A graduate level course on economic metrics and innovative finance mechanisms for wind

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Abstract. A graduate level course on economic metrics and innovative finance mechanisms for wind energy has been developed. Topics include non-traditional financing structures for project development and the application of economic metrics to investment decision making. The development of this course was motivated by recent surveys and through consultation with wind energy professionals. Recent surveys have indicated that highly qualified persons entering renewable energy fields are lacking knowledge of the technical, economic, and policy-connected aspects of their work. Synthesis of these discussions, which have guided the development of course content, highlighted that an understanding of market policy and project economics would greatly enhance the efficacy of energy technical professionals. The purpose of this course is to develop holistically equipped wind energy professionals who can intelligently engage with business and finance professionals in their field. Both live instruction and online versions of this course intend to provide this knowledge through application-based lectures and case studies to set graduates of this course apart from their peers. Course delivery, topics, learning outcomes, and evaluation methods are provided.

1. Introduction
Wind energy education has traditionally focused on engineering aspects of wind power systems including aerodynamic analysis, mechanical design, support structure design, wind field analysis, system concepts and analysis. While these skills are critical, it is becoming increasingly important that professionals in the sector be knowledgeable on the economics and financing structures surrounding project development and investment decision making. Securing financing for wind energy development projects is a prerequisite for increasing their utilization in energy supply. Part 1 of this proposed course will focus on non-traditional strategies that have emerged as financing mechanisms in the energy sector, such as public capital vehicles [1], carbon revenue bonds [2], community co-ops [3], and crowdfunding [4]. The way in which energy is procured is also undergoing transformation [5]. Non-utility procurement of energy by large corporations is one example that will be presented in this course [6]. Part 2 of the course will focus on the application of economic metrics to investment decision making. Specifically, net present valuation (NPV) and levelized cost of energy (LCOE) concepts will be taught and applied to project-based work.

The development of this course was motivated by recent discussions and collaborations through the Climate Led Energy Evolution Network 2040 (CLEEN2040). This network is a connected group of stakeholders that includes international universities, businesses, and government agencies with a vested interest in the future of energy systems. Wind energy developers and professionals compose a significant proportion of the network with representation from Kruger Energy, Enbridge, The Wind...
Energy Institute of Canada (WEICan), and others. A recent CLEEN2040 energy sector skills and experience study that suggested that the evolving energy sector could benefit from flexible highly qualified persons (HQP) that have a broad and credible knowledge of the technical, economic, and policy-connected aspects of their work. Through conferences, workshops, meeting events and calls, more than 200 participants were engaged. The results of which were synthesized in an emerging study. A review of Figure 1a. suggests that of the pool poled, less than 10% felt that current HQP were adequately prepared for energy sector entry. Soft skills were cited as a major deficit. Technical skill application was also underscored as an area requiring further development. Figure 1b. emphasized the critical need for effective communication skills (40%) across the energy workplace. This was followed by a need for employee flexibility (27%). The results resonated with comments from study participants. Steve Ray of Essex Energy remarked, “Engineers that can write a good technical report are few and far between”. JJ Davis of Kruger Energy commented, “Understanding even basic implications of market policy and project economics would greatly enhance the efficacy of energy technical professionals”. This aligned well with a comment from David Arkell of 360 Energy, “Energy is no longer a strict engineering field, it requires engineering, plus business, plus finance, to succeed”. Energy professionals stressed that an understanding of market policy and project economics would greatly enhance the efficacy of energy technical professionals.

![HQP Preparation Adequacy on Energy Sector Entry](image1)

![Desirable Qualities For HQP Entering Energy Sector](image2)

Figure 1. Highlights of CLEEN2040 Energy Sector Skills and Experience Study.

Outcomes from the YR21 Investment Decision Support for Commercial Wind further motivated this development. This project is a collaboration between two universities and three industrial partners with substantial wind farm assets. Involvement in this project provided insight into the critical factors that enable operations, beyond technical assessments, which motivated this course development. In this collaborative multidisciplinary project, economic metrics were applied to inform owners on the preferred course of action for investment in their assets. LCOE concepts were also applied to evaluate lifetime extension options. These are simple, yet powerful, metrics and this course will aim to make them accessible to a wider stakeholder group.

