

Master in Statistics for Data Science  
2024-2025

*Master Thesis*

“Optimizing Wind Turbine  
Placement in Wind Parks via  
Mixed Integer Optimization using  
Neural Network based Constraint  
Learning.”

---

Simon Schmetz

Carlos Ruiz Mora  
2nd Tutor complete name  
Madrid the 29. of January

**AVOID PLAGIARISM**

The University uses the **Turnitin Feedback Studio** for the delivery of student work. This program compares the originality of the work delivered by each student with millions of electronic resources and detects those parts of the text that are copied and pasted. Plagiarizing in a TFM is considered a **Serious Misconduct**, and may result in permanent expulsion from the University.



This work is licensed under Creative Commons **Attribution – Non Commercial – Non Derivatives**



## Acknowledgments

TODO Acknowledgments



## ABSTRACT

---

This thesis combines Linear Optimization with Constraint Learning to optimize wind turbine placement for maximum performance in a predefined area under randomly distributed wind. A Neural Network is trained on simulated data to model the impact of turbine positioning on power output. This model is integrated as a constraint in a linear optimization problem, and the problem evaluated for a current state-of-the-art wind farm configuration.



## CONTENTS

---

Acknowledgments	iii
Abstract	v
1 Introduction	1
2 State of the Art	3
3 Data Source	5
4 Addenda	7
5 Abbreviations	9
List of Figures	11
List of Tables	13
Bibliography	15





## INTRODUCTION

---

With the clean energy transition currently taking place in europe with ambitious targets for 2030 and beyond

, wind energy is playing a central role in that transition, with wind energy expected rise to 50 % in the EU energy mix

With wind energy thus expected to become the main contributor to the EU's energy production and large potentials identified for both onshore and offshore parks

attempts to optimize all parameters of windparks with even minor power efficiency improvement can be expected to yield significant returns in absolute power due to the scale of future wind energy production.

[1]

As a contribution to increasing power efficiency on future wind farms, this thesis is dedicated to a new approach for optimizing the placement of a fixed number of wind turbines in a predefined area (typically a square).

FIG: Wind Park birdseye

To solve this optimization problem, an extension to the pyomo python library is used, that allows the introduction of Neural Networks to the optimization problem as constraints

. This extension allows for introducing a Neural Network to model the effects of wind turbine placement relative to each other on power production for the respective wind turbines. Introducing this model to the optimization problem defined in pyomo then allows for the optimization of overall power productions across all wind turbines in the wind park. To create a model optimally fit to the needs of the optimization problem, the model is trained on data specifically generated with the FLORIS wind farm simulation tool (<https://www.nrel.gov/wind/floris.html>) for optimal coverage of the parameter space of the optimization. (HOW IS THE MODEL VALIDATED ?)

To simplify the problem, the surface below the turbines is assumed to be perfectly flat and equal wind speed is assumed along the entire height of the turbines.

Data Generation and Neural Network:

(...)

Optimization Problem:

(...)

This thesis is structured according to the two main steps required to solve the optimization problem as presented above.



## STATE OF THE ART

---



## DATA SOURCE

---

With the goal of training a model tailor made to the requirements of the optimization problem, the data used for training the model has to be generated using an open source simulation method, allowing to set the parameter space of the model as required to the given optimization problem. After investigating the two python based wind farm simulation tools FLORIS and PyWake, FLORIS was chosen due to solid documentation, what appears to be very stable releases and broad functionalities regarding wake modelling. FLORIS is a wind farm simulation tool developed by the National Renewable Energy Laboratory (NREL).

Wind turbine power curve modelling under wake conditions using measurements from a spinner-mounted lidar: <https://www.sciencedirect.com/science/article/pii/S0167636918300011>

Floris: <https://github.com/nrel/floris>

Main Effects of Wake Turbulence: - Wind Speed (needs time to mix with outside airflow) - Turbulence



ADDENDA

---





## ABBREVIATIONS

---

ACM    Aerodynamic Characteristics Model



## LIST OF FIGURES

---



## LIST OF TABLES

---



## BIBLIOGRAPHY

---

- [1] Leslie Lamport. *LaTeX : A Documentation Preparation System User's Guide and Reference Manual*. Addison-Wesley Professional, 1994.