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Renewable Energy at Home: A Look into Purchasing a Wind Turbine for Home Use—The Cost of Blindly Relying on One Tool in Decision Making

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Abstract: Small-scale wind turbines simulations are not as accurate when it comes to costs as compared to the large-scale wind turbines, where costs are more or less standard. In this paper, an analysis was done on a decision for a wind turbine investment in Bellingham, Whatcom County, Washington. It was revealed that a decision taken based only on a software tool could be destructive for the sustainability of a project, since not taking into account specific taxation, net metering, installation, maintenance costs, etc., beyond the optimization that the tool offers, can hide the truth.

Keywords: green communities; energy independence; HOMER; wind turbines

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1. Introduction

1.1. Current Research Framework

Wind turbines have been at the forefront of renewable energy technology. Many Americans have noticed this development in pictures of Europe with tall white wind turbines scattered over green rolling hills. Many have seen the news from Texas developing large wind farms over miles of prairie lands, as well as of Block Island, Rhode Island, where the nation's first offshore wind turbine was recently installed [1]. The future of renewable energy in the United States continues to expand to residential backyards. After decades of wind turbine research and development, many European countries, such as Belgium and Denmark, lead the market with small wind turbines for private or community use—especially since Denmark's amazing turbine development began with community-bought wind turbines [2,3]

Wind turbines have recently become much cheaper, smaller, more efficient, and easier to transport and assemble [4–6]. This new technology allows families to purchase wind turbines for their homes and connect to the grid to be able to sell extra electricity back to the utility company or share with their neighbors. The Peer-to-Peer (P2P) approach from a computing application scheme has been made possible to be applied in other fields, such as in the renewable energy sector.

Generation Y, also referred to as Millennials, grew up during the birth of the internet. While this generation experienced a childhood similar to their parents—playing outside until the streetlights came on—the coming-of-age period of this generation occurred while the internet was being developed to function from people's hands, no longer on dial up, but on wireless cellphone computers. This was the time that humans began socializing in chat rooms, work began using emails, and you could search the internet for endless knowledge. The internet provided an amazing change in the way lay people could access information about the world around them. This generation would prove most concerned for the environment, as they absorbed much global information growing up [7]. Today, this generation have families and have bought or are looking to buy houses, and many are also looking to lower their carbon footprint—often not following the most efficient path. Electrification of their consumption is a top priority, including EV ownership [8], heat pumps, and other residential appliances [9]. Thus far, whenever energy surplus was generated via, e.g., a fireplace, via a fuel-based boiler etc., it was simply lost. Now, with P2P technology and the liberalization of the electricity markets (and how modern grids operate), it can be offered to the neighbor at a competitive price [10]. When the local utility company does not sell energy from renewable sources, there are options for families to do so themselves [11]. Over the last few years, in the Western world, the global Not-In-My-Back-Yard (NIMBY) approach has moved from there to Yes-In-My-Back-Yard (YIMBY). More and more are looking to be prosumers and—if in a warm climate area—are trying to invest in solar (or wind) energy resources and storage as much as possible, aiming at having a zero-electricity bill (considering—ultimately falsely—that they are at times grid-independent of the local utility) [12].

The renewable energy market offers a variety of wind turbines, solar panels, and biofuel options. Wind turbines are one of the older technologies that have undergone recent decades of research and development [13] and "is the fastest growing source of energy in the world—efficient, cost effective, and nonpolluting," according to [14], which makes it an ideal option for consumers, especially when paired with solar panels. Installing a wind turbine and/or solar panel requires research into the amount of energy used by the household, the laws of the local area and/or homeowners association, and the consumer's budget.

Although there is a large number of articles published focused on remote or rural areas, mostly in African countries [15–18], a significant amount of literature—though not extensive—is devoted to renewable energy at home, with a focus onto purchasing a wind turbine for home use. Oliver and Groulx [19] presented a homeowner-centric approach of a hybrid renewable energy system, which included a wind turbine, which proved what was already known for wind turbines: that they are clear economies of scale. Ugur et al. [20] moved on to a financial analysis for small wind turbines for home use in Turkey. Based on their results and the wind resource analysis in Konstantinoupoli, they have identified where the most profitable areas in the city for small wind installations are. Rodriguez-Hernandez et al. [21] did another economic feasibility study for small wind turbines in the Valley of Mexico metropolitan area, based on three years of data, 28 wind turbine models, and 18 locations. Hemmati [22] published a techno-economic analysis of a home system, which included a small-scale wind turbine and a storage subsystem. Mixed integer linear programming was used, and it was proven that the lowest planning costs were for a 20-kW wind turbine.

