Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

KEVIN GORDON PALMER-WILSON

MSc (University of Freiburg, 2013)
BEng (Bochum University of Applied Sciences, 2010)

“How do we power decarbonization?
Land and other resources in Canada’s West”

Department of Mechanical Engineering

Monday, February 10, 2020
2:00 P.M.
Clearihue Building
Room B017

Supervisory Committee:
Dr. Andrew Rowe, Department of Mechanical Engineering, University of Victoria (Co-Supervisor)
Dr. Bryson Robertson, Department of Mechanical Engineering, UVic (Co-Supervisor)
Dr. Peter Wild, Department of Mechanical Engineering, UVic (Member)
Dr. Tom Gleeson, Department of Civil Engineering, UVic (Outside Member)

External Examiner:
Dr. Sarah Jordaan, School of Advanced International Studies, Johns Hopkins University

Chair of Oral Examination:
Dr. Peter Cook, Department of History, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

Mitigating climate change requires elimination of fossil fuel related greenhouse gas emissions. Transitioning electricity generation to low-carbon sources and substituting fossil fuels with electricity in non-electric sectors is considered to be a key strategy. This dissertation investigates resource options to and land area impacts of decarbonizing electricity generation and electrifying adjacent sectors. Three studies analyze transition options in the western Canadian provinces of Alberta and British Columbia.

The first study investigates technology transition pathways and land area impacts of reducing electricity generation related carbon emissions in Alberta. Coal and natural gas fuels each provided 45% of the province’s electricity demand in 2017, making it the most carbon intensive electricity system in Canada. Reducing emissions by 90% between 2015 and 2060 with a 70% share of wind, solar, and hydro power requires 5% additional land area for electricity generation annually. This land area impact is mostly attributed to wind power, with smaller shares attributed to ground-mounted solar and hydro power. System planners can reduce the land area impacts by deploying more compact geothermal, biomass, rooftop solar and natural gas with carbon capture and sequestration technologies. Such technology compositions can hold land area impacts constant in time, but total net present system costs increase by 11% over the 45-year period.

The second study investigates sedimentary basin geothermal resources in northeastern British Columbia. Geothermal energy is a potentially low-cost and low-carbon dispatchable resource for electricity generation. A two-step method first geospatially overlays economic and geological criteria to highlight areas favourable to geothermal development. Next, the Volume Method applies petroleum exploration and production data in Monte Carlo probability simulations to estimate electricity generation potential at the four areas with highest favourability (Clarke Lake, Jedney, Horn River, and Prophet River). The total power generation potential of all four areas is determined
to be 107 MW. Volume normalized reservoir potentials range from 1.8 to 4.1 MW/km$^3$. The required geothermal brine flow rate to produce 1 MW of electric power ranges from 27.5 to 60.4 kg/s.

The third study investigates electricity impacts of electrifying space heat and road transportation using a portfolio of renewable energy sources. The Metro Vancouver Regional District in British Columbia serves as a case study. The district’s 2016 fossil fuel demand is converted to an equivalent electricity demand at hourly resolution. The annual electricity demand of 30 TWh increases by 48% to 81%, depending on space heating efficiency. A one-year capacity expansion and dispatch model quantifies a broad range of feasible electricity system compositions. Results reveal that between 70 and 2203 km$^2$ of additional land area need to be designated to electricity generation to supply the additional demand. Increasing the space heating coefficient of performance from 1.08 to 3.5 halves land area impact and electricity system costs. The maximum potential 8.8 GW of rooftop solar capacity can generate up to 23% of the district’s annual electrified demand. Required electricity storage capacities range from 6 to 61 GWh.