to 15%. An **"**average day**"** should be represented in the graphs and some discussion of the range of results would be relevant. Specifically, some days the solar system exports zero to the grid. The minimum half-hour export value is zero and the maximum one-half hour value is 6.579 kWh. Also note that the **"**average day**"** has mean one-half hour consumption of 5.91 kWh, with mean one-half hour avoided imports of 0.821 kWh (note 0.821 is about 14% of mean usage), and mean one-half hour exports of 0.107 kWh. This system seems under-sized and there should be some discussion of alternative sized systems (i.e., sensitivity analysis, optimization).

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[1]A photovoltaic (PV), or solar electric system, is made up of several photovoltaic solar cells.

Second, the gas heat pump and compressed air energy system examples are somewhat confusing because of the direction of the arrows (inputs v. outputs). In addition, it would be helpful if the results were compared to alternatives and be subject to sensitivity analysis and scenario analysis (e.g., negative cash flow values dominate the compressed air system – only two compression/generation combinations yield positive value out of sixteen possibilities) since the options seem quite fragile.

Chapter 4: Financial Analysis

In this chapter, which is really the centerpiece of the document, the authors summarize almost every conceivable financial metric applicable to the evaluation of energy projects/policies. These include net present value (NPV), levelized cost of energy, savings-to-investment ratio, alternative payback periods, return on investment, internal rate of return, and life cycle cost. In addition, the authors examine a host of complicating factors such as nominal v. real prices, present value, discounting, cost of capital, taxation and depreciation, and unequal project lives. Each metric and complicating factor is defined and a simple-to-follow numerical example provided. Overall, the examples and case studies are very informational, although quite dense in the details (i.e., they takes some real thought to work through).

Issues include the following.

First, the order of presentation is somewhat uncommon. Net present value (NPV) is the most widely accepted evaluation method and probably should really be the focus of the chapter. Rather the authors introduce the treatment of specific issues (real v. nominal, discounting, taxation and depreciation, unequal project lives) and a variety of other financial measures (payback, return on investment, profitability index, and savings-to-investment ratio) before introducing NPV. This leads the reader to fail to understand the relative advantages of NPV until the summary section at the end of the chapter.

Second, the ranking of projects is more complicated than described in this chapter as there may be sequencing or divisibility issues that reduce the overall benefit to the investor. That is, ranking projects and proceeding from the best to the worst until the budget is exhausted may not provide the greatest possible benefit

Third, the suggestion that for individuals **"**a typical discount rate of 20% is suggested for energy-related investments**"** seems inconsistent with alternative investments available to individuals (passbook savings accounts, stock market returns, etc.) and may be reflective of survey errors.

Fourth, page 98 contains a strong statement regarding the impacts on nearby of landowners and households of transmission lines. This statement goes well beyond the literature (see Jackson and Pitts, 2010).

Fifth, the equivalent annual cost does not provide any additional information not contained in NPV. In addition, the least common multiple method seems less than useful and further, extending the analysis can affect the results. In the example provided (Example 4.10) Project A dominates for very low discount rates (less than about 4%) whereas Project B dominates for discount rates above about 4%. If one extends the analysis to 30 years to achieve the least common multiple, then Project B dominates for all positive discount rates.

Sixth, in the case study (Municipal Bus Fleet Conversion to Compressed Natural Gas) the language regarding the fuel efficiency is confusing. The text states that fuel efficiency of the diesel bus is 45 km/100 l. This suggests that it takes 100 liters of diesel to go 45 km. In fact, it means that each km travelled uses 0.45 liters of fuel or 100 km requires 45 liters of fuel. Note the equivalent miles per gallon (MPG) give the number of miles that can be driven on one gallon, not the number of gallons it takes to travel one mile.

Chapter 5: Multi-Criteria Analysis

This is where the authors take a detour. After presenting the financial criteria for optimal decision making, the next logical step would be to broaden the analysis to include aspects that were not the exclusive domain of the individual decision maker (e.g., external effects, valuation of non-market goods, non-use values, etc.). That is, social benefit-cost analysis was the obvious next topic to be the discussed. However, the authors chose to present a variety of multi-criteria decision methods.