On the other hand, Canale et al. [23] were not focused on the economic analysis. Instead, they focused on an innovative blade technical analysis and their application on small-scale wind turbines. Numerical and experimental results were evaluated based on the Blade Element Momentum (BEM) theory in small wind turbines, which is not usually the case. Such experimental set-ups are usually met in large scale testing facilities. Another technical analysis was done for a 5-kW wind turbine system for a home with the inclusion of batteries [24]. A net-zero energy home was studied by Rasouli and Hemmati [25], by using mixed integer nonlinear programming (MINLP) and solved using the particle swarm optimization (PSO) technique. It was proven that any net zero energy home is heavily dependent on the wind turbine, solar sizing, battery sizing, and hydrogen (or in some cases electric) vehicles.

1.2. Renewable Energy at Home

What has not been studied adequately over the last years—and definitely not after the renewable energy's progress in the USA—is if people currently have a more positive attitude with regards to having a wind turbine in their back yard compared to the NIMBY approach, which has clearly lasted for a long time worldwide. It should be pointed out, however, that over the last year, the coronavirus pandemic derailed renewable energy's overall progress in several countries. The public deficit has increased, and the GDP, although it has experienced small ups and downs throughout the past decade (mainly ups, up to 5% compared to the previous calendar quarter every time), over the last two quarters in 2020 plummeted by −5.0% (Q1) and −32.9% (Q2) in the US [26] (Figure 1). Therefore, liquidity and available funds for investing in renewable energy sources for home use shrunk. Thus, the necessity to lower the initial capital investment of all renewables, mainly of small wind turbines, in order to achieve substantial growth in the small wind sector in addition to the large wind turbine sector is crucial. Furthermore, as we approach the American elections, budgetary-wise, liquidity for investments will become tougher to find and funds will be limited.

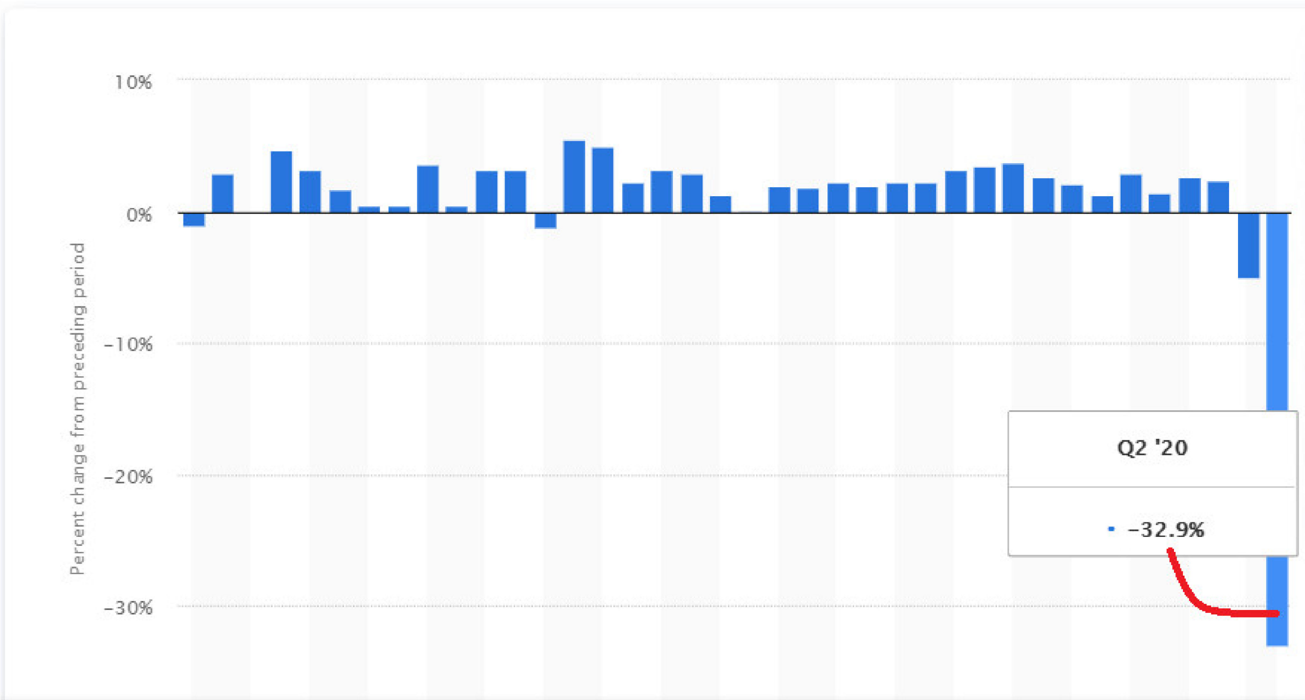


Figure 1. Quarterly growth of the real GDP in the United States from 2011 to 2020.

