UNIVERSITY OF NORTH DAKOTA

FINAL REPORT

SUBMITTED TO

North Dakota Industrial Commission (NDIC)

WORK PERFORMED UNDER AGREEMENT

Contract No. R-046-056c

Electrostatic Lubrication Filtration of Wind Turbine Oil Reservoirs

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SUBMITTED BY
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Requested Funding from NDIC: $286,234
Match Fund from ELF Technologies LLC: $198,380
Match Fund from NextEra Energy: $100,000
Total Proposed Project Cost: $584,614

Total Project Duration: 36 Months (June 1st, 2021 to June 30th, 2024) (18 months plus 18-months of approved extensions)

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1 FINAL REPORT – EXECUTIVE SUMMARY
Project Number: R-046-056c
Recipient: University of North Dakota (CEMRI)
Award Amount: $286,234
Total Project Costs: $584,614

Goal of Project:

The overall goal for this project was to demonstrate a transformational Electrostatic Lubrication Filtration (ELF) technology that significantly increases the operational life of lubricant oils used in industries such as the wind turbine industry, thus reducing maintenance costs and extending the life of critical assets that provide value to the state of North Dakota. To achieve this goal, the project team proposed to significantly reduce the cost of manufacturing the ELF systems and to demonstrate the technology on an active wind turbine in the state of North Dakota.

Significant Findings:

Scaling down and optimizing the ELF technology proved to be successful. A reduction in size of over 90% of the previous generation was achieved, while still yielding comparable filtration performance to all prior models. No negative impacts on the properties of the cleaned oil (additives, viscosity, oxidation) were observed for the scaled down unit. ISO compliance has been achieved with ELF technology, ensuring it meets high-quality standards, legal requirements, and gains a competitive edge in the market. As a result of this project, the technology is now fully deployable and capable of filtering oil reservoirs of nearly all sizes. The second goal of the project – demonstration the technology in an active wind turbine was not completed due to the withdrawal of the wind turbine industry partner late in the project, efforts to secure a new wind turbine partner were unsuccessful before project ended, but will continue beyond project funding.

Next Steps:
Priority is on securing commercial interest for the technology, and explore new markets unlocked thanks to the lower cost and smaller size. This technology is applicable in broader markets, which can now be pursued. These markets include hydropower, biofuels, and other industrial powerplants which use oil.

Benefits of the Project to ND:
ELF company Technologies LLC is actively seeking the first commercial customer for the technology, and anticipates establishing the manufacturing of the units in North Dakota. When successful, this will ensure tax revenue and job creation in ND.

2 Introduction

2.1 Background

ELF Technology, LLC. (ELF) has a novel product to maintain lubricant cleanliness within ISO 9000 standards to extend the usable life, prolong the gearbox's lifespan, and avoid costly turbine shutdowns, all of which will increase the value of the North Dakota wind industry. Proof of concept was established through field-testing on two large lubricant reservoirs of approximately 10,000 gallons. The starting oil condition as defined by ISO 4406:99 specification was 20/19/16, where after 60 days of operation the ELF unit was able to filter the oil to a particle count of 18/16/14, which is over 90% reduction in particulate. The ELF unit achieved a peak of 96% reduction of particles with an ISO code of 16 /15 /13, which is comparable to new oil. For deployment in a wind turbine, scaling down the technology to fit within a wind turbine is required.

2.2 Statement of the problem

Many wind turbine field-operating failures are related to poor lubricant quality, consequentially resulting in gearbox bearing failure. Regular or unexpected maintenance can create significant downtime, resulting in lost revenue from a lack of power generation. Turbine gearboxes use oil to reduce friction. As the turbine spins, tiny contaminant particles are generated from the metal on-metal friction, which sticks to the turbine's internal components and creates what is known as "Varnish Build-up." The resultant varnish necessitates scheduled maintenance and can cause catastrophic failure, resulting in millions of dollars in damages. Mesh strainers and solid particulate filters have been trialed and were found to be inadequate for removing varnish and maintaining and cleaning the oil.

Manufacturers such as General Electric and Siemens provide an ISO 4406:99 specification for lubrication oil to preserve the warranties for their systems and maintain operational integrity. This ISO code, which refers to the level of contaminants at various micron sizes, is typically in the 17/16/13 range for new oil. If the contaminant levels exceed the recommended requirements, the oil is replaced representing a periodic cost. The related labor costs are substantial, and the old, contaminated oil must be disposed of as hazardous waste, representing an additional cost.

2.3 Technology description – Electrostatic Lubrication Filtration (ELF)

The Electrostatic Lubricant Filtration technology was an outgrowth of a decades-old development in the Electrostatic Air Filtration industry. KLEENTEK Industrial Co, Ltd. first reported the application of an electrostatic filter to remove contaminants in oil-based systems. Their work demonstrates that in the case of an oil-based system, the creation of electrostatic fields within the filter stacks charge metallic contaminants, which are then drawn into a series of aluminum plates where they are permanently "welded," eliminating them from the source lubricant. Instead of the "once-through" operation of gas cleanup systems, oil filtration occurs on a 24-hour a day basis when used in a circulating system. This 24-hour filtration is essential, as the efficiency of the one-pass method in an oil-based system is low by conventional gas cleanup standards due to the dialectic properties and high viscosity of the oil. Since the oil is continuously recirculated, the cumulative effects of the relatively low removal efficiencies result in high overall collection efficiencies over time. The ELF apparatus removes contaminants down to the molecular level, which is not the case with their air filtration counterparts. Once the source liquid achieves a contaminant-free consistency, the fluid will remove varnish build-up within the turbine and further protect the internal mechanisms.

The system's design is based upon the fundamental equations governing electrostatic systems provided in the proposal application. The process, as designed for large oil reservoirs, involves a stainless-steel canister housing aluminum plates separated by a medium. These plates provide a large collection area, which improves the overall efficiency and provides adequate surface area for particle collection, yielding a longer lifetime for the filter. When a large electric potential gradient is applied across the plates, an electrostatic field is generated, which attracts positively charged contaminant particles and binds them to the aluminum plates, thereby efficiently removing them from the source lubricant. The source lubricants will have a longer lifespan due to the reduced metal and polymerized oil oxidation contaminants. The ELF Technology can also remove existing varnish buildup from the interior surfaces when added to a "dirty" turbine, reducing or eliminating most maintenance activities. In a "clean" turbine, the ELF Technology is expected to eliminate or significantly reduce the varnish build-up on the turbine surfaces. Utilizing the ELF technology improves the bottom-line for turbine owners by decreasing the cost of frequent oil replacement and increasing revenue from continuous power production.

2.4 Scope of Work

Task 1.0 involved project management and planning. Task 2.0 was On-site field demonstrations at two NextEra wind turbines. Task 3.0 was developing research units, including validation testing and further scale-down. Task 4.0 was market analysis and iso compliance of ELF for commercial deployment.

3 Technical Achievements

3.1 Goals and objectives

The overall goal for this project was to demonstrate and develop the transformational Electrostatic Lubrication Filtration (ELF) technology with the aim of significantly increasing lubricant life, improving turbine performance, and overall increasing the value and economics of the North Dakota wind turbine and renewable energy industry. Four major activities were planned to achieve this goal:

- Scaling down the current ELF system to fit within a wind turbine. This was successfully completed.
- Significantly reducing the costs of the ELF unit to improve the economics for deployment in low operating cost industries link the Wind Industry. This goal was met with a 90% reduction in cost of the system achieved.
- Demonstrate the scaled down and reduced cost system in an actual wind turbine. This task was not successfully completed as project partner NextEra declined to support the demonstration of the technology.
- Achieved ISO compliance by documenting and implementing standardized processes for the ELF organization, including an operator's manual, safety handbook, troubleshooting guidelines and fabrication methods.

