

WattJoule BCL Generation II Vanadium Bromine Flow Battery

Executive Summary of BIRD Project Proposal

	Israeli Company	U.S. Company
Company name	Bromine Compounds Ltd. ("BCL"), a Company within Israel Chemicals Group, and part of ICL Industrial Products, which is the industrial chemicals arm of Israel Chemicals Group ("ICL-IP")	WattJoule Corporation
Company locations (headquarters and relevant division address, including full street address, state, city, zip code)	Maklef House, 12 Kroitzer St. Beer Sheva 84101 ISRAEL	100 Jackson Road Devens, MA 01434
Company website	www.icl-group.com	www.wattjoule.com
Year established	1961	2012
Revenues: most recent fiscal year _____	ICL-IP (2015) \$1,115 million	Pre-revenue
Increase / (Decrease) over previous year	ICL-IP (2014) \$1,324 million	0 %
Number of employees	800 (approx.)	4
Ownership (Public / Private)	BCL is 100% owned by Dead Sea Bromine Company Ltd. (DSB), an Israeli private company. DSB is 100% owned by Israel Chemicals Ltd. ("ICL"), an Israeli public company	Private
Percentage ownership of the company by the other company	0%	0%
Relationship of the companies – