Team 27 Progress Report

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BACKGROUND INFORMATION

Due to several reasons including changes in energy cost dynamics, advancements in modern technologies, response to climate change, and geopolitical pressures, there has been a steady push for developed nations to shift from heavy reliance on fossil fuels to more alternative sources of energy. While this push is continuing and growing every day, there is still heavy reliance by European nations (as with most nations) on oil.

Traditionally, Russia has been the primary supplier of oil to its European neighbors. In response to the Russian invasion of Ukraine in 2022, nations in the EU have systemically imposed economic sanctions on Russia and as a result are facing a reality of being cut off from the Russian oil supply. While short-term arrangements with alternative suppliers are in the works, it is clear this global trade shift will add increased pressure on the adoption of alternative energy.

Some European nations like Germany and France have had more advanced developments in the search for alternative energy sources and have mapped out their future progressions. However, there are still countries in a less- advanced state of alternative energy adoption. It will be critical for energy suppliers to project where those countries are headed and capitalize on these growth opportunities while the added pressures are in place for adoption of their technologies.

PROBLEM TO ANSWER

Analyzing historical alternative energy trends with the most advanced European countries, how can we project future alternative energy adoption for less sophisticated European nations and how key energy companies might financially benefit from their adoption?

INITIAL HYPOTHESIS

Our hypothesis is wind turbine market sector will experience accelerated exponential growth in the next few years. We will provide revenue growth predictions for the two companies we researched. We have also filtered the stock data to focus on the companies Vestas and Gamesa.

DATA

We focused on two themes of data for this topic, energy related (electricity production/consumption, wind energy and weather conditions) and historical stock data for the companies under consideration (VESTAS and SIEMENS GAMESA) and their key performance indicators from the financial reports.

In regards to the energy related datasets, we found annual data containing figures for energy production, capacity installed and climate data for Germany and Poland. However, the biggest challenge we faced with the data was that it was highly correlated. We continued to analyze capacity installed and energy produced separately. However, the behavior was similar in that we decided to clean up by one factor and go with electricity produced.

Next, we spend a considerable amount of time searching for monthly available wind energy with historical data for Germany and Poland. Our rationale was to run a Holt Winters on it and see the behavior. We could find annual data, but we had a tough time finding monthly data. We were able to find a site with energy generated in the same format that we expected, but the data was only for Belgium.

The biggest hurdle that we faced during the collection of stock and financial datasets was that the numbers from various websites were not synchronized. We then had to verify numbers from the company website and then decide on one site as our source of truth for all the numbers.

The process of searching for Key KPIs was tedious since we had to dig into each of the annual reports for the two companies. We did this so we could take the numbers and use them in our model. VESTAS was a concise report, however, we had to perform extensive data profiling for SIEMENS GAMESA to determine what we need to retain and what needs to be removed from the analysis.

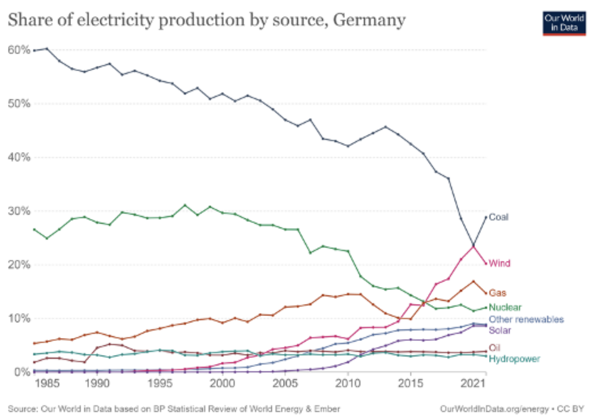
We are constantly refining our data and looking for energy factors that are not correlated such that we can use them to enhance our analysis.

A new addition to our datasets, is the capacity of wind production Germany and Poland can maintain. As discussed in the Literature Review below, Germany has a 2% target capacity. Currently Poland has a .3% cap due to legal frameworks. However, we will assume that they will adopt to other European countries and exhibit a 2% target to match Germany.