3.2 Results and Discussion

3.2.1 Experimental setup and procedure:

UND conducted a study to investigate the effect of different factors, including electrode material, temperature, and applied DC voltage, on collection efficiency. Figure 1 represents the ELF experimental setup and includes a 1) Thermocouple, 2) Oil tank, 3) Control box, 4) heater, 5) Hydac sensor, 6) Motor, 7) Fluid life sensor, 8) Oil canister and filter, and 9) High-voltage connector.

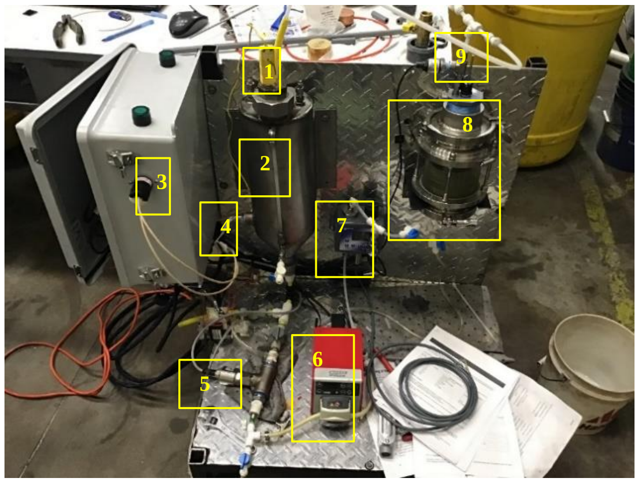

Figure 1: Experimental Setup

Three different electrode materials were used: aluminum, copper, and stainless steel. Both the emitter and collector electrodes were made of the same material given in Figure 2: (Left) Solid Electrode, (Right) Hollow Electrode. To provide the necessary power to charge the particle and filter the oil, a variable high-voltage power source was attached to the emitter and the collector was grounded.

Figure 2: (Left) Solid Electrode, (Right) Hollow Electrode

The design of the experiment is provided in Table 1. The emitter provides a negative charge, while the collector is positively charged. The fluid life sensor reports the oil cleanliness level, and two pressure sensors provide regular pressure rates during the oil flow. The cleaned oil is fed back into the reservoir. To enhance the effectiveness and swiftness of our collection process, foam was installed within the hollow cylinder. The foam had a diameter of 1 inch.

Table 1: Design of Experiment

Electrode Material	Temperature °C	High Voltage Application
Al	50	10 KV
Al	45	5 KV
Al	45	15 KV
Al	50	5 KV
Al	45	10 KV
Al	50	15 KV
Cu	50	5 KV
Cu	45	15 KV
Cu	45	10 KV
Cu	50	10 KV
Cu	50	15 KV
Cu	45	5 KV
Steel	50	5 KV
Steel	50	10 KV
Steel	45	10 KV
Steel	45	15 KV
Steel	45	5 KV
Steel	50	15 KV

3.3.1 The impact of aluminum on the efficiency of collection:

Figure 3 displays the reduction in particle size over a 24-hour period, with measurements taken every four hours. Despite using the same condition and type of oil for testing, the sensor data shows variations in the initial stage of particle collection with the 14-micron size particles consistently collected in higher amounts than other particle sizes, regardless of temperature and voltage conditions.

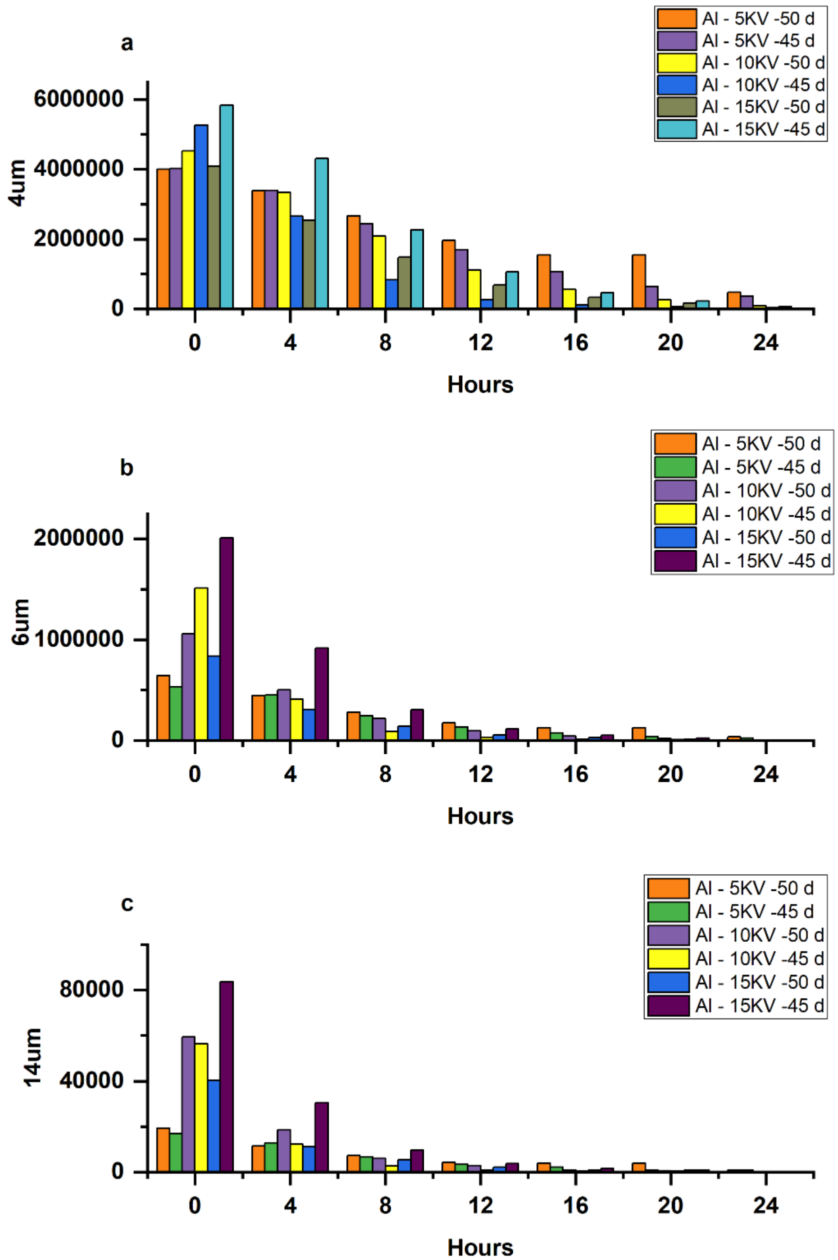

Figure 3: Particle collection speed (Aluminum)

It was observed that smaller particle amounts were collected at the initial stage for 10KV and 15KV at 45°C, but the other particle sizes had nearly the same amount collected. The highest collection rate for aluminum was observed at 10KV and 45°C, with almost 54% collected within 4 hours. The second-highest collection rate was observed at 15KV and 50°C, with 42% collected. The lowest collection rate was observed at 5KV in different temperatures. After the initial stage, all five particle sizes had a similar collection range between 17 to 19%, except for aluminum at 10KV and 4 °C, which had a higher collection rate. see Figure 4.