Beyond that, the insufficient infrastructure for small-scale investments, such for as small wind turbines, was the barrier for developing such business activities. However, Electric Vehicles (EVs), along with the P2P infrastructure, has led citizens to start thinking in another way. It is not only their will to produce their own wind energy and have a near-zero (or even negative) electricity bill towards energy independence, it is also a prestige-related attitude, the increase in social status, and the social acceptance related to the purchase of an EV and the expectance of its purchase to soon be a good value for money [27]. Moreover, such investments could follow the EV ownership approach. A "create-your-own-electricity" approach could be another label of social status. Such investments are linked more to summer houses than to houses in cities and densely urban areas, where the electricity demand is highly increased due to the increased flow of tourists. In fact, for some very hot days in summer when the grid is stressed, in order to fulfill the cooling demands, small wind turbines could contribute significantly to electricity generation. In those areas, there is a narrow security margin of electricity supply and a high risk of the system's breakdown in case of malfunctions/power cuts in periods with high load demand. Additionally, because of the different demand profile with the winter in the summer houses, the large daily and seasonal electricity load demand fluctuations, the summer peak can be many times greater than the lowest electricity demand in winter, and the daily fluctuation could be ±50–60% of the average value [28]. Approaching the above-mentioned issues from the perspective of microgrids and hybrid systems, many solutions can be found on several levels, even leading to a holistic energy climate water nexus [29,30]. Concerning financial issues, this will lead to energy savings and a reduction in operational costs. From another point of view, independent microgrids, which include wind turbines, should be able to operate as autonomous power networks in case of failure and forced isolation, providing uninterruptible power to crucial loads at least. In addition, microgrids with small wind turbines should be able to meet the peak loads and improve the power quality and stability of the grid-connection. To this end, the appropriate energy storage method (battery system) will play an important role.

Above all, ultimately, the goal is to create green communities, a large step towards energy independence and energy democracy. By introducing, e.g., small wind turbines via the P2P approach, the current grid-based electricity is changing. In such communities, the power comes from solar panels (on every roof) or small wind turbines, and is channeled to the same busbar, which is linked to energy storage, community heating, EV charging, etc. Energy is, therefore, consumed in the vicinity where it is produced, and the end-users do not need to worry about transmission losses.

2. Materials and Methods

The importance of software tools in decision making is high and is meaningful for all builders, architects, and decision makers. Software tools are helping them to allocate resources, make decisions for investments, decide on the companies' philosophy, etc. This is rather profound in the renewable energy sector. The work in this paper was supported by the HOMER tool (Figure 2). The HOMER Grid is an excellent software tool to help one discover the resource availability in the specific location of their choice. The program was designed by a retired Senior Economist at the U.S. Department of Energy's National Renewable Energy Laboratory [31]. The program offers not only resource information, but also options for specific models of wind turbines, solar panels, generators, and information from the utility company, alongside the associated costs and profits. Once a consumer determines their future address, the energy use of the household will be determined, and the HOMER Grid will find which systems would work best, after which it will find the local laws and apply for the building permit, and then contact the retailer to find the installation costs; finally, it will decide whether or not to invest.