APPROACH

Data cleaning has been finished and we are comparing different model results, such as Simple Linear Regression, Time Series, Gompertz and Logistic Regression. The data has been filtered for Germany and Poland as that is where our research is focused.

We began our analysis by reviewing the state of renewable energy growth in Germany.
Observe from Figure 1 and Figure 2, wind is the fastest growing renewable energy source in Germany, in both volume and percentage.



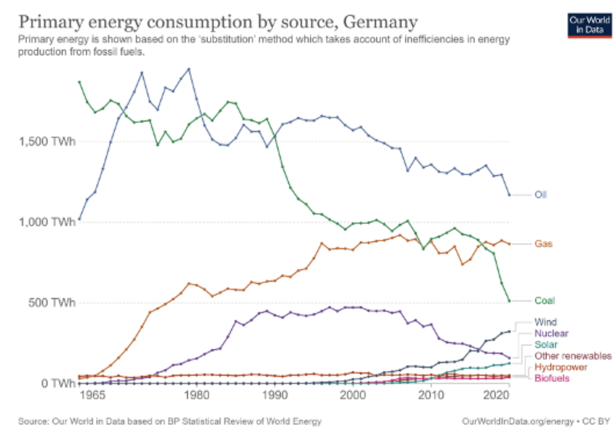


Figure 1

Figure 2

We used a simple linear regression (SLR) model with electricity from wind as the dependent variable and year as the independent variable to find lambda for BoxCox transformation. Germany Lambda = 0.34. We then applied a BoxCox transformation on the dependent variable (wind_electricity), and re-trained the SLR model and analyzed SLR model assumptions. After BoxCox transformation, the dependent variable presents a good linear relationship with year, and residual assumptions hold. We end up with a prediction for the next 15 years for Germany, as shown in Figure 3.

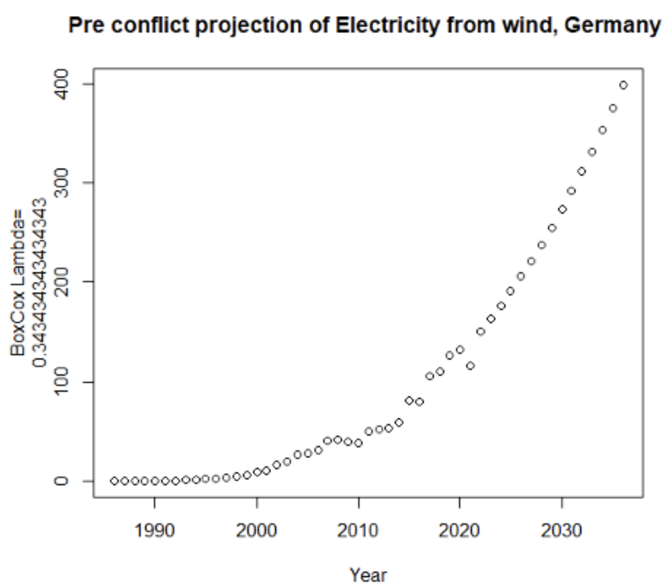


Figure 3

Next, we did a similar analysis with Poland. Observe in that Figure 4 that wind energy is still at an early stage in terms of the percentage of total energy source, but it is the fastest growing renewable energy source in Poland as well.

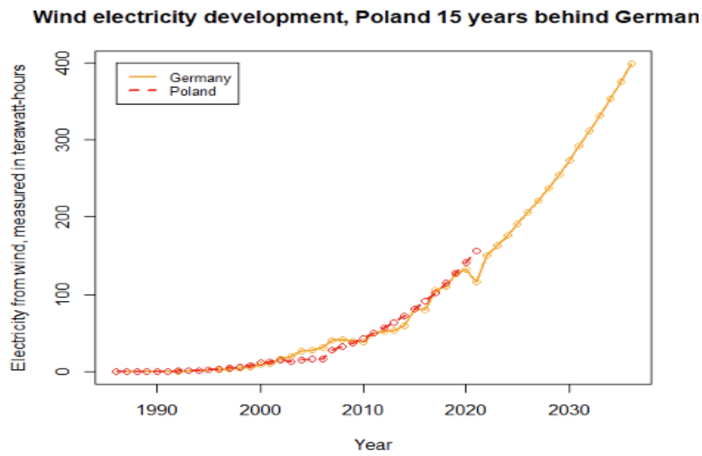


Figure 4

We followed the same SLR model procedure as with Germany, and we find Poland Lambda = 0.26. After the same BoxCox transformation. As before, we predicted the next 15 years for Poland as shown in Figure 5. If we plot Electricity generation from wind, measured in terawatt-hours, vs year on Germany and Poland, and move Poland year ahead 15 years, both countries follow similar parabolic trajectories and Poland's wind electricity adoption rate is slightly faster.