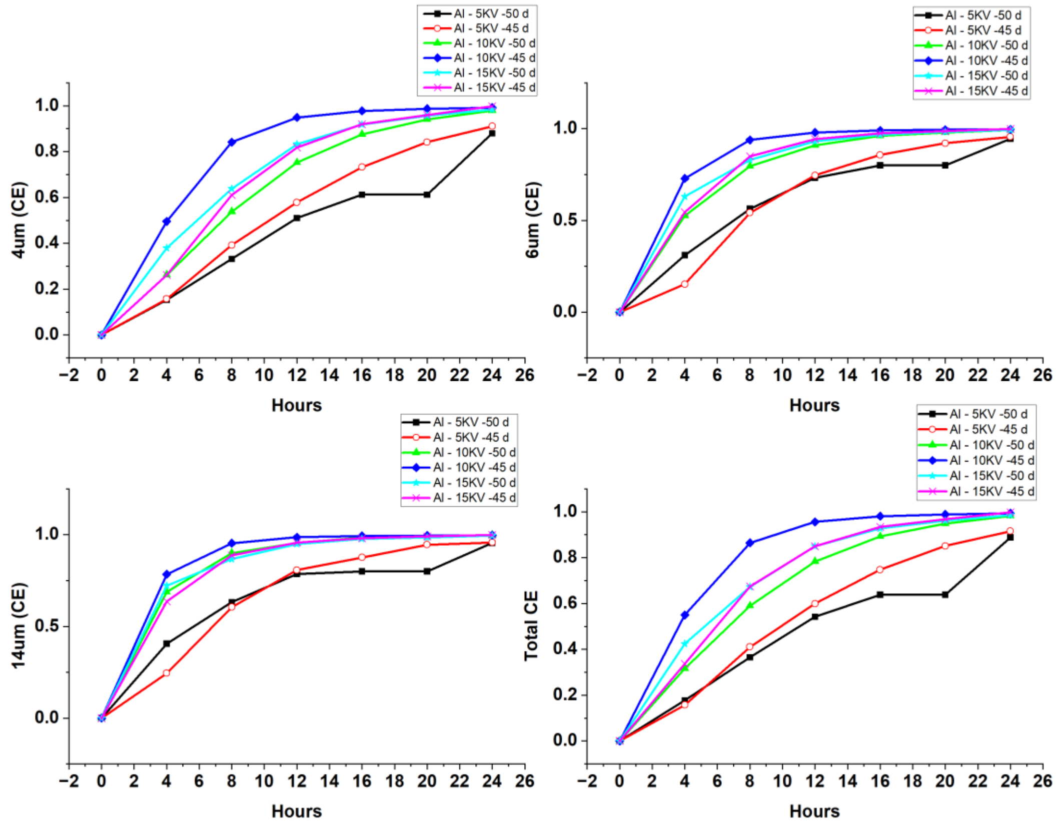

Figure 4: Collection efficiency of different type of particle size and overall collection efficiency

Based on the data presented, it appears that aluminum with 10KV and 45°C had the highest collection efficiency within a period of 8 hours. Aluminum with 5KV and 50°C had the lowest collection efficiency. It is a common understanding that aluminum with a higher voltage is better for particle collection due to its superior electric field. However, it is noteworthy that 10KV demonstrated better results than expected. Upon observation, we noticed that during high voltage applications, there were more particles present compared to other instances. This suggests that it may have collected particles faster. However, it also exhibited a slower collection speed for additional particles.

3.3.2 The impact of Stainless Steel on the efficiency of collection:

In general, high voltage applications are known to have the highest particle collection capacity. However, when used in steel emitter and collector applications, it was discovered that 5KV power application at temperatures of 45°C and 50°C had the maximum particle collection, as opposed to 10KV and 15KV. Based on Figure 5 it can be observed that almost all particles were collected within four hours.

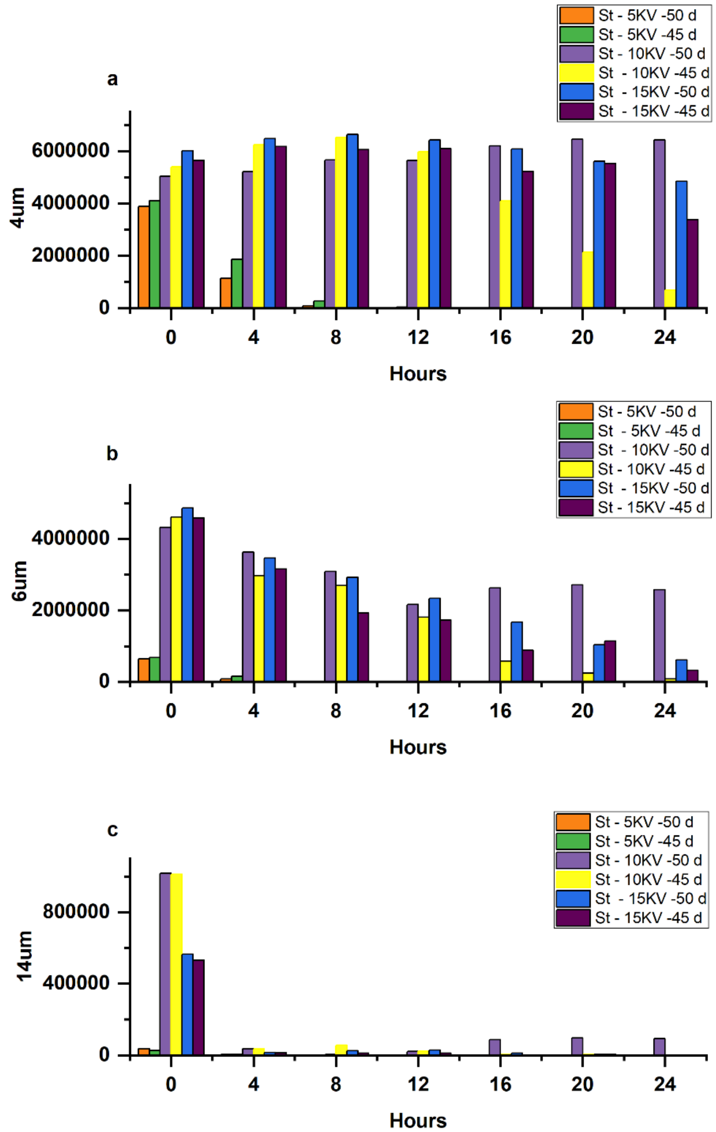

Figure 5: Particle Collection Speed (Steel)

In Figure 6: Collection efficiency of different type of particle size and overall collection efficiency it is evident that 57% and 73% of particles were collected in the first four hours for the 5KV application, while other applications had a maximum of 13% to 16% particle collection that decreased in the next four hours. Surprisingly, particle collection increased for the 10KV and 15KV applications, even though no additional particles or oil were added during testing. Upon further observation, it was found that the temperature had increased by 5 to 6 °C more than the reference point.

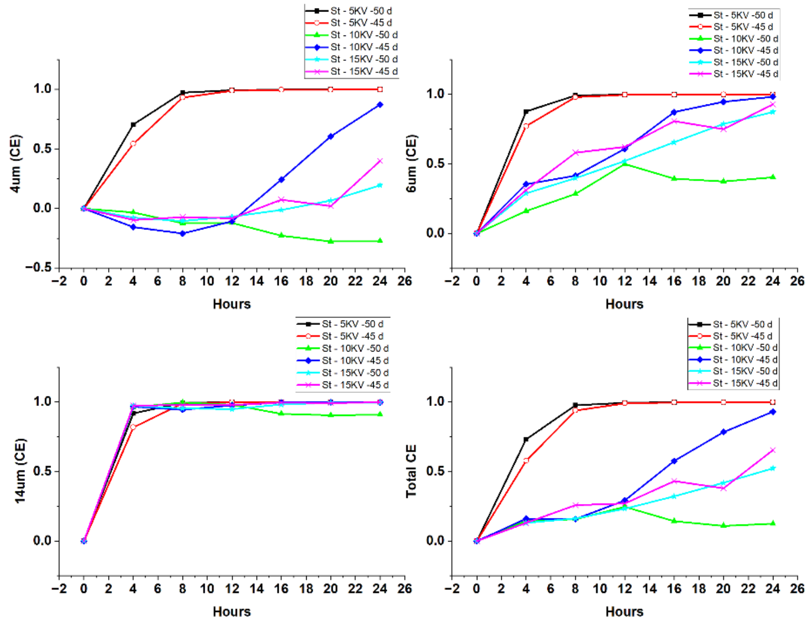

Figure 6: Collection efficiency of different type of particle size and overall collection efficiency

This was a new discovery that the foam could be affected by high voltage and temperature inside the oil, as shown in Figure 7 which presents the foam and electrode condition after the 10KV-50°C application. The presence of a purple color on the electrode and some on the foam indicates that steel with high voltage and high temperature in oil can have a negative impact on the oil. The foam appeared to have melted more in the 10KV application compared to the 15KV application.