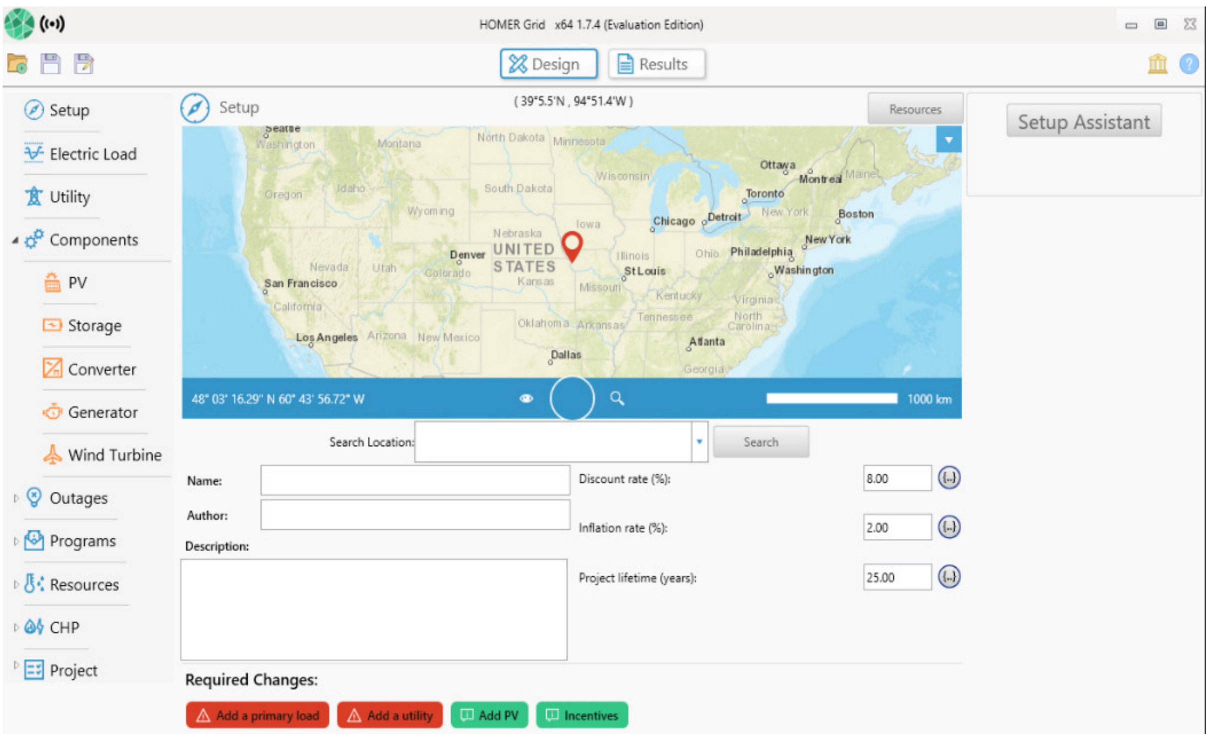


Figure 2. Screenshot from HOMER Grid showing the start screen when opening the application (2020).

This specific proposal is for a XANT M-21 100 kW to be installed in Bellingham, Whatcom County, Washington. This location was chosen as one option for a future home and a small farm for rescued animals. This turbine was introduced in the HOMER Grid program, which is the main component used in this proposal. This proposal and the steps taken to reach a conclusion may be helpful for any person curious about renewable energy for their home, or for communities looking into purchasing a wind turbine to share, as well as the types of people looking to live off the grid.

The wind turbine proposal will describe the steps taken to find the best results for the wind turbine purchase in this specific location in Bellingham, Washington, and an actual residence for sale on Zillow (Figure 3). Following the proposal, the reader will find a thorough analysis and explanations for the costs and cash flow. The analysis describes the few overlooked obstacles in the HOMER Grid program and with the Puget Sound Energy company, as well as building permit information and costs from Whatcom County. Following the analysis, the reader finds a discussion of the background steps, the proposal, the analysis, what the future of this proposal will look like, and how the reader may research their own personal energy system for their family.