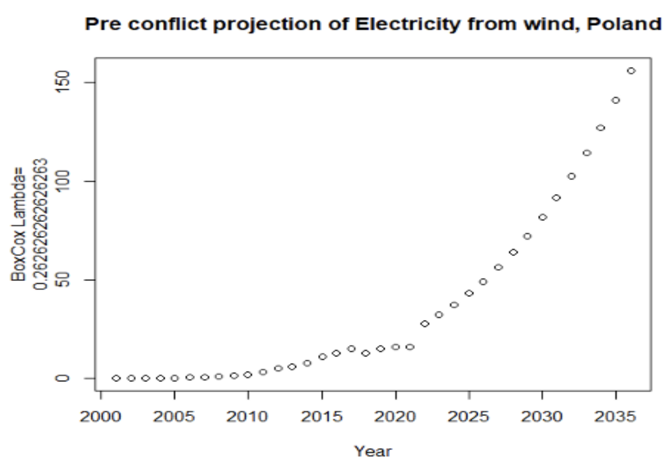


Figure 5

Next, we used a Time Series Model to compare our finding with a Simple Linear Regression Model. However, we do not have enough data to be comfortable with the results of the model. We need to be able to add a cap for wind electricity due to a limited supply for each country. We need to analyze and compare Gompertz and Logistic, to pick one model in order to further explore business cases.

FINDINGS AND CHALLENGES

Our first model was a Simple Linear Regression on Wind~Year for both Germany and Poland. We then fit the model to calculate lambda of BoxCox and used lambda for a BoxCox transformation for Germany (Figure 6 and Figure 7) and Poland (Figure 8 and Figure 9). The last step of the SLR was to retrain and get a prediction for the next 15 years.

