New Dominion Enterprises Inc.

February 16, 2018 (Updated)

We are pleased to present to you a copy of a Technology Assessment Report written by the University of Texas at Austin, IC^2 Institute.

Please note that since the report was written, we have accomplished the following key milestones:

- The intellectual property for the Inorganic Additive known as FM2 has been secured via an exclusive license from Idaho National Laboratory. Included in this license is an option for an exclusive license for a second product, an Inorganic Co-solvent (referred to as PA).

- Two major manufacturers of lithium batteries dealing with the energy storage, grid back-up and transportation sectors have agreed to test the additive material in their batteries (third party validation).

- The Jeff Dahn Research Group at Dalhousie University that is in a research partnership with Tesla Motors to develop lithium ion batteries with longer lifetime, higher energy density and lower cost has agreed to test the additive material in its batteries (third party validation).

- A company capable of manufacturing sample quantities up to 100 kilograms per month has been identified. This company has indicated that it should be able to introduce us to companies that will be able to supply the full scale-up quantities of the material when demand requires.

We look forward to further discussions with you.

Jay Fraser, President

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The University of Texas at Austin
IC² Institute
Office of the Vice President for Research

NEW DOMINION ELECTROLYTE ADDITIVE

Brief Technology Assessment Report

January 2018

Summary: New Dominion Enterprises Inc. (NDE) is seeking to commercialize new inorganic electrolyte additives for lithium batteries that will stabilize organic lithium ion battery electrolytes. The additives replace a percentage of the organic materials and improve the thermal performance and chemical stability of the lithium battery electrolytes. Furthermore, it allows significantly increased operational duty cycles over existing lithium battery technology. The technology has significant economic potential as it partially solves the key issues currently faced by lithium ion battery producers by replacing the organic electrolytes with Phosphazene-based inorganic electrolytes. Idaho National Labs owns a process patent that protects the intellectual property of the innovation and NDE is in the process of negotiating an exclusive license to the patent and plans to sell the additive to battery manufacturers as a substitute for a percentage of the volume of electrolytes in lithium batteries. While the technology shows tremendous potential, there is still a long path to commercialization as NDE must still secure the IP rights, raise the necessary funding and proceed through additional development and testing. The technology has significant market potential in both defense and commercial applications with successfully testing already having occurred with the Department of Defense. However, the technology still faces an uphill challenge with scaling to production levels and commercialization.

1. Technology Description

New Dominion Enterprises Inc. (NDE) is seeking to commercialize a new inorganic electrolyte additive for lithium batteries that will stabilize organic lithium-ion battery electrolytes. Existing lithium-ion batteries are inherently unstable and are prone to fire or explosion. Several high-profile examples of damage caused by lithium-ion batteries include Samsung's Note 7 mobile phone,[1] Sony's laptop batteries,[2] and Boeings "cockpit smoke" from overheating batteries underneath the cockpit.[3] NDE claims to solve these problems by using inorganic electrolyte additives to replace 25% of the organic materials and improve the thermal performance and chemical stability of the lithium battery electrolytes. Furthermore, the inorganic additive significantly increases the number of operational duty cycles compared to existing lithium battery technology.

Dr. Mason Harrup, one of NDE's co-founders, developed the technology while he was at Idaho National Labs (INL). The company plans to license the additive to a large chemical manufacturer who already has the necessary production capabilities. The processed inorganic electrolyte will then be sold to battery manufacturers to replace a portion of organic electrolytes in the manufacturer's batteries.

The technology has significant economic potential as it partially solves the key issues currently faced by lithium-ion battery producers. The primary usage for this technology will be commercial, but Department of Defense uses are also significant. IBIS World reports that the primary DOD applications for battery technology are transportation and communications equipment.[4] There are challenges to commercialization including, securing the license to the technology from INL, securing funding for testing and the time requirements for a validation test of the technology. Despite these drawbacks, the potential of the technology to have a significant impact on the battery market makes it worth considering for the testing stage of commercialization.