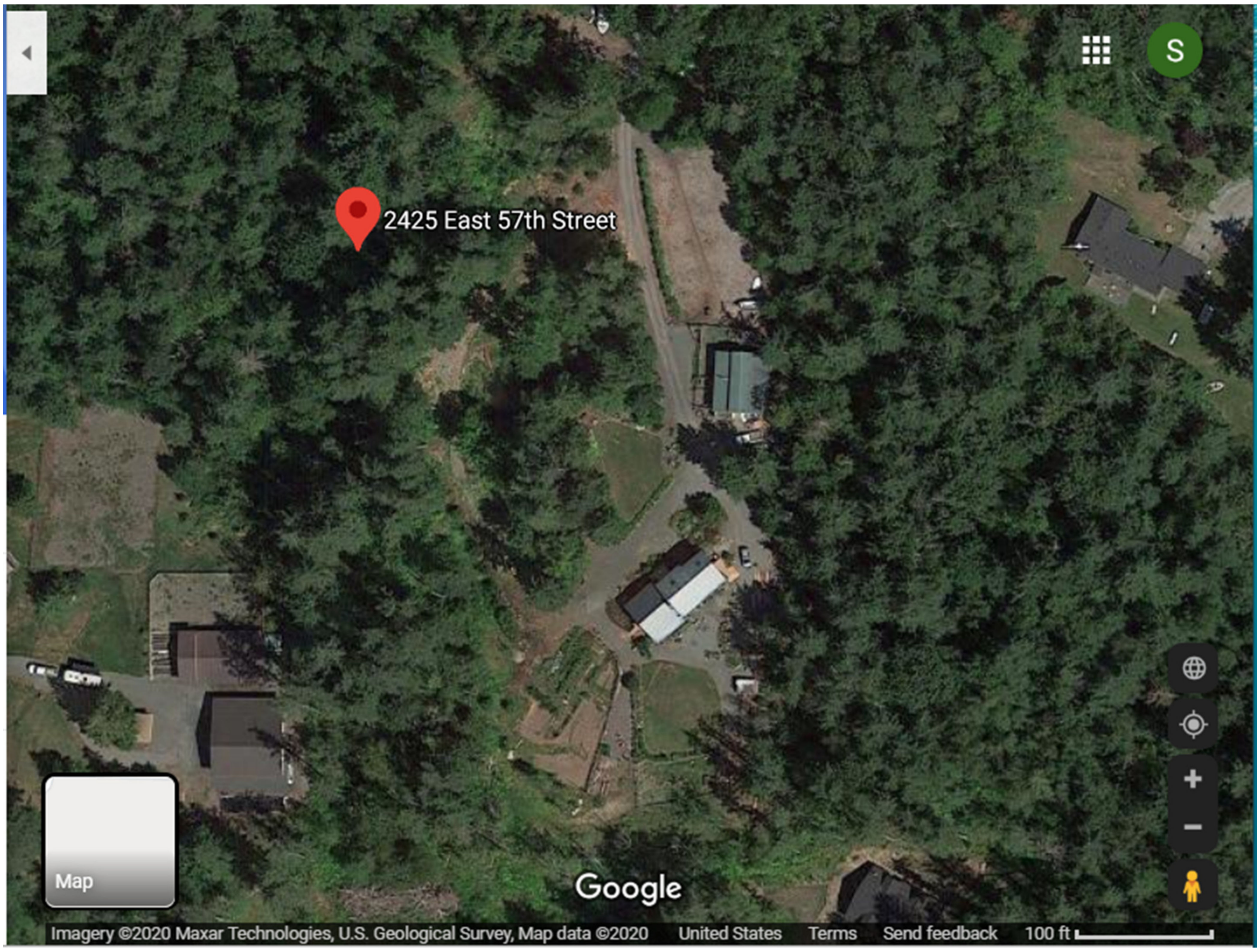


Figure 3. A screenshot of the plot of land and home for the wind turbine proposal (Google Maps).

3. Results

The project was set in Bellingham, Washington, a desirable living location for those searching for cooler climates, liberal policies, and a beautiful scenery. To begin, a home for sale was found using the website Zillow. This address was used in the HOMER Grid. The program prompts the user to download data from NASA.gov for wind speeds, radiation, and utility prices. The user must input the amount of electricity that they intend to use per day. The U.S. Energy Information Administration claims that most households in the country will use around 10,000 kWh per year, but the highest use is closer to 15,000 kWh per year. To ensure a fair outcome and some cushion for error, a higher energy use was assumed. The National Renewable Energy Laboratory recommends only a 1.5 kW wind turbine along with a solar panel to supplement. Wind turbines and solar panels create an optimum duo, since wind turbines create maximum electricity when solar panels are creating none [32].

The radiation in Bellingham appeared high and steady throughout, from one to six kWh/meter squared/day. The wind speeds appeared low, namely, under four meters per second throughout the year, as you can see in Figure 4. It appeared from the HOMER Grid resource projections that the house would benefit most from solar panels. Surprisingly, the program results showed otherwise. The solar panels would end up costing the user hundreds of thousands to millions of dollars more than the wind turbine that HOMER favored. The best result included using a specific 100-kW XANT wind turbine [31].