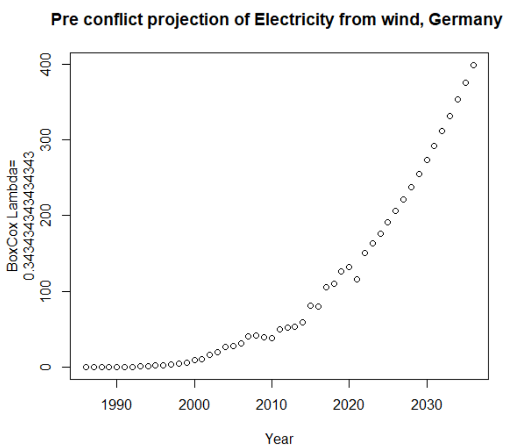


Figure 6

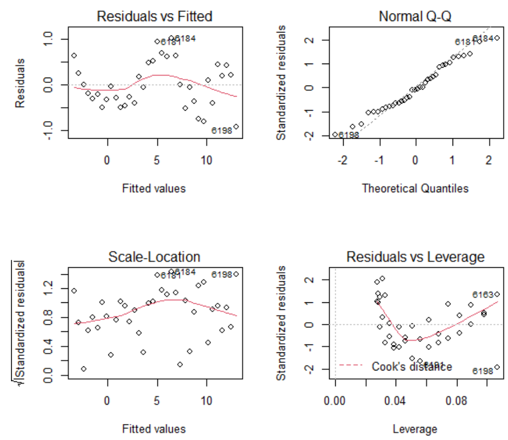


Figure 7

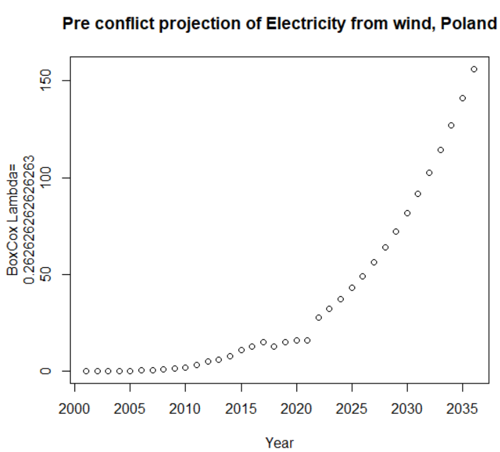


Figure 8

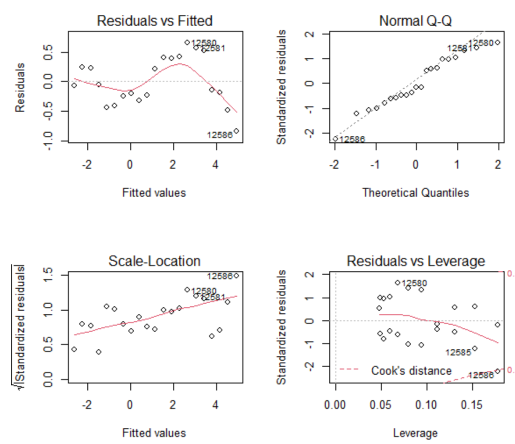


Figure 9

After seeing these results, we decided to try a time series model to compare since it would be better suited than a linear regression model, since linear regression works best for interpolation. Also, from looking at Figure 7 above, we can see our assumptions do not hold due that the residuals vs fitted chart. The curve shows our model as issues and is not linear.

Looking at the time series models below Figure 10 and Figure 11, it is clear these models are much more conservative than our SLR models. However, there is concern that we do not have enough data to properly forecast beyond our sample period. Additionally, ARIMA does not allow us to set caps on the amount of wind energy production. For this reason, we have decided to explore another model, Gompertz, in order to create a logistic regression that can be capped at the upper limit of energy production we identified through our research.

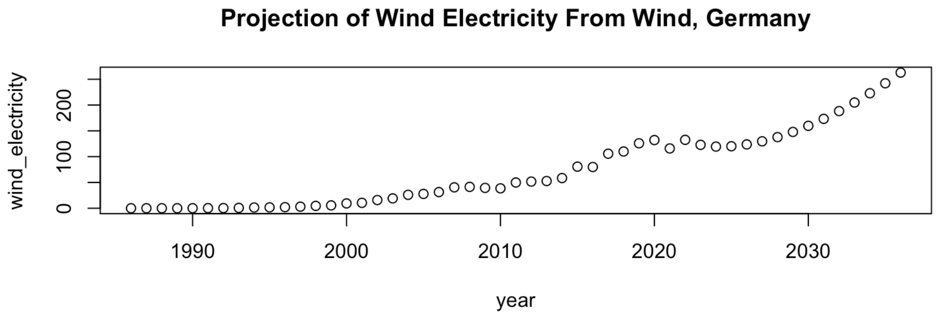


Figure 10

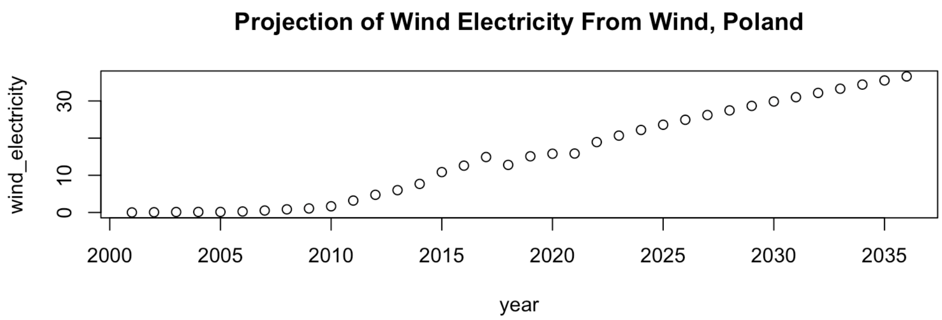


Figure 11

Next, we explored Gompertz model, which was successfully used in modeling dynamics of tumor growth. The challenging part of using this model is that the dataset we have only covers less than the first half of the curve, and we are trying to use a fitted model to predict majority rest in the future. So, we made assumptions that Germany will reach max capacity 390TWh in 2060, and Poland will reach max capacity 67TWh in 2070, so that we could set limit for the model.