2. Uniqueness:

Electrolyte chemistry is the primary limiting factor for the next generation of Li-Ion batteries, especially for energy storage and electric vehicle applications. Currently, electrolytes for lithium-ion batteries are composed chiefly of organic carbonate solvents mixed with a lithium salt for ionic conductivity. While these electrolytes efficiently convey lithium-ions from one electrode to the other during operation and re-charging, they suffer from several intrinsic flaws. The fundamental flaws of current Li-Ion battery electrolytes (mostly LiPF6 salt dissolved in a mixture of organic carbonate solvents) are as follows:

1. Loss of useful power after multiple charge/discharge cycles due to heat build-up
2. Irreversible material decomposition of the electrolyte and loss of soluble lithium
3. Potential safety issues from thermal runaway
4. Increased safety and energy density requirements for large lithium-ion cell packs for electric vehicle and storage cells

NDE solves these problems by replacing the organic electrolytes with phosphazene-based inorganic electrolytes. The company has refined and tested the process for replacing up to 25% of the organic compounds with plans to increase the number to 100% in a second development phase. The company monitors publicly available information and patent filings for competing companies targeting a similar path for battery chemistry. As of the date of this report, NDE has not discovered any similar claims.

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[1] http://www.techradar.com/news/samsung-galaxy-note-7-battery-fires-heres-why-they-exploded [Accessed November 16, 2017]
[2] https://www.cpsc.gov/Recalls/2016/sony-recalls-vaio-laptop-computer-battery-packs [Accessed November 16, 2017]
[3] http://www.bbc.com/news/business-21054089 [Accessed November 16, 2017]
[4] LeClair, Madeline. 2016. "*Lithium Battery Manufacturing in the U.S.*" IBIS World. p. 13

3. Problem Validation and Market Potential:

The technology is a good fit for Department of Defense applications as well as other industrial and consumer applications because high-density, stable lithium batteries are needed for 1,000's of military and commercial uses. If this technology can be successfully commercialized, it could have a monumental impact on a variety of industries. One example is electric vehicles (EV). Most EV's have a relatively small range before they need to be recharged.[5] With a more stable battery, the energy density could be increased which would also increase the range of the vehicle. Other adjacent transportation markets include buses, subway systems, railroad locomotives, and 18-wheeler trucks. "The opportunity is exponential."[6]

The previously mentioned challenges with unstable batteries from Samsung, Sony, and in Boeing aircraft, resulted in millions of dollars of lost profits to recall products, and in the case of Boeing, grounded aircraft and a delayed production schedule on the 787 Dreamliner. NDE battery technology could reduce the costly recalls and expand the overall market into other areas that are currently served by other battery technologies.

4. Technology Validation:

Dr. Mason Harrup developed the inorganic electrolyte additive for batteries while he was at Idaho National Labs (INL). The DOD provided the funding for the initial development of the technology. Dr. Harrup has partnered with Jay Fraser to commercialize the technology, and the pair are in ongoing negotiations with INL to license the additive. NDE plans to bring the technology to market through a licensing agreement with chemical manufacturing partners that can scale up production faster than NDE could on its own. NDE will add value by providing the technical expertise on the development of the additive as well as sales and marketing to battery manufacturers. Mr. Fraser shared that they have four non-disclosure agreements with potential partners and end-users.[7]

The technology has been successfully tested by Dr. Harrup and the process has been developed and refined so it is ready for both third-party testing as well as scaling to production levels. The technology is owned by Idaho National Labs, and NDE is in ongoing negotiations for the license to the technology. Currently NDE is the only bidder for the technology. Dan Vogler provided a high-level assessment of the chemical components of the technology and confirmed that based on the available information, the battery should be viable. It will require third-party testing to validate those claims. The commercialization path is outlined in the Market Analysis and Strategy section below.

