# THE ENVIRONMENTAL IMPACT EVALUATION OF A WIND FARM IN VIETNAM

**TRONG QUYNH NGUYEN**

**Faculty of Engineering and Information Technology**

**University of Technology, Sydney**

**A thesis submitted to the University of Technology, Sydney in fulfillment of the requirements for the Master Degree (Engineering)**

**2014**

**Certificate of Authorship/Originality**

I certify that the work in this thesis has not been previously been submitted for a degree, nor has it been submitted as part of the requirements for a degree, except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and preparation of the thesis itself has been acknowledged. In addition, I certify that any information sources and literature used indicated in the thesis.

Signature of Candidate

**Acknowledgement**

I would like to express my great gratitude to the people who have supported me over my Master course. Firstly, I sincerely thank to my supervisor A.Prof. David Dorrell for his guidance and encouragement. His insights into the problem, review of material and support throughout my graduate program are appreciated.

The Faculty of Engineering and Information Technology (FEIT) provided financial support for the last year of my study, for which I am graceful. I would also like to express my appreciation to the assistance from the Research Degree Office of the Faculty Engineering and Information Technology.

I also would like to give my special thanks to the NhaTrang University (NTU) and the Ministry of Education and Training (MOET) Vietnam, where I received scholarship and encouragement from colleagues for my study.

A special note of gratitude goes to Graham Alliband - Team Leader of the Australian Scholarships for Development in Vietnam (ASDiV);

To my family, I thank so much for the incredible support you given me during my study. I am sincerely graceful to my parents, especially thanks to my wife Kim Dzung Nguyen, who supported me for proofreading and caring in my finalizing phase and all my family members for their words of encouragement throughout my candidature.

# Table of content

# List of tables

# List of figures

# Abbreviations

| | |
|---|---|
| LCA | Life Cycle Assessment |
| RECTERE | The Research Centre for Thermal Equipment and Renewable Energy |
| US EPA | United States Environmental Protection Agency |
| $ | United States dollars |
| AC | Alternating Current |
| AP | Acidification potential |
| CF | Capacity factor of wind farm |
| $CH_4$ | Methane |
| CO | Carbon oxide |
| $CO_2$ | Carbon dioxides |
| DFAG | Doubly Fed Asynchronous Generator |
| DFIG | Doubly Fed Induction Generator |
| EIO-LCA | An economic input-output analysis based LCA |
| EIO-LCA | An economic input-output analysis based Life Cycle Analysis |
| EU | European Union |
| EVN | Electricity Group of Vietnam |
| FL MD – 77 | Fuhrlander 1.5 MW wind turbine, rotor diameter 77m |
| fU | Functional Unit |
| GHGs | Greenhouse gases |
| GWP | Global warming potential |
| $GWP_{100a}$ | Global Warming Potential 100 years applied in this thesis |
| HVAC | High Voltage Alternating Current |
| IE | Institute of Energy, Vietnam |
| IEA | International Energy Agency |
| IEC -IIA | International Electro-technical Commission of wind Turbine under turbulence intensity distribution class IIA |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Standard Organization |
| Kg $C_2H_4$-eq | Kg of ethane equivalent |
| Kg $CO_2$-eq | Kg of carbon dioxides equivalent |
| Kg $SO_2$-eq | Kg of sulphur dioxides equivalent |
| kV | Kilo voltage |
| kW | Kilowatt |
| kWh | Kilowatt-hour |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Category |
| m | Meter |
| m/s | Meter per second |

| | |
|---|---|
| MGh | Megawatt-hour |
| MJ | Mega-Joules |
| MoIT | Ministry of industry and Trade |
| MVA | Megavoltage – Ampere |
| MW | Mega Watt |
| $N_2O$ | Nitrous oxide |
| NMVOC | Non-Methane Volatile Organic Compounds |
| $NO_x$ | Nitrogen Oxides |
| NP | Eutrophication potential |
| OECD | Organization for Economic Co-operation and Development |
| PLCA | Process analysis based Life Cycle Assessment |
| POCP | Photon Oxidant Chemical Potential |
| Project site | Binh Thuan Vietnam |
| REVN | Renewable Energy company in Vietnam |
| $SO_2$ | Sulphur dioxides |
| t.km | Ton × kilometre |
| TCVN 5844:1994 | Vietnamese Standard No 5844, year 1994 |
| TR-XLPE | Tree-retardant cross-linked Polyethylene |
| USA | United States of America |
| VNRE | Vietnam Renewable Energy Joint Stock company |
| WB | The World Bank |
| XLPE | Cross linked Polyethylene, insulation polyethylene |

# Abstract

This research conducts an in-depth analysis of the environmental impact assessment of a wind farm in Vietnam, with a view to identifying the various environmental stressors and then assess them under suitable impact categories. Although wind power releases no emissions during operation, there is an environmental impact related to the wind turbine during the entire life cycle from manufacturing to dismantling. In this study, a Life Cycle Assessment is carried out to quantify the environmental impact of twenty existing 1.5 MW wind turbines. The assessment analyses emissions in different unit processes and compares the means of different emissions during the lifetime of a wind farm. Furthermore, at the end of the thesis, the energy payback time is determined based on the cumulative energy requirements for a 20-year life period.

For the quantitative analysis of the material and energy balances over the life cycle, all unit processes based on life cycle assessment are determined, and many matrix series are designed and calculated. Moreover, the environmental impact categories are set to match the conditions in Vietnam and the aims of the research.

This study also shows that while the comprehensive life cycle inventory of a wind farm is heavily dependent on the unit processes, the impact can be divided into three categories: raw material data input, energy consumed in each unit process, and the emission outputs such as CO2, SO2, CH4, etc.. The three impact categories allow the classification of the emissions and give results for all life cycle assessment.

Finally the findings shows that the largest emission contribution is mainly derived from the manufacturing phase, which varies from 60 % to 80 % of the total life cycle stages. The totalCO2 equivalent emissions in the climate change category is around 14 g for every kWh of electricity generated from the wind plant and the primary energy return is 5 months.

This research is a good example that proves that a wind plant is one of the best options for mitigating climate change and for providing electricity in rural areas that are not connected to the grid. It can be stated that wind energy is among one of the cleanest sources of energy available today.