Gompertz base model is given by,

$$y = ae^{-be^{-cx}}$$

Where a = y_max when x goes inf. When x=0, compute b = log(a/y0), and c is growth rate coefficient.

If use, nlsfit(model =10), to fit model, like described in

https://www.youtube.com/watch?v=0ifT-7K68sk

R provides error output, "singular gradient"

In order to fit the model, we need to modify base Gompertz model to single exponential function for a better fit, given by

$$y = ae^{-bc^x}$$

After nls fit and scale adjustment, we produced predictions, using Gompertz single exponential form in Figure 12 and Figure 13

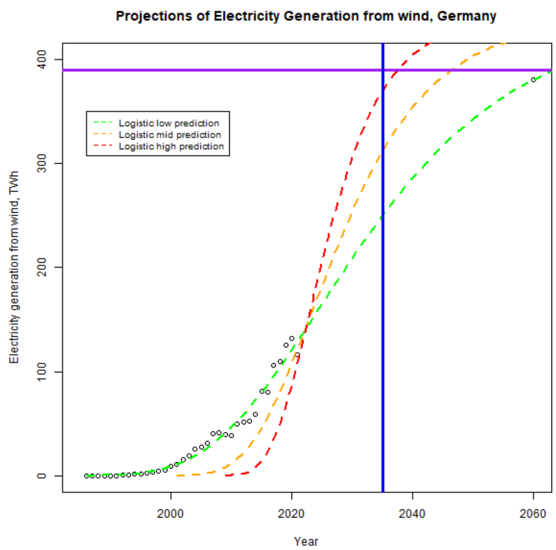


Figure 12

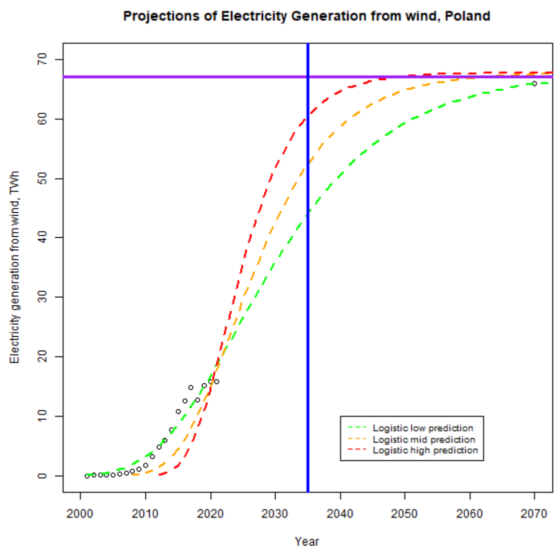


Figure 13

Since we are fitting a modified Gompertz function, the upper limit is no longer capped by our research number. So, we further explored a logistic model.

Again, we made assumptions that Germany will reach max capacity 390TWh in 2060, and Poland will reach max capacity 67TWh in 2070

$$y = \frac{Asym}{1 + e^{\frac{xmid - x}{scal}}}$$

Using a logistic model and nls fit, we produced predictions, using logistic model in Figure 14 and Figure 15.