5. Intellectual Property Protection:

Idaho National Labs (INL) owns a process patent that protects the intellectual property of the innovation. NDE is in negotiations with INL to secure an exclusive license to the patent and plans to sell the additive

[5] Berckmans, Gert et al. 2017. "*Cost Projections of State of the Art Lithium-Ion Batteries for Electric Vehicles up to 2030. p. 2.*
[6] Interview with Dan Vogler conducted November 2017
[7] Interview with Jay Fraser conducted October 2017

to battery manufacturers as a substitute for a percentage of the volume of organic electrolytes in lithium batteries. The additive will be produced in conjunction with a large chemical manufacturer and then licensed to the battery manufacturer.

6. Market Analysis and Strategy:

Attached in the appendix of this report are summaries of interviews conducted with several industry experts and potential end-users of the NDE technology. Their insights provided a baseline evaluation of the technology as well as helped to substantiate the market potential. A few highlights are below:

- Lt. Col Steve Fournier U.S. Air Force (retired). Col Fournier provided a high level assessment of the NDE's batteries for military use. One of the biggest challenges with making changes to the existing battery technology is dealing with the supply chain logistics. In essence, all of the manufacturers of the various pieces of equipment from radios, to GPS units, to handheld devices would need to adopt the new technology. It is unlikely the military would go through that process unless the returns were monumental.
- Jon Johnston: Mr. Johnston is a mechanical engineer that specializes in lithium-ion battery safety. He indicated the primary battery trend is to make things more compact and dense. He noted that producers are competing for energy density. If the NDE electrolyte has inferior performance to existing solutions then it is a problem. Performance and safety are both equally important factors when considering a battery for commercial applications. For battery safety, sometimes you do things with software to limit over-charging or under-charging. With increased safety at the cell level it would be possible to reduce add-ons, which could potentially increase the operating range of the battery.
- Captain Bill Rojek. Captain Rojek is a medical officer in the U.S. Army He observed that In aggregate there are pockets of units that use batteries. Some combat units are using small portable drones connected to tablets for surveillance. There may be an opportunity for portable applications. There are temperature extremes in Iraq and Afghanistan that need to be considered for any battery tech. Current suppliers for DOD products will have latitude to source new materials as long as it is within specifications.
- Dan Vogel: Mr. Vogel is the former CTO of California Lithium Battery and is very familiar with the industry. He provided extensive observations on the viability of the technology and laid out a path for production to scale the NDE battery up to commercial levels. He highlighted the importance of testing the technology by 3rd-party labs. He emphasized if the battery can do what NDE claims, it will be very lucrative commercially and will have many military applications as well.

According to Dan Vogel, if the technology is as good as it claims, then the major battery producers will easily adopt it. Consumer and industrial users are constantly looking for increased battery life, more safety, and increased battery cycles. Based on the interviews and research conducted for this report the recommended path for commercialization is as follows:

During the course of the interview with Dan Vogel, he recommended testing the battery with a 3rd party lab and suggested the resources at the University of Texas' Engineering School would be an ideal location. He estimates that for between $50-100K the testing could be completed and then for another $5 million the battery could be scaled up to production levels. Dr. John Goodenough at the University of Texas is credited with discovering the sequence and chemical components that went into what eventually became lithium-ion batteries. As such, the domain expertise, testing equipment, and research capacity are all at the university. The missing ingredient is funding. A seed round of $100K in funding should be feasible given the promise of the technology and then subsequent funding will be easier to acquire with successful test results.

Mr. Vogel's funding requirements he suggested for commercialization path are virtually identical to the numbers shared by Jay Fraser. This cross-corroboration from an outside source confirmed that New Dominion had a clear understanding of the necessary steps and funding requirements to bring the inorganic electrolyte additive to the market.

7. Competitive Matrix:

	Advantages	Disadvantages	Comparison to this innovation
NDE, (inorganic electrolyte additive):	Inorganic electrolyte that increases the stability of batteries as well as the number of duty cycles	Technology needs to be further tested and is not scaled up to production levels	
Tesla (organic electrolyte batteries)	Massive scale and production capacity coming online soon	Older technology and organic electrolyte that doesn't have the stability or range potential of NDE	NDE claims to have superior performance and stability. NDE is a startup company with limited resources.
Samsung (organic electrolyte batteries)	Economies of scale and production capability	Organic electrolyte technology caused mobile phone fires that resulted in financial losses as well as a loss of trust in the market	NDE claims to have superior performance and stability. NDE is a startup company with limited resources.
Panasonic (organic electrolyte batteries)	Well known reputation for quality, currently producing Tesla's batteries and will be running the giga-factory with its equipment	Organic electrolyte technology that doesn't have the stability or charge cycle potential of NDE	NDE claims to have superior performance and stability. NDE is a startup company with limited resources.