Figure 7: Foam and Electrode condition after 10KV- 50 °C application

3.3.3 The impact of Copper on the efficiency of collection:

Copper is known for its excellent conductivity. It has the highest collection efficiency at 15KV and 45°C. **Figure 8** shows that it collected the most particles within four hours. At the start, all conditions had similar amounts of particles, making it evident that 15KV and 45°C had the highest collection rate within four hours. Compared to 10KV applied voltage at 45°C and 50 °C, copper had a 30% higher particle collection rate. Furthermore, it collected over 40% more particles than the conditions at 15KV and 50 °C, as seen in Figure 9Figure 9: Collection efficiency of different type of particle size and overall collection efficiency.

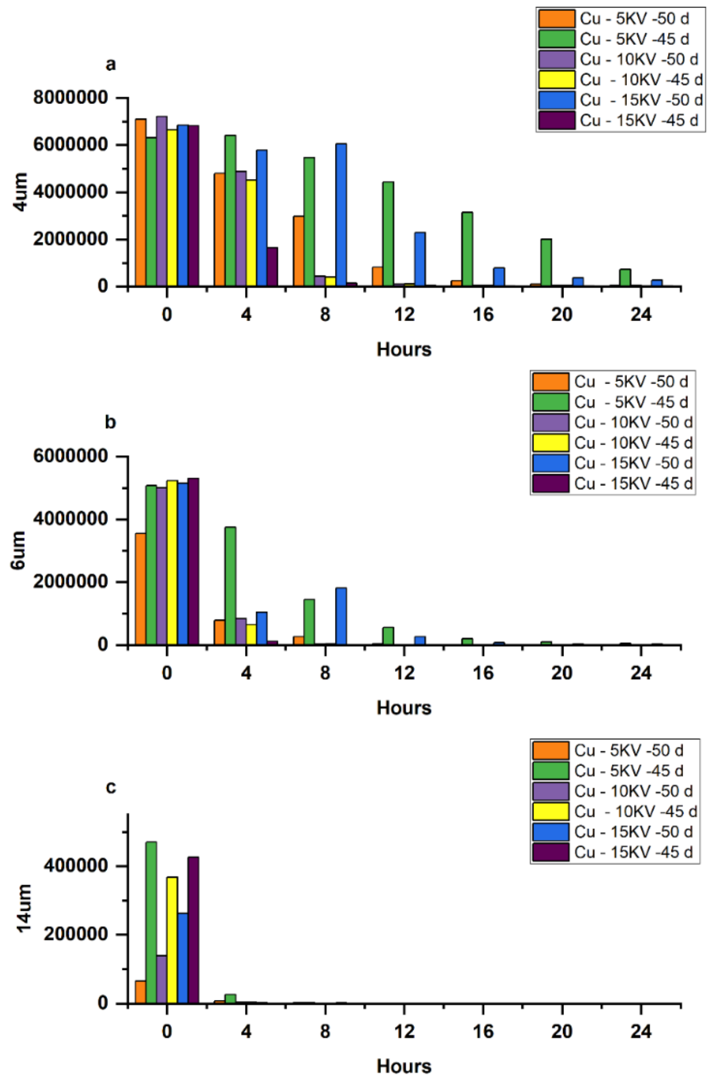

Figure 8: Particle Collection Speed (Copper)

It has been observed that when the system operates at 15KV and 50°C for 12 hours, there is an increase in the size of particles in the system. Upon investigation, it was discovered that the foam had melted and mixed with the oil. A similar occurrence was observed when the system operated at 10KV and 50°C, but it took 16 hours for the particles to increase in size. When the system operates at high temperature and voltage, there is a temperature increase of 5-7°C. This indicates that high voltage and temperature directly impact the foam which is not beneficial for any filter. It is important to note that after 4 hours of operation at 50°C, all three different applied voltages had nearly the same collection rate.

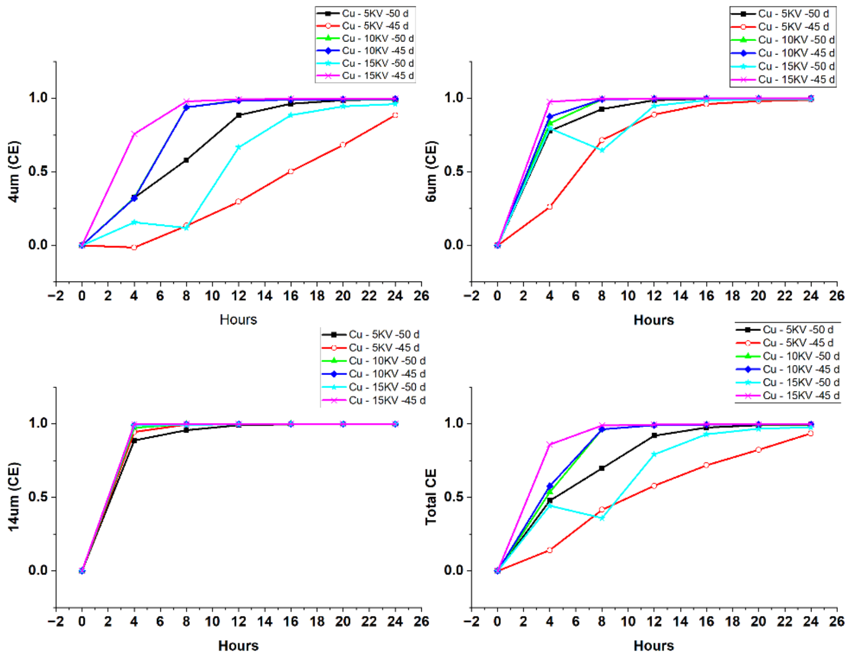

Figure 9: Collection efficiency of different type of particle size and overall collection efficiency

Figure 10 provides a comparison of the overall total collection efficiency. It shows that particle collection follows the same trend for all different temperatures and applied voltages. It takes almost 12 hours to collect 90% of the particles. However, with 10KV and 45 degrees Celsius, it collected over 80% within 4 hours. Copper and Steel showed irregular behavior for different temperatures and applied voltages. Steel showed the best collection at 5KV applied voltage for both 45 and 50-degree Celsius, while Copper showed the best collection at 10KV applied voltage for both 45 and 50-degree Celsius. Both Copper and Steel melted the foam, which is an alarm for high-temperature applications. Aluminum, on the other hand, is free from this risk. Therefore, for high-temperature applications, Aluminum electrodes for both emitter and collector would be the optimal choice.