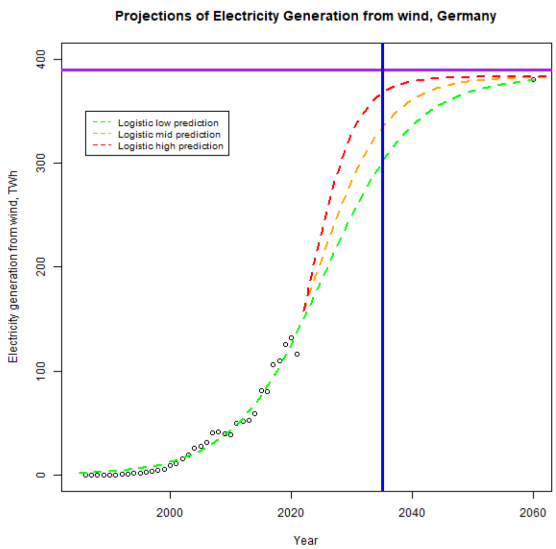


Figure 14

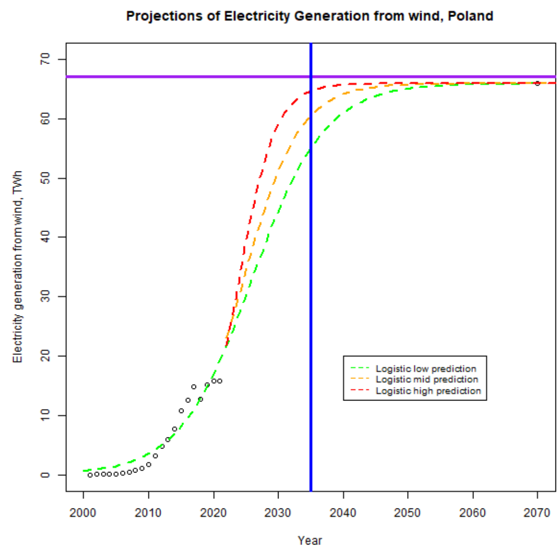


Figure 15

We studied 3 different research papers to help us decide capacity levels for the different countries on how much wind power could be sustained. Our Literature Review states for Germany we will be using a 2% target and Poland although currently only allow 0.3%, we are using same 2% target as Germany due to east Europe tension.

LITERATURE REVIEW

When creating future wind energy projections for our target countries it is critical that we consider the maximum amount of wind energy each country can produce. Without understanding the maximum capabilities of each country our projections could pass beyond what is realistically possible and thus render their estimates, and any resulting analysis from them, useless.

Like any existing energy source there is a limit to how much can be built out and deployed based on available resources. With wind energy this can be simplified down to available land. For the purposes of this analysis, we will limit our scope to onshore wind and ignore offshore wind capacity limits.

Just as it has been the primary basis for our other analyses in this project, we will use Germany as the baseline for our projections into the emerging Poland market. Based on a study "Potenzial der Windenergienutzung an Land" (2011) by the German Wind Energy Association (BWE) and further analyzed by Beckius and Magnusson (2013) it has been estimated that a realistic target for the total wind energy output of Germany would utilize a footprint equivalent to about 2% of German land area.

The 2% target equates to an estimated 189 GW capacity potential. While this capacity target may end up smaller than reality due to advancements in turbine technology or other factors, for the purposes of this project we will set the 189 GW capacity estimate as our cap for future energy potential.

Next, we need to estimate the realistic wind capacity for Poland. To do this, further research was done to determine if previous studies had been done to estimate a Polish wind energy cap. In a study by Ember Coal to Clean (Czyzak 2022) they determined that Poland currently can use only 0.3% of their total land for wind turbines due to current policies around turbine distancing. They estimated this capped their max capacity at 10 GW.

Since the 0.3% cap is largely due to legal frameworks and not technical or landscape constraints for the purposes of our analysis we will assume that Poland will adopt a similar policy to other European countries and can reach a similar 2% target we set for Germany. If we extrapolate from the 10GW estimate for .3% land use for Poland a 2% land use would place Poland total capacity target at ~67 GW.

WORKS CITED

Beckius, D., & Magnusson, D. (2013). The German wind energy market and its developers – a study of sourcing models, success factors and challenges. http://www.diva-portal.org/smash/get/diva2:644677/FULLTEXT01.pdf

Umwelt Bundes Amt (UBA) (2013), Potenzial der Windenergie an Land. https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/01-mensch-und-umwelt/03-naturschutz/bwe_potenzialstudie_kurzfassung_2012-03.pdf

Czyzak, P. (2022). Change is in the Wind. https://ember-climate.org/app/uploads/2022/03/Briefing_-Unlocking-onshore-wind-in-Poland.pdf

Rafael Lahoz-Beltra, Gompertz Function with R. https://encyclopedia.pub/entry/626