8. Key Findings:

Tesla and Panasonic have a joint venture to develop and produce batteries for Tesla's car production. Once the factory is complete, it will produce more than the entire world's current lithium battery production.[8] Though it is risky to tie up with only one customer, securing a business relationship with Tesla will be important to the long-term success of NDE. Assuming the technology does indeed provide the promised gains and stability, one would expect that a business deal could be made.

The NDE battery technology has significant market potential with uses in both commercial and defense applications. The path to commercialization will likely be through industrial markets, and then defense contractors can integrate the technology into DOD specified applications. Based on the massive potential of the technology and the current development and funding stage of the company, obstacles for commercialization appear to be surmountable.

Though the endorsement for the technology is optimistic based on the potential opportunity and the validation provided by industry experts, there still are a several things to consider. First, the rights to the technology are not yet secured. This could be a significant problem that will need to be solidified before further investment capital is put towards the project. Secondly, the company does not have any funding at this point and does not have the means to do the basic testing. Finally, it will require a minimum of 10 months for a third party to fully test the technology. Despite these cautions, I still recommend the technology at least move to the testing stage as the funding requirement for the test is relatively small compared with the multibillion-dollar opportunity of a successful new additive.

[8] https://www.tesla.com/gigafactory [Accessed November 16, 2017]

Appendices:

Interview Notes:

1. Jay Fraser: President of NDE
2. Steve Fournier: End User
3. Jon Johnston: Partner/Channel
4. Dan Vogel: Industry/Technical Validator
5. Bill Rojek: End User

Key secondary research sites or documents for further investigation:

1. https://www.wired.com/2017/03/dont-blame-batteries-every-lithium-ion-explosion/website
2. https://www.army.mil/article/141816/unprecedented_technology_poses_challenges_for_special_ops
3. Berckmans, Gert et al. 2017. “Cost Projections of State of the Art Lithium-Ion Batteries for Electric Vehicles up to 2030
4. LeClair, Madeline. 2016. “Lithium Battery Manufacturing in the U.S.” IBIS World
5. Weatherill, Jay. “Tesla to pair largest lithium-ion battery with Neoen Wind Farm in SA”

INTERVIEW NOTES

NAME: Jay Fraser
Title: President
Organization: New Dominion Enterprises
City: San Antonio
Phone: 210-542-0014
Email: jay@newdominionenterprises.com
Interviewee Type: Company Representative

Interview Date: October 2017
Via phone
Interview conducted by Michael Peterson

Product is finished has been tested in a DOD contract.

Formulation is known, method of manufacturing it is known. There is no magic in scaling the mfg. up to the kilogram and metric ton stage. The issues are identifying places where we can go from the kilo to the metric ton stage of production. Don't have any interest in becoming a chemical mfr. company. There is too much liability to go that way. Want to reduce complication in process and license the margins.

The technology doesn't completely reduce the fire hazard but it is self-extinguishing. For example: have a demonstration video of an 8-cell battery pack. There is a center pack surrounded by 7 cells. The center cell is purposefully ignited and all the other cells catch fire.

In the second scene, it is the same battery pack, but the center cell has 20% inorganic material. It is overcharged and catches fire, self extinguishes and the 7 cells are unaffected.

The cells last longer on a charge with the chemical compound. Additive will slow the degradation of the battery. Will prevent the battery from eventually dying.

The company has one mfr. partner that they have used in the past. Expect to be able to do single digit kilograms of production. NDE has had discussions with chemical companies that should be able to do the production. It will require a large chemical company to do the production.