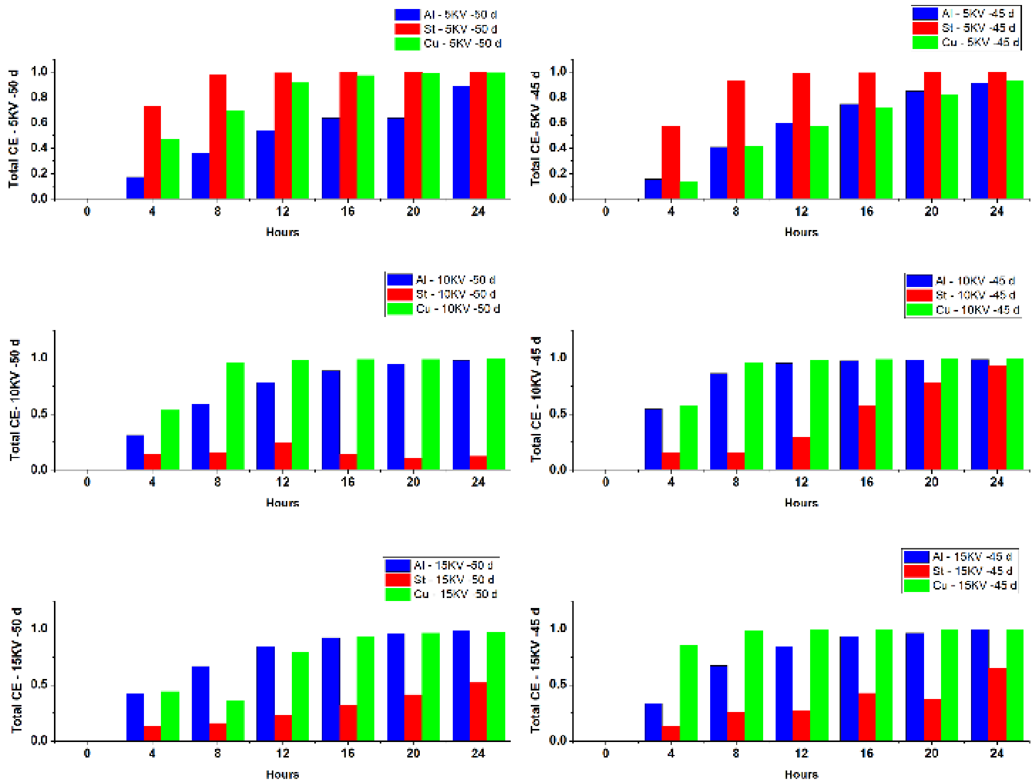

Figure 10: Compare Total Collection Efficiency.

3.3.4 Lab sample test result analysis:

Figure 11 presents the comparison between wear metals and sample number. It is noteworthy that a copper particle caused the significant mark. This particle could have originated from a copper electrode. High Particle Count can result in increased wear of the component. Moreover, wear articles can also contribute to an increase in Particle Count, which ultimately reduces the life of the component. It is important to mention that the other sample did not generate such an alert.

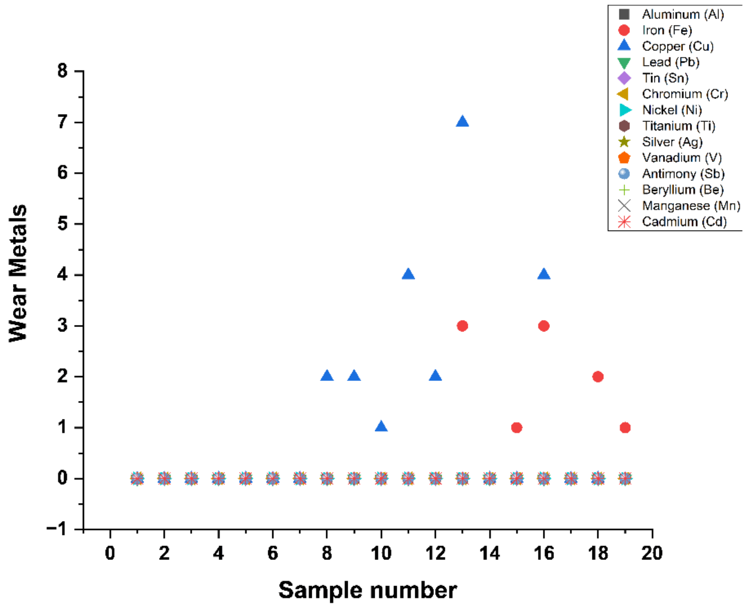

Figure 11: Wear Metal vs Sample numbers

In Figure 12, there is a correlation between contaminants and sample number. Sodium and potassium were within the range of 1 to 2 ppm, while silicon was at 3 ppm. Potassium was found between 1 to 2 ppm and silicon was between 2 to 3 ppm. These results indicate that the contamination levels were within an acceptable range.

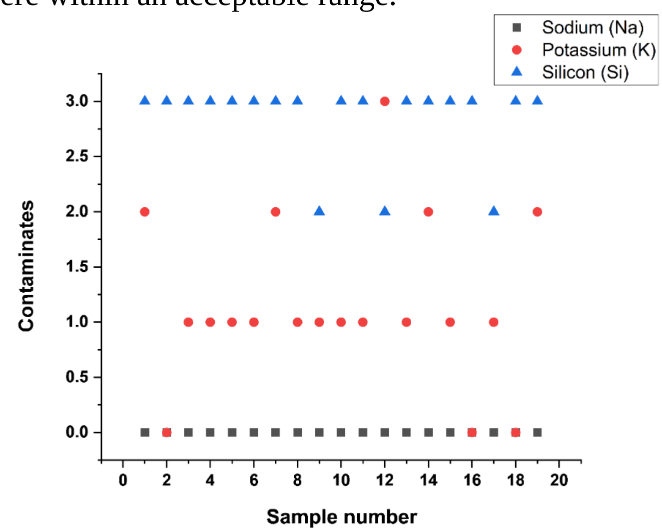

Figure 12: Contaminates vs Sample Number

Through various sample tests, it was found that there were notable fluctuations in the Phosphorus and Zinc levels in a few combinations. The results of the additives versus sample number are showcased in Figure 13. Phosphorus consistently exhibited higher levels than the other additives, but despite the elevated levels, the lab test did not reveal any alarming outcomes. Hence, it can be concluded that the sample is in a satisfactory state.

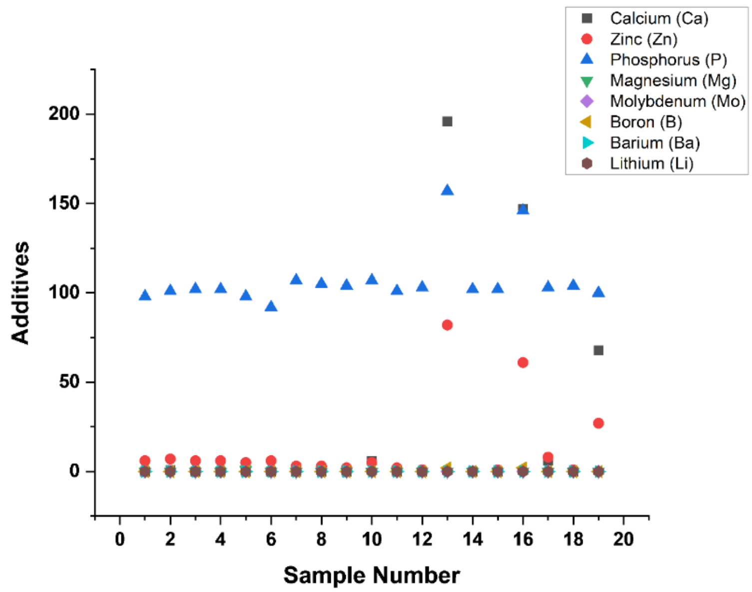

Figure 13: Additives vs Sample Number

No changes were detected in the viscosity or viscosity index for all samples, as they remained within the same range. Viscosity typically has set standard limits for increases and decreases. Cautionary upper limits are usually set at a 10% increase, while critical upper limits are set at a 20% increase. For lower limits, cautionary decreases are usually set at 5 or 10%, while problematic decreases are set at 10 or 20%. displays the viscosity graph versus sample number, where it can be observed that there were no significant changes compared to the new oil viscosity.