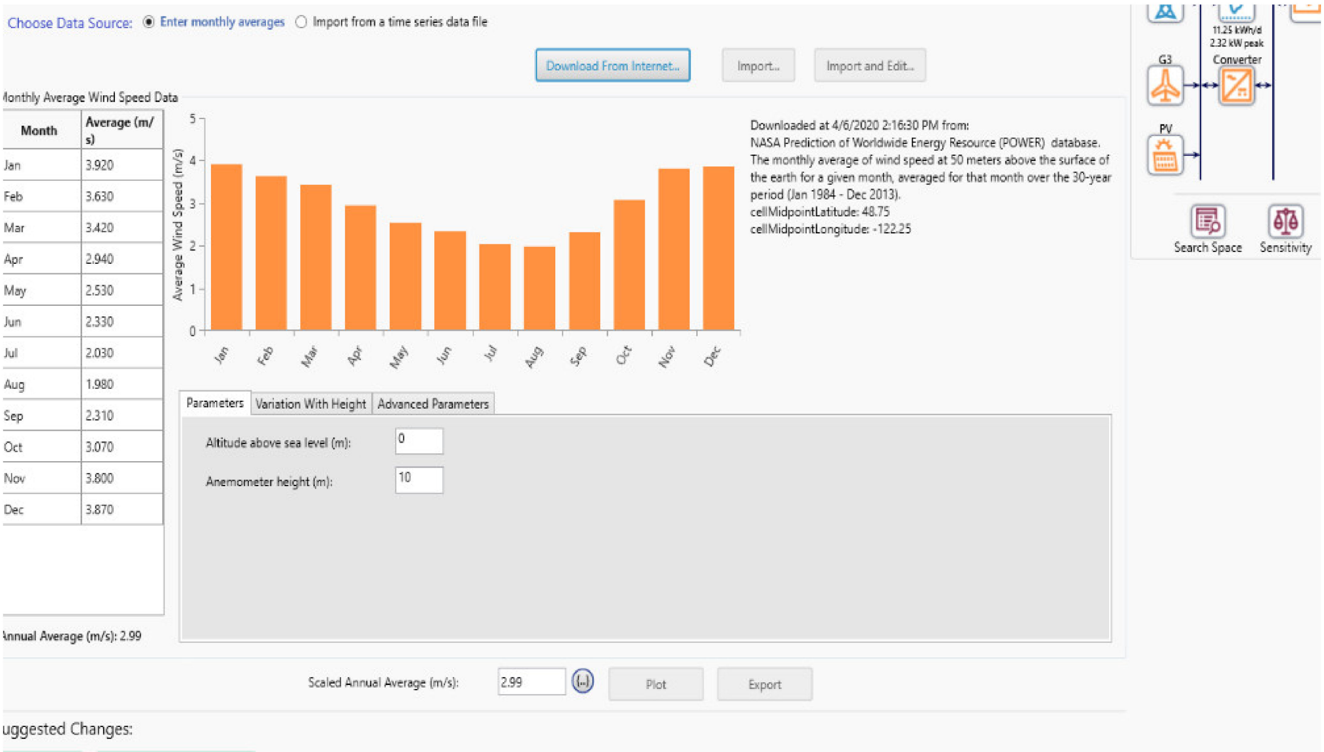


Figure 4. Screenshot of the HOMER Grid program with the wind resource information for Bellingham, Washington from NASA.gov (year: 2020).

The wind turbine options available in the HOMER Grid program include: XANT M-21 (100 kW), the XANT M-24 (95 kW), and three generic wind turbines with varying electricity production capacities: 1 kW, 3 kW, 10 kW, and 1.5 MW. The generic models were created by the HOMER Energy team to represent standard wind turbines with the latest technology. The XANT systems were created by the Belgian company of the same name. These turbines could easily be some of the best on the market for residential or community use. According to their website, these turbines have been IEC 64100-1 and GL certified (XANT, 2020). The International Electrotechnical Commission (IEC) was created in 1906 to showcase the "International Standards for all electrical, electronic, and related technologies", a standard approved by many state and national governments [33]. The turbines were created for easy transport, as it fits into a 40-foot container, can be erected without cranes, and can withstand storms [31]. The project set in Bellingham, Washington would require a building permit before moving forward. The permit ensures a bureaucratically labor-intensive process. The county of Whatcom requires that any residential wind turbine is under 100 kW. In fact, the program recommends this size and the proposal will include a specific 100-kW wind turbine from XANT. After this first win, there are many other conditions and administrations to check your property before building can commence [34]. The checklist in Figure 5 shows that the resident must also pay a fee for the application, but hidden is also the sewer verification process, the cost of the building plans, and possible extra costs for the site plan and rainwater verification. However, that amount may only be around $2000 total, according to the spreadsheet that the county provides on the webpage (2020). This number is added to the cost of the turbine, reaching an initial capital cost of $76,000. The HOMER Grid chose the XANT M-21 100 kW turbine because it had the most potential to create revenue for the property and the lowest Net Present Cost [31].

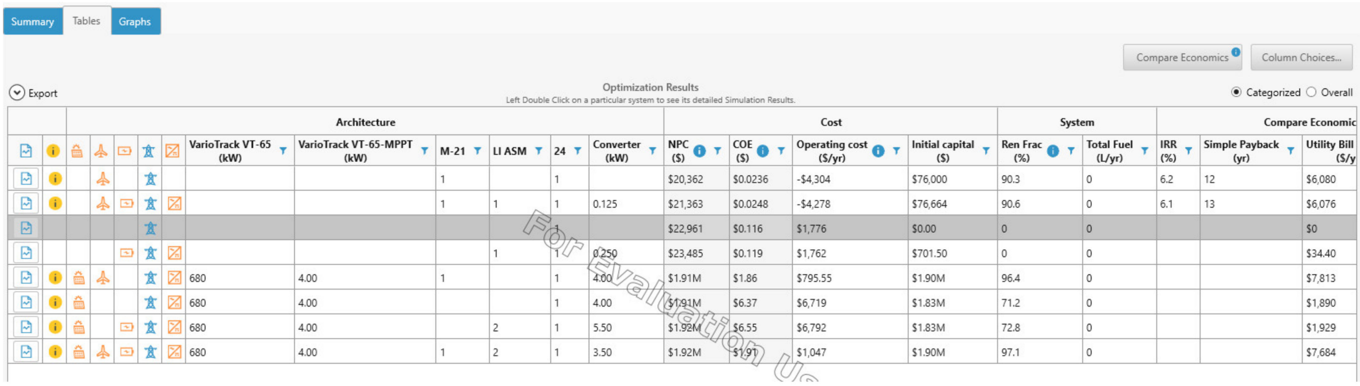
Items Required For a Complete Application:

Bring all of the following with you to your appointment:

- ☐ Whatcom County Planning & Development Approved Screener Checklist
  - Including your Natural Resources Assessment Approval or All Items Required through the Natural Resources Assessment
- ☐ Completed Building Permit Application Form – 3 pages (included in this packet)
- ☐ **2** Complete Sets of Building Plans and (if determined by staff) Structural Engineering
- ☐ **3** Copies of Site Plan
- ☐ Washington State Energy Code Form (Prescriptive Zone 1 Worksheet)
- ☐ Public, Private or Rain Water Verification
  - This form is NOT required if your building project:
    - Does not include plumbing for potable water, or
    - Is a residential remodel or addition that does not add additional bedrooms or result in an increase of floor space of more than 50%
- ☐ Whatcom County Health Department Approved Septic Permit & Design or Sewer Verification
  - AND if an existing septic a current inspection report completed by a licensed O & M specialist.
- ☐ Copy of Most Current Deed
- ☐ Current Contractor's License Number or Owner Contractor Statement of Understanding
- ☐ Whatcom County Engineering Approved Revocable Encroachment Permit
- ☐ Agent Authorization Form (if you are an agent applying on behalf of the owner)
- ☐ Cash or Check (U.S. Funds) are accepted as payment for fees. You may also pay by debit card or credit card, in person only, at the Planning & Development Services Permit Center Counter.