Another potential application is public transportation like buses. Long-term, the largest market is China who has decided to go fully electric within the next decade. Backup power supplies for the grid that capture the renewable energy that is being produced by wind and solar will be another significant market.

Business plan calls for $3.5-5Million in funding long-term and $150K in the short tem to get final testing completed. Mr. Fraser currently has NDA's with four companies.

NAME: Steve Fournier
Title: LT Col, Pilot U.S. Air Force (Retired)
Organization: U.S. Air Force
City: Austin
Phone: 512-739-7661
Email:
Interviewee Type: DOD (end-user)

Interview Date November 2017
Via phone
Interview conducted by Michael Peterson

Mr. Fournier is a retired Lieutenant Colonel in the U.S. Air Force. He provided insights on the technology based on his 20+ years of military experience.

One of the biggest challenges with making changes to the existing battery technology is dealing with the supply chain logistics. In essence, all of the manufacturers of the various pieces of equipment from radios, to GPS units, to handheld devices would need to adopt the new technology. It is unlikely the military would go through that process unless the returns were monumental.

NAME: Jon Johnston
Title: Senior Mechanical Engineer for Li-ion Battery Modules
Organization: A123 Systems
City:
Phone: 734-926-6534
Email:
Interviewee Type: Channel

Interview Date November 2018
Via phone
Interview conducted by Michael Peterson

Mr. Johnston is a senior product development engineer A123 systems. He specifically focuses on the safety aspects of lithium-ion batteries the company develops.

In general, the industry is putting more energy into a smaller space. When there is a thermal runaway event there is a more energy to be released. The NDE technology is promising because it is self-extinguishing.

There isn't a lot of interest in things that increase the size of the battery. People are competing for energy density. If this electrolyte has inferior performance to existing solutions then it is a problem. Performance and safety are on par with one another in terms of commercial importance.

Production issues: the mix of chemicals that goes into a battery is very specific. It is difficult to change an ingredient in the chemistry it is very difficult on an existing production line. Production happens in a clean room.

For battery safety, sometimes you do things with software to limit over charging or under charging. With increased safety at the cell level it would be possible to reduce add-ons that could increase the operating range of the battery.

Mr. Johnston recently attended a battery conference where several smaller companies were looking for partners to help develop the technology. A conference or a scholarly partner may be a good outlet to find a development partner.

NAME: Dan Vogler
Title: CEO
Organization: The Corporation of Things/California Lithium Battery (former)
City: Austin
Phone: 512-923-4741
Email: dan@falcongreen.com
Interviewee Type: Tech Expert

Interview Date November 2018
Via phone
Interview conducted by Michael Peterson

Mr. Vogler is the CEO of The Corporation of Things, an IoT company targeted towards the smart grid, measurement and control of electricity he was the CTO of California Lithium Battery (CLB). CLB engaged Argon National Labs in Chicago for battery technology and he managed a contract for 18 months with them. Argon has 30 plus researchers dedicated to lithium batteries. CLB focuses on graphene silicon stabilized anodes, improvements in an electrolyte and a separator.

The National Labs love to commercialize technologies through a license on a non-exclusive basis. There are a bunch of different chemistries and approaches in batteries. There are a number that have amazing charge density, but most of them have a lower lifecycle. A good lithium battery will have 3000 or more charge cycles. Lead acid car batteries have a cycle range of 90% of charge down to 20% depth of charge. You don't want to run a lithium battery below 10% because it destroys the battery. Just deep cycling the battery once can reduce the number of cycles from 3,000 down to 600. If 3,000 is good then 10,000 is really good for a satellite or military battery. Many of the variation are reduced to less than 100 even though they have much higher charge densities.

On first view this is a very complex chemical that is very specialized. It has some very strong molecular bonds, once it is made it will be hard to break it down. It will be a good electrolyte because it won't break down or suffer the dilution from water. Lithium is very water soluble, depending on the packaging, humidity can diminish the battery. Chemically using phosphazene is a good approach.