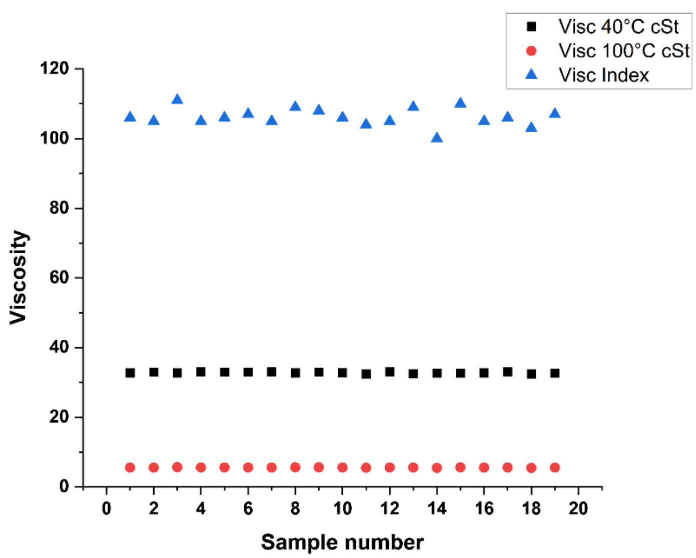

Figure 14: Viscosity vs Sample number

3.3 Optimization and Scale Down for Field Demonstration

The ELF unit has been compacted down to a 20”x16”x12” Pelican Air 1557 case as shown in Figure 15. This represents an overall size reduction of 91% of the large reservoir units. The filter assembly was reduced by 97.5%. Shown on the outside is the oil inlet/outlet, power connection, emergency stop, and communications port. All components were made of readily available commercial materials and rated for use with high temperature oils.

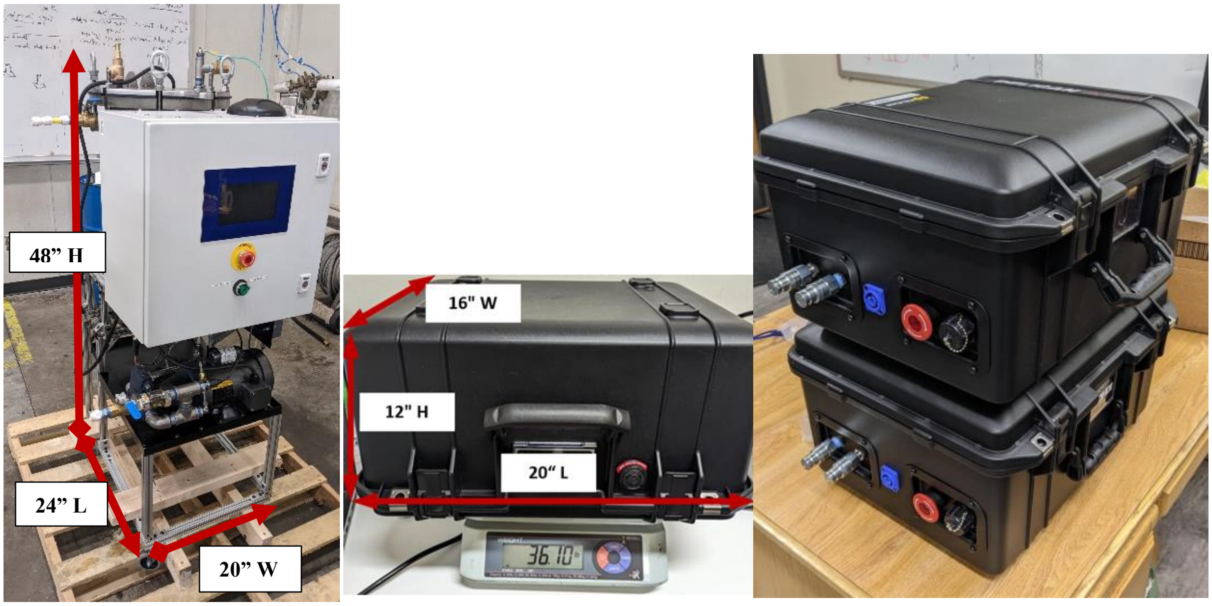

Figure 15: ELF Gen 1 (left) vs Gen 2 Scaled Down Pelican Case (middle, right)

The ELF filter assembly is mounted to the lid of the pelican case as shown in Figure 16. The oil flows into the unit on the right side and leaves on the left. A pressure switch, temperature switch, and leak detector are included for safety purposes. The pressure limit switch is set to 30 psi, which will shut down the unit if a blockage happens. The temperature switch is set to 65C, which will protect the unit/case from overheating.

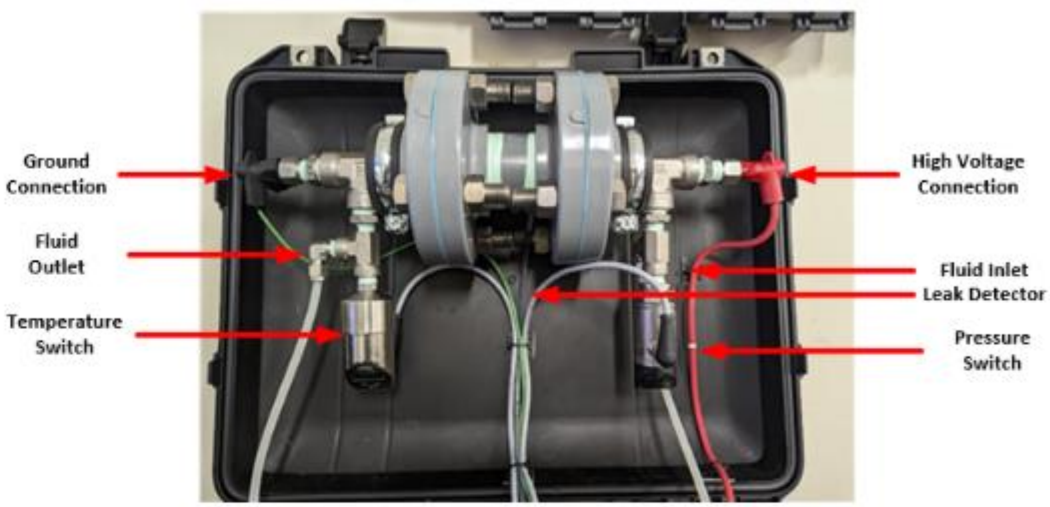

Figure 16: ELF Filter Assembly Mounting Location

The switches and leak detector will provide power to the valves, pump, and high voltage equipment. Power will always remain to the power supply, switches, and leak detector. Each switch also has a digital indicator to give operators a real time process measurement. The electronics assembly is located in the bottom tub of the case, as shown in Figure 17.

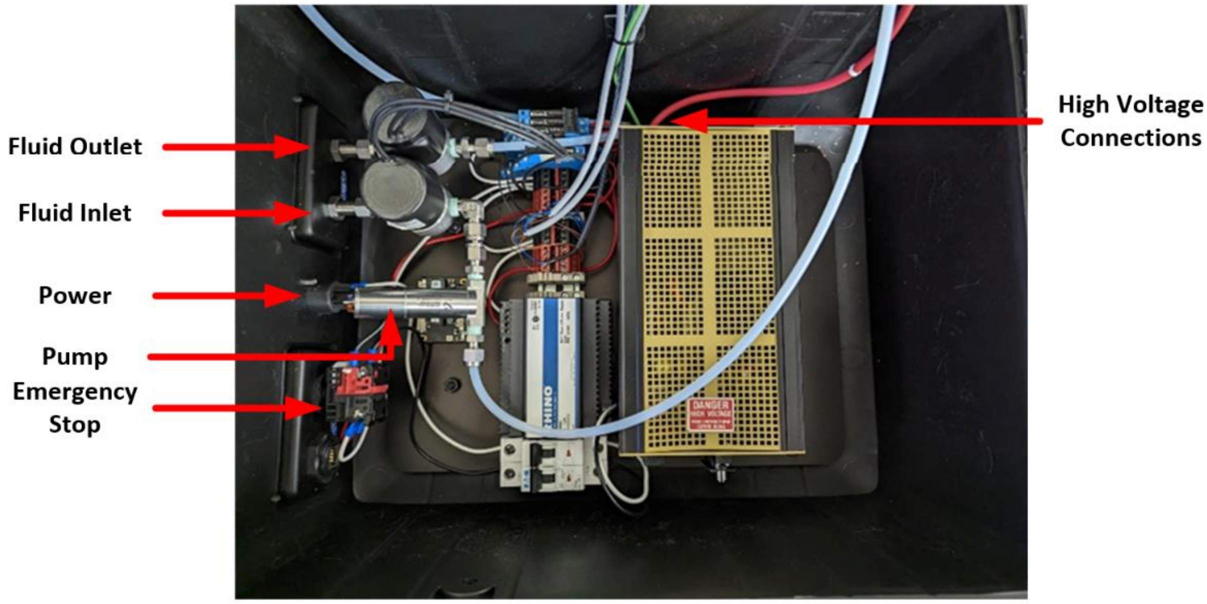

Figure 17: Electronics assembly and inlet valving/pump

The unit draws low power (40 Watts) and weighs only 36.50 lbs when full of oil. This keeps it under the 45 lbs carrying capacity limit for tower climbers and allows for installing in most environments where 120VAC is available. The unit makes use of minimal loss quick connects, which leak less than 0.3 ml when disconnected. The unit's pump could prime up to 5 ft.

Based on these conditions, the unit would be able to cycle through the 20-gallon wind turbine reservoir every six hours. Each wind turbine unit is being tested for robustness and safety shutoff conditions. Each unit was bench tested with several 200-hour continuous runs under varying conditions. Table 2 represents filtration results starting with dirt oil (20/18/16). It shows that the scaled down technology is successful in filtering the dirty oil for a variety of operating conditions, bringing the oil to conditions that are equal to new oil or cleaner.

Table 2: Field Demonstration unit in-house testing

ISO Code	ISO 4u Count	ISO 6u count	Test Description
20/18/16	5180	2440	1 kV
17/15/13	670	200	2.5 kV
18/17/15	1110	390	5 kV
17/16/12	1960	650	14 kV
19/17/12	3150	650	New AW 32 Oil
18/16/13	1580	430	Clean Turbine Oil
20/18/16	6300	2000	Dirty Oil Reference

3.4 Reporting on Field Demonstrations on NextEra Energy wind turbines

We were successful in scaling down and optimizing the ELF technology. It is fully deployable and capable of filtering turbine reservoirs of nearly any size. We have also achieved drastic cost reductions making the technology more economical at the smaller scale. This opens the ELF technology's use to more markets that before this project it would have been unable to enter. However, we were unsuccessful in the field demonstration portion of this project due to the project partner pulling out late into the project.

4 Market Analysis

4.1 Revenue Forecast

The project team performed a revenue forecast for the technology based on all potential industries were the technology could be deployed. Estimates for total revenues from sales, services, and licensing of the ELF technology, to be about $16.5 million dollars during the first 5 years commercialization assuming 4,700 units of Gen 1 to Gen 3 are sold.

4.2 The Market

Our focus initially is on wind turbines, covering their gearbox and hydraulic systems. The most recent U.S Geological Survey reported that there are 74,511 wind turbines covering 45 states[1] for a combined capacity of 140 GW that represents between 10% of electricity generation in the USA. Capturing a 3% market share over five years would represent 3,570 ELF wind turbine apparatus installations, or roughly 60 installations per month. The market for wind turbines is growing: The Department of Energy projects an increase to 224 GW by 2030 and 400 GW by 2050. This market increase presents an opportunity for yearly demand and continuous need for the product.

Table 3: Initial Projected Costs and Earnings (3500 units/5 years)

Projected Costs and Earnings						Cumulative Total
Units produced/year	**250**	**500**	**750**	**1000**	**1000**	3500
	USD/year 1	USD/year 2	USD/year 3	USD/year 4	USD/year 5	
Fixed Costs						
ELF - Gen 3 Material Cost	$ 550,000	$ 1,100,000	$ 1,650,000	$ 2,200,000	$ 2,200,000	$ 7,700,000
Filter Assemblies	$ 6,250	$ 12,500	$ 18,750	$ 31,250	$ 43,750	$ 112,500
Labor (1 shift, X assemblers, 1 manager)	$ 149,760	$ 199,680	$ 249,600	$ 299,520	$ 299,520	$ 1,198,080
Overhead, G&A, and Insurance	$ 120,000	$ 120,000	$ 240,000	$ 240,000	$ 240,000	$ 960,000
Maintenance Costs	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 201,250
Travel Costs	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 150,000
Total costs	$ 896,260	$ 1,502,430	$ 2,228,600	$ 2,841,020	$ 2,853,520	$ 10,321,830
Product Sales						
ELF Unit Sales	$ 1,100,000	$ 2,200,000	$ 3,300,000	$ 4,400,000	$ 4,400,000	$ 15,400,000
Rent/Lease	$ 30,000	$ 60,000	$ 90,000	$ 120,000	$ 120,000	$ 420,000
Licensing (2% of sales)	$ 22,000	$ 44,000	$ 66,000	$ 88,000	$ 88,000	$ 308,000
Aftermarket Parts	$ 12,500	$ 25,000	$ 37,500	$ 62,500	$ 87,500	$ 225,000
ELF Professional Install Service/Fee	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 150,000
Total Revenue	$ 1,194,500	$ 2,359,000	$ 3,523,500	$ 4,700,500	$ 4,725,500	$ 16,503,000
EBIT	$ 298,240	$ 856,570	$ 1,294,900	$ 1,859,480	$ 1,871,980	$ 6,181,170

Cost projections are based on three generations of the system. Gen 2, the scaled down design from this project is currently around $5,300 of the scaled-down unit. This is roughly 6x reduction in cost over the Gen 1 units. Gen 2’s most expensive 4 components account for 87% of the total cost. We estimate further reductions for a Gen 3 design to around $2,200 per unit with economies of scale benefits on the most expensive components. Labor is conservative, with 1 unit built per day per assembler. Two assemblers would be capable of building 500 units per year. Labor is calculated as approximately $50k/yr for assemblers and $100k/yr for a manager. Overhead, G&A, Insurance is estimated at 80%, and maintenance is estimated at a constant 40k/year.

The sale price will land around $4,400 per unit, with additional income in the form of rent/lease agreements, licensing, aftermarket parts sales, and professional installation. The price per unit was guided by budgeting allowances for turbine improvements. Based on a gradual approach with 250 units built in the first year, the potential revenue would exceed one million dollars. Reaching a production of 1000 units a year would result in revenues north of four million dollars per year.

Table 4: Projected Costs and Earning (1000 units/5 years)

Projected Costs and Earnings						Cumulative Total
Units produced/year	**100**	**150**	**250**	**250**	**250**	1000
	USD/year 1	USD/year 2	USD/year 3	USD/year 4	USD/year 5	
Fixed Costs						
ELF - Gen 3 Material Cost	$ 220,000	$ 330,000	$ 550,000	$ 550,000	$ 550,000	$ 2,200,000
Filter Assemblies	$ 2,500	$ 3,750	$ 6,250	$ 9,375	$ 12,500	$ 34,375
Labor (1 shift, X assemblers, 1 manager)	$ 149,920	$ 149,920	$ 149,920	$ 149,920	$ 199,840	$ 799,520
Overhead, G&A, and Insurance	$ 89,952	$ 89,952	$ 89,952	$ 89,952	$ 89,952	$ 449,760
Maintenance Costs	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 201,250
Travel Costs	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 150,000
Total costs	$ 532,622	$ 643,872	$ 866,372	$ 869,497	$ 922,542	$ 3,834,905
Product Sales						
ELF Unit Sales	$ 440,000	$ 660,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 4,400,000
Rent/Lease	$ 12,000	$ 18,000	$ 30,000	$ 30,000	$ 30,000	$ 120,000
Licensing (2% of sales)	$ 8,800	$ 13,200	$ 22,000	$ 22,000	$ 22,000	$ 88,000
Aftermarket Parts	$ 5,000	$ 7,500	$ 12,500	$ 18,750	$ 25,000	$ 68,750
ELF Professional Install Service/Fee	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 150,000
Total Revenue	$ 495,800	$ 728,700	$ 1,194,500	$ 1,200,750	$ 1,207,000	$ 4,826,750
EBIT	$ (36,822)	$ 84,828	$ 328,128	$ 331,253	$ 284,458	$ 991,845

With a more conservative approach of ~1% market capture, or 1000 units across 5 years, the break-even point is around 120 units per year. The total revenue across this time is near five million dollars.

There are still many opportunities with technology at the larger scale as well. According to the EIA, there are 12,538 utility scale power plants in the USA, representing bio power, coal, and natural gas[2]. As shown in Table 5, a 3% market capture across 10 years would represent total revenues of approximately $22 million. Biomass power represents more than 350 of these plants[3].

Table 5: Gen 1 ELF Projected Costs and Earnings

Gen 1 - Large Reservoirs Projected Costs and Earnings											Cumulative Total
Units produced/year	**12**	**12**	**24**	**24**	**24**	**48**	**48**	**48**	**48**	**48**	336
	USD/year 1	USD/year 2	USD/year 3	USD/year 4	USD/year 5	USD/year 6	USD/year 7	USD/year 8	USD/year 9	USD/year 10	
Fixed Costs											
ELF - Gen 3 Material Cost	$ 288,000	$ 288,000	$ 576,000	$ 576,000	$ 576,000	$ 1,152,000	$ 1,152,000	$ 1,152,000	$ 1,152,000	$ 1,152,000	$ 8,064,000
Filter Assemblies	$ 12,000	$ 12,000	$ 24,000	$ 24,000	$ 24,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 336,000
Labor (1 shift, X assemblers, 1 manager)	$ 149,920	$ 149,920	$ 149,920	$ 149,920	$ 149,920	$ 199,840	$ 199,840	$ 199,840	$ 199,840	$ 199,840	$ 1,748,800
Overhead, G&A, and Insurance	$ 89,952	$ 89,952	$ 89,952	$ 89,952	$ 89,952	$ 119,904	$ 119,904	$ 119,904	$ 119,904	$ 119,904	$ 1,049,280
Maintenance Costs	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 40,250	$ 40,251	$ 40,252	$ 40,253	$ 40,254	$ 40,255	$ 402,515
Travel Costs	$ 4,000	$ 4,000	$ 8,000	$ 8,000	$ 8,000	$ 16,000	$ 16,000	$ 16,000	$ 16,000	$ 16,000	$ 112,000
Total Costs	$ 584,122	$ 584,122	$ 888,122	$ 888,122	$ 888,122	$ 1,575,995	$ 1,575,996	$ 1,575,997	$ 1,575,998	$ 1,575,999	$ 11,712,595
Product Sales											
ELF Unit Sales	$ 720,000	$ 720,000	$ 1,440,000	$ 1,440,000	$ 1,440,000	$ 2,880,000	$ 2,880,000	$ 2,880,000	$ 2,880,000	$ 2,880,000	$ 20,160,000
Rent/Lease	$ 28,800	$ 28,800	$ 57,600	$ 57,600	$ 57,600	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 806,400
Licensing (2% of sales)	$ 14,400	$ 14,400	$ 28,800	$ 28,800	$ 28,800	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 403,200
Aftermarket Parts	$ 24,000	$ 24,000	$ 48,000	$ 48,000	$ 48,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 672,000
ELF Professional Install Service/Fee	$ 4,000	$ 4,000	$ 8,000	$ 8,000	$ 8,000	$ 16,000	$ 16,000	$ 16,000	$ 16,000	$ 16,000	$ 112,000
Total Revenue	$ 791,200	$ 791,200	$ 1,582,400	$ 1,582,400	$ 1,582,400	$ 3,164,800	$ 3,164,800	$ 3,164,800	$ 3,164,800	$ 3,164,800	$ 22,153,600
EBIT	$ 207,078	$ 207,078	$ 694,278	$ 694,278	$ 694,278	$ 1,588,805	$ 1,588,804	$ 1,588,803	$ 1,588,802	$ 1,588,801	$ 10,441,005

The job growth and supply chain required to meet this demand translates to multitudes of jobs and millions of dollars of economic impact with a significant ripple effect throughout the North Dakota economy. The economic impact also grows exponentially when considering the variety of unique applications outside of wind farm arrays where an ELF unit can be utilized. The technology is already being used in coal-fired power plants in the state and is looking to be adopted into bio power and natural gas combined cycle plants.

5 ISO Compliance

The UND team, in conjunction with ELF, has documented processes and procedures needed for achieving ISO 9001 compliance. The project team has completed work on an operator's manual, safety handbook, troubleshooting guidelines and fabrication methods to comply with ISO quality standards. This work has been performed and iterated to include both generation/scales of the technology. Achieving this compliance will enable ELF technology to access the global market and facilitate ongoing improvement.

6 Financial Summary/Expense Descriptions

Table 6: Project Expenses as of 6-26-2024

Budget Category	Total Project	Total Accumulated Expenses	ELF	Accumulated Expenses	NDIC	Accumulated Expenses	NextEra Energy	Accumulated Expenses
Personnel	$ 267,270.00	$ 328,840.00	$ 112,500.00	$ 170,000.00	$ 154,770.00	$ 158,840.00	$ -	$ -
Travel	$ 29,741.00	$ 30,470.00	$ 20,880.00	$ 30,470.00	$ 8,862.00	$ -	$ -	$ -
Equipment	$ 68,247.00	$ 44,189.00	$ 25,000.00		$ 43,247.00	$ 44,189.00	$ -	$ -
Supplies	$ 10,050.00	$ 3,565.00	$ 6,250.00		$ 3,800.00	$ 3,565.00	$ -	$ -
Subcontracts	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ -	$ -	$ -	$ -
Other Direct Costs	$ 104,900.00	$ 27,755.00	$ -	$ -	$ 4,900.00	$ 6,005.00	$ 100,000.00	$ 21,750.00
Indirect Costs	$ 101,906.00	$ 133,264.00	$ 31,250.00	$ 64,214.00	$ 70,656.00	$ 69,050.00	$ -	$ -
Total Cost	$ 584,614.00	$ 570,583.00	$ 198,380.00	$ 267,184.00	$ 286,234.00	$ 281,649.00	$ 100,000.00	$ 21,750.00
Percent of Total	100%		33.93%		48.96%		17.11%	
	% Remaining	2.40%	% Remaining	-34.68%	% Remaining	1.60%	% Remaining	78%

7 DISCLAIMERS

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8 Citations

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3. Biomass Power Research - NREL. (n.d.). https://www.nrel.gov/docs/gen/fy98/24865.pdf