The objective of the multi-criteria models is to include project/policy attributes that are not included in the standard financial analysis. However, most of these methods require a common unit of measurement (i.e., a scale) and a decision rule that is often subjective (e.g., decision maker weighting) or sub-optimal, relative to an accurate social benefit-cost analysis. For example, the basic lexicographic system may yield one answer whereas lexicographic semi-order might give a different answer for the same basic information set. In effect, these simple methods over-ride the multi-criteria situation with a simple rule, basically ignoring the situation.

Overall, the material in this chapter, while interesting reading, seems to make decisions more complex and less understandable (i.e., confusing) since there is no apparent rule that makes one method better than another. The general consensus is that social benefit-cost analysis is the best evaluation system and it seems that these multi-criteria decision models provide relatively limited (or no) information that is not included in a social benefit-cost assessment. That is, in benefit-cost analysis all criteria are converted to cash equivalents (common unit) and prices (or price equivalents) are used to reflect relative scarcity. For example, one is trying to minimize land use then the corresponding relative land price will reflect the relative scarcity of land.

Chapter 6: Policy Aspects

The key sentence of this chapter is on page 209: **"**All policies should be subject to this (Social Cost-Benefit Analysis) analysis.**"** This leads to two questions. First, if that is the case then why do the authors focus so much attention to relatively limited appraisal methods such as the multi-criteria decision analysis or MCDA? Second, if social benefit-cost analysis is so important then why not expand the discussion of the issue?

For example, the sections on revealed preference and stated preference methods for determining the value of non-market goods are very brief. The word **"**hedonic**"** appeared in the book only one time (page 234) and was not even mentioned in the index (for summaries of hedonic studies related to environmental issues see, for example Simons and Saginor, 2006; Boyle and Kiel, 2001; Sirmans, et al, 2005; and Jackson, 2001). Also, there have been some very recent hedonic studies that are especially important to the evaluation of renewable energy projects (see Atkinson-Palombo and Hoen, 2014; Carter 2011; Gibbons, 2014; Heintzelman and Tuttle, 2012; Hinman, 2010; Hoen, et al, 2011; Lang, Opaluch, and Sfinarolakis, 2014; Jensen, Panduro, and Lundhede, 2014; Municipal Property Assessment Corporation, 2012; Sunak and Madlener, 2012; Hoen, et al, 2013; Hoen, et al, 2015). Also, the book missed entirely on stated preference methods (see Hanneman, 1994; Portney, 1994; Carson and Mitchell, 1989) and non -use values.

Overall Evaluation

The book has much to recommend it. Specifically, the overviews of renewable and energy efficient technologies and system modeling/simulation are great. And the financial analysis is comprehensive and provides the reader with all relevant evaluation methods, including excellent examples and case studies. Finally the writing style, essentially workbook-like wherein concepts are defined and demonstrated makes for an excellent textbook.

On the flip side, the book offers relatively too much information on relatively unimportant methods (e.g., 50 pages on multi-criteria decision models) and relatively too little information on methods that are really consequential, such as social cost-benefit analysis. In addition, I would have preferred some additional examples on everyday task oriented decisions like lighting (changing out light bulbs – LED for incandescent or compact fluorescent), individual space comfort (space heater at 1000 – 1500 watts for a confined area or a central natural gas furnace), or celebrating the holiday season (old style Christmas tree bulbs or LED). Additionally, I would have liked to see a discussion of interactive effects

Finally, there remain some typographical errors and errors of omission. A sampling would include

- Equation 2.26 is missing the L subscript.
- Page 140, maintenance cost of CNG buses is 10850, not 8530.
- The Transmission use-of-system charge is give as 4 /MWh but Table 3.14 uses 3 /MWh.
- Some of the examples are missing relevant information (e.g., example 4.11 – capacity factor; example 4.15 – capacity factor; example 4.18 – project life).

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