There are fewer than six suppliers in the world, and most of them are off shore. Sigma Aldrich out of Germany is one of them.

Where is it in testing?

He provided information on charge cycles: If you were to cycle the battery at a .8C discharge factor, it is the typical test norm. With a 10amp hour in and out it would take one hour to charge it and one hour to discharge it. Can only get 12 cycles per day for 10 months to get to 3,000 cycles in order to get valid test data on the number of cycles. It is not easily done in terms of the time commitment.

With instrumentation you can do a 1/10th of that and make some projections of what charge cycles will likely be. Most laboratories don't invest in the testing cycles. The testing of the phosphazene additive to get to the irrefutable data would be 10 months of testing.

John Goodenough researchers at UT, he is 90 years old. Wrote the patent for the first physical lithium battery in 1987. It was early days in terms of understanding how to turn the technology into a revenue stream. They sold the patent to Ontario Water Company for a one-time fee of $150,000. The company has since derived $6 billion from the patent.

The NDE technology appears to be worth pursuing.

"Ram" Menthiram wrote a research paper on lithium batteries in 1994. Ram has all of the test equipment in his lab. It would be good to test the ability to replicate what they have done in their lab from scratch.

Normally test batteries are done as coin cells using a stainless steel package. Could get testing done in $100-150K range at UT

Battery business is $500 billion worldwide. A small improvement of just 5% would mean a massive change in the market place. It would be worth a lot of money. There are 200 researchers around the world working on improvements on Lithium batteries. Samsung is the largest manufacturer in the world. Tesla giga factory will produce 30 gigawatt hours/year exceeds all of the production capacity in the world combined. Tesla was buying its batteries from Panasonic. Panasonic makes some of the best batteries in the world. Elon Musk paid $200 million up front to take the entire battery output that Panasonic could produce.

Panasonic is the operating partner of the Tesla factory just 10X bigger

Production roadmap followed at California Battery: 10 gram, 100 gram, kilogram batches, and then stabilize to five kilo batches and then replicate 5 kilo machine en mass to meet 40% of worldwide demand of the anode powder. If the anode powder did bring about a 5X charge cycle the entire industry would move to their battery. If the range in an electric car or the battery life of a mobile phone goes up then it will be significant.

The NDE production schedule looks like it is feasible but needs 3rd party testing and an engineering contract with a material science company to ramp up production to bulk quantities.

BASF and Bosch, Dow chemical, would invest in this and understand the value and have the in house skillset.

Investment capital necessary: 3rd party testing $50-100K. Ramping up the bulk-processing machine to get it from prototype to pre-production model would be $5 million approximately. The chemical is existing which means it will always be outsourced.

There would be a competition in the battery mfr. business to invest in the technology. To get to that point will require some testing.

DOD application: communications equipment, transportation. The commercial uses translate well to military. Today's soldier might have a dozen different batteries in their weapon, vehicle, flashlights, scopes, night vision. More charge density and at least 3,000 charge cycles. There are Toshiba batteries on submarines good for 10,000 charge cycles. Some satellite batteries are 10-15k charge cycles and are very expensive.

The caution is exploding batteries: Sony, Samsung, "hover boards" Sony had to set aside $500 million for liability and replacement.

NAME: Bill Rojek
Title: Captain
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City: San Francisco
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Email: billy.rojek@sbcglobal.net
Interviewee Type: Customer

Interview Date November 2018
Via phone
Interview conducted by Michael Peterson

Bill Rojek is a Captain in the U.S. Military with specific responsibility over the medical mission. His group supports field sanitation and hygiene efforts for the Army.

In aggregate there are pockets of units that use batteries. Some combat units are using small portable drones connected to a tablet for surveillance. There may be an opportunity for portable applications. Can the batteries be built to accommodate specific devices.

There are temperature extremes in Iraq and Afghanistan that needed to be considered for battery tech. Current suppliers for DOD products will have a limited amount of latitude to source materials as long as it is within specifications.

“Exploding batteries is not a big issue from bullets hitting the battery. Soldiers are more worried about the bullets.”