Figure 5. Screenshot of the building permit requirements for Whatcom County [34].

The next step was to run the simulations via HOMER Grid, examining all different scenarios. The scope of this work was to investigate different hybrid setups with the XANT M-21 100 kW wind turbine to optimally confront the challenge of setting up a small-scale renewable energy system. Inevitably, a general methodology and HOMER tool was used, focusing on proposing hybrid systems in autonomous grids, taking into account energy demand, local weather conditions, and long-term energy planning. Figure 6 shows the options provided by the HOMER Grid program after finding resources and choosing which solar panels and wind turbines to use for the analysis. The first option in Figure 6 shows the cost of using the wind turbine with the utility company. The simulation shows that this option would turn a profit if the utility company buys the surplus of the electricity produced. This is dependent on the production of the XANT M-21 100 kW wind turbine, which can produce higher amounts of electricity than most wind turbines due to the proficiency of the turbine technology. The next row shows the option of using the wind turbine with the utility company during the low wind speed months in the summer and a 1-kVA energy storage battery. This is the second-best option for the project. The third-best option is in the third row, which would be to use only the utility company and buy power like everyone else in the neighborhood. The options after that mix solar, wind, and storage, but are not profitable or even cost effective.



Architecture						Cost				System		Compare Economic		
VarioTrack VT-65 (kW)	VarioTrack VT-65-MPPT (kW)	M-21	LI ASM	24	Converter (kW)	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	IRR (%)	Simple Payback (yr)	Utility Bill ($/y
		1		1		$20,362	$0.0236	-$4,304	$76,000	90.3	0	6.2	12	$6,080
		1	1	1	0.125	$21,363	$0.0248	-$4,278	$76,664	90.6	0	6.1	13	$6,076
				1		$22,961	$0.116	$1,776	$0.00	0	0			$0
			1	1	0.250	$23,485	$0.119	$1,762	$701.50	0	0			$34.40
680	4.00	1		1	4.00	$1.91M	$1.86	$795.55	$1.90M	96.4	0			$7,813
680	4.00			1	4.00	$1.91M	$6.37	$6,719	$1.83M	71.2	0			$1,890
680	4.00		2	1	5.50	$1.92M	$6.55	$6,792	$1.83M	72.8	0			$1,929
680	4.00	1	2	1	3.50	$1.92M	$1.91	$1,047	$1.90M	97.1	0			$7,684

Figure 6. Screenshot of the HOMER Grid program results in Bellingham, Washington (2020).

The option chosen for the project is the XANT wind turbine along with the utility company. This option has a Net Present Cost (NPC) of $20,362, a levelized cost of electricity (LCOE) at $0.0236, a capital cost of $76,000, and operating cost (O&M) at −$4300 a month. This NPC represents the total cost of installing, operating, and maintaining the energy source minus the revenues it makes over its 25-year lifetime [31]. To look at this number another way, after 25 years, the total electricity bill will be about $20,000. When divided by the years in use, that is about $800 a year, a steal in electricity spending. One last important benefit to installing a wind turbine on one's property is the Federal Tax Credit, which pays back the consumer 22% of the installation and capital cost of the renewable energy system. However, this tax incentive expires in 2020, but if extended, this could make the NPC closer to $0 for the project.

4. Discussion

The wind turbine results in HOMER projected that it would pay itself back within 12 years, an amazing feat for investing in renewable energy. After using the program to find the NPC of the XANT 100 kW turbine, contacting the local energy supplier was crucial for verification. Email correspondence revealed that the Puget Sound Energy (PSE) company would not buy electricity for $0.90/kWh, as was illustrated by the computer software. Instead, the company would purchase the electricity at "the market competitive price of around 2 or 3 cents per kWh" (Zachary, M., personal communication, 24 April 2020). Reevaluating the numbers with the new data revealed less enthusiastic results. The HOMER Grid program found the yearly cost of the 100 kWh XANT wind turbine to be −$4304.00. This assumes that the surplus of electricity would be sold at the rate of 9 cents/kWh and that the operating costs would be covered by the revenue. The new numbers would present a yearly cost of −$707 and an NPC closer to $65,273 [34].

After contacting a representative at the Puget Sound Energy company, there are new costs to consider which were not prompted by the HOMER Grid software. Connecting to the grid can cost tens of thousands of dollars and takes two years, later learned from Mr. Zachary of the PSE. As the project unfolded, new questions unfolded; XANT claims on their website that they deliver a product which costs half the normal installation cost because their wind turbines do not need cranes to be erected. These costs are relevant, of course, to any person's specific location and needs and can vary from only a few thousand dollars to half a million dollars, leaving doubt as to what the actual capital costs would be [14].

The potentially high costs of connecting to the grid greatly offset the payback period, especially after the new data from Mr. Zachary about their price for the electricity. The PSE will, however, connect someone to the grid for almost no cost if the resident agrees to use their "net metering" program. This program offers credits for the resident's electricity generated and "sold" back to PSE; then, when the resident needs electricity while the turbine is not producing, they can use their credits to buy their electricity. This option may be practical if a cheaper wind turbine is purchased, such as the 1.5 to 3 kW, which are much cheaper. However, the HOMER Grid program chose the XANT M-21 100 kW wind turbine because of its wind energy capturing potential [35,36]. Therefore, the importance of other parameters is not taken into account—nor simulated in any way—and their impact might be decisive.

The importance of investing in renewable energy, such as a wind turbine, has proven essential throughout the last decade. Private citizens are even taking the initiative to buy solar panels for their roofs now that the technology is more affordable. Thanks to software such as HOMER Grid, communities and families can investigate their own home solar panel and/or wind turbine. Using the program, one can look up the resources in their area, such as radiance from the sun, wind speeds, and local utility company prices. After conducting the project, the authors recommend that future endeavors contact their utility company for information about buy back prices and grid connection to assure HOMER is accurate. However, it is not panacea. Calhoun et al. [37] have pointed out the possibilities of deception in simulations, pointing out the importance decision makers give to simulation results, while in another study, they stressed the educational and ethical implications [38]. Goldberg et al. [39] pointed out that deceptions of simulations should be considered as unexpected events and take a decision if these are real or not. Realism and a critical approach are always needed, especially when investing is part of the plan. Only few studies have focused on the pitfalls of the software tools, the deceptions in simulations, and the need to quantify decisive parameters that are usually omitted. Using HOMER in an example of a simple case in the US proves that random and qualitative parameters could make an investment from absolutely non-viable to viable and successful investment even if the simulation results are exactly the same. Therefore, it would be helpful to also contact others in the area who have followed through with their own wind turbine and/or solar panel for actual installation costs.

While the resources in the desired location in Bellingham, Washington were not promising, there was still a turbine on the market that could create more than enough electricity for the household. The building permit and the inspections on the property add time and additional cost capital costs. Moreover, connecting to the grid after the permit has been approved and the new turbine shipped and installed could take years to finish and possibly a few tens of thousands of dollars extra. All this time and money added along with the research time means it would take between two to five years to complete. It appears that the biggest obstacle for a consumer looking to lower their carbon footprint are the installation and grid connection costs as well as the loss of the Federal Tax Credit, which would rebate residents 22% of installation and operating costs—a huge benefit that needs to be renewed in 2020 before it expires [14].

In fact, the importance of making personal wind turbines easier and cheaper for residents and communities could be the pathway to relying 100% on renewables, similar to the case study of Denmark, a country currently relying on renewable energy for more than 50% of their energy needs. A movement by residents buying and investing in wind turbine shares drove research and development as well as anti-nuclear lobbyists, who pushed representatives to choose wind turbine investment over nuclear power in the 1970s [2]. While the US is littered with fossil fuel lobbyists, grassroots initiatives from homeowners to purchase wind power could be the accelerator this country needs right now. The nation's leaders need to cover grid connection costs and renew the federal tax credit to make owning personal wind turbines the future.

5. Conclusions

Wind and solar energy contributed in total more than 20% to Europe's power supply in the first half of 2020; Denmark reached 64%, followed by Ireland and Germany, with 49% and 42%, respectively. Thus, great achievements have been made for some countries, but there is still a long way to go, and small-scale wind energy is needed for achieving greater numbers for some countries, and a kick-start for others. This study focused on small-scale wind energy, and specifically on (a) the need of a generation to move on in producing their own electricity, either as a philosophy of life or as a status symbol and (b) the decision-making process. For the latter, it was revealed that there are tools that can simulate and propose hybrid system solutions; however, installation costs, maintenance costs, net metering options, and taxation schemes are not included in most of these tools. This is happening not only for this specific tool, but many more, especially in tools that are linked to investment decisions [40]. Therefore, it is meaningless and careless to only rely on the results of the tool and assume most of the above-mentioned parameters. The different assumptions in these parameters can make a project have a payback period from 10 to more than 20 years, or else from being a totally sustainable project to an inviable one.

However, when seen from a more general perspective, the practical cost for decision makers of counting only on simulation results can be unbearable when this is not coupled with the overall picture. A future educational agenda around the deception of simulations can advance the scientific areas of simulation as a learning tool.

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