This course will offer in person and online options for students, along with guest lectures from industry professionals. Case studies and a final project will be used for evaluation. The objective of
the course is to educate students on the economics of project development and investment decision making for wind energy so that they can engage and inform all aspects of wind energy projects including contract components and evaluation of repair investment options. The use of economic metrics requires operators to be more familiar with the characteristics of the operating and financial targets which will ultimately, enable better management and investment decisions.

2. Method of Defining Course Content
Based on the surveys discussed above and involvement with the YR21 project, topics were selected to cover the spectrum of project finance and economic metrics that are relevant to wind energy. It is critical for HQP to be exposed to real case studies and to understand the realities of wind farm operations, and for this reason, guest speakers will deliver a portion of the lectures for this course. Guest speakers from the Wind Energy Institute of Canada (WEICan) and Kruger Energy have confirmed participation. A live instruction and an online version of the course will be available to increases HQP access to the course. The course is intended to be a component of the CLEEN2040 Certificate program, however, can also be taken as an option for students in any M.A.Sc. stream. Both versions will include interactive lectures, influential guest speakers, case studies, and a final project. Case studies were selected to improve critical thinking and communication skills which were identified as desirable qualities for HQP entering the energy sector. Topics will include: Levelized Cost of Energy (LCOE), Net Present Valuation – Application to Investment Decision Making, Power Purchase Agreements, Economic Considerations in the Context of Lifecycle Extension for Wind, and Innovative Finance and Procurement Mechanisms.

3. Course Content
The course will be offered as both live instruction and online options. Both options will consist of 36 hours of instruction and will include guest speakers, case studies, and a final project. The course will begin with 6 hours of introduction, followed by 15 hours of Part 1 and 15 hours of Part 2, all described in detail below.

3.1 Introduction
This section will introduce students to the key concepts surrounding renewable energy project finance and the importance of considering economic metrics in decision making. The following topics will be covered:
Renewable energy project finance – key concepts & definitions
- What is project finance and why is it necessary?
- Basic premise and parties involved.
- Characteristics of renewable project finance structures.
- Tax incentives, Renewable Energy Credits (RECs).
- List and discuss relevant definitions.

Levelized cost of energy (LCOE) – key concepts
- LCOE equation.
- CAPEX components.
- OPEX components.
- Discounting revenue and annual energy production (AEP).
- LCOE of wind compared to other generation types.
- LCOE – what does it mean?

Following the introductory lectures, the students will complete Case Study 1. This case study will present characteristics of a farm that is being developed and require that the students calculated the
LCOE based on variables including capital costs, operating costs, interest rates, nameplate capacity, capacity factors, etc.

3.2 Part 1 – Innovative Financing Mechanisms for Renewables
The next section of the course will focus on innovative financing for renewables. High capital costs and long payback periods require most projects to secure financing for a portion of the initial costs. Market-based incentives and policies can be credited with lowering development costs, but these come with uncertainties and expiration dates. To secure financing, project developers have turned to innovative mechanisms. This section of the course will present case studies of innovative financing for renewable energy development in North America. Examples include financing through public capital vehicles, hybrid and carbon bonds, and through corporate power purchase agreements. Specific topics will include:

**Financing through public capital vehicles**
- Benefits of availability of public market capital to the RE industry.
- Function of a public market vehicle.
- Case Study: Topaz Solar Farm, California

**Financing through hybrid bonds**
- Advantages of a pooled portfolio over single financing approaches.
- Optimizing risk-reward portfolios.
- Barriers to practical implementation.

**Financing through carbon revenue bonds**
- Carbon revenue bonds as a complementary financing tool to raise capital for initial costs.
- Factoring in uncertainty surrounding future environmental credit prices.
- Case Study: Blackspring Ridge Wind Project, Alberta Canada

**Community wind**
- Drivers, benefits, and challenges of community wind.
- Overview of applicable financing structures including municipal wind, co-operatives, private placements, flip structures, utility-sponsored, special purpose entity, non-profit, others.
- Case Study: Millbrook Community Wind and Truro Heights Community Wind Projects, Nova Scotia

**Non-utility power purchase agreements**
- Contract structure.
- Recent momentum in the U.S.
- Virtual PPAs.
- Benefits for developers and corporations.
- Aggregate deals.
- Case Study: Google

At the end of Part 2 of the course, students will be required to complete Case Study 2. This case study will require students to develop a term sheet between a corporation and developer based on a number of specified inputs such as capacity, availability, environmental attributes, curtailment, etc.

3.3 Part 2 – Economic Metrics for Investment Decision Support
The levelized cost of energy (LCOE) is a commonly applied economic metric that enables quick comparison of the costs of energy generation technologies. Slight variations in LCOE calculations are
provided, however, generally this metric is a ratio of the present value of total costs ($) divided by the present value of all energy produced over the project lifetime (MWh). LCOE values can also be calculated to inform lifetime extension decisions. Rather than the capital costs of asset acquisition and installation, the initial costs for extension would include retrofits and replacement costs as well as the sunk costs associated with technical assessments to determine the remaining useful life of the assets. The net present value (NPV) metric can be used to compare repair / replace options when faced with unanticipated failures during operation. This section of the course will present the metrics discussed above and will provide relevant case studies to illustrate their application to representative wind farms in North America. Specific topics will include:

**Levelized cost of energy for extensions (LCOE\textsubscript{EXT})**
- How does the LCOE\textsubscript{EXT} differ from the original LCOE?
- CAPEX\textsubscript{EXT} components
- Valuing extension related activities such as visual inspections, non-destructive testing, review of SCADA and maintenance logs plus the costs of any repairs or retrofits.
- Assumptions and sensitivities.

**Contingency budgets**
- What’s left over (i.e. PPA price – LCOE\textsubscript{EXT})?
- Referring to contingency budget for quick repair / replace decisions.

**Net present value of farm**
- Calculating the NPV of a wind farm.
- Using NPV to compare investment options and separate various practical scenarios by their economic feasibility.

**Post PPA Options**
- Extend the original (utility) contract.
- Enter into new (non-utility) contract.
- Sell to the open market.
- Sell assets.
- Decommission farm.

At the end of the Part 2 lectures, students will complete Case Study 3. This final case study will require students to make an informed decision as to whether or not an operational wind farm should consider extending their PPA based on identification of necessary repairs / replacements, operating characteristics and proposed PPA terms.

4. **Learning Outcomes and Course Evaluation**

At the completion of the course, students will be able to:
- Differentiate, select, and apply relevant wind energy finance metrics including net present value and levelized cost of energy (LCOE) to simple investment decision analysis.
- Design PPA terms to align with the LCOE for a project.
- Evaluate feasibility of lifetime extension options for wind farm operations.
- Select appropriate project development funding structures based on project specific criteria.

Students will be evaluated based on submission of three case study exercises (15% each), a midterm exam (20%) and a final project (35%). Final projects will be proposed by the students and must include project development and investment decision analysis components.
5. Conclusions

A novel graduate course in wind energy economics and innovative project finance has been developed to equip graduate students with critical skillsets. While technical skills are very important to those working in the wind industry, it is also critical for wind energy professionals to understand project financing aspects and relevant metrics surrounding investment decision support and lifetime extension considerations. An overview of energy project finance basics will teach students the key terms and considerations. Next, innovative mechanisms will be discussed to make students aware of the mechanisms that are available to enable wind farm development and increase wind energy supply. The course will then focus on presenting and evaluating relevant economic metrics such as the LCOE and LCOE_{EXT}, contingency budgets, and NPV. Throughout the lectures on these, case studies will be presented to increase the understanding of the applications of these to wind energy investment decisions. Overall, this course will result in the development of holistically equipped wind energy professionals who can intelligently engage with business and finance professionals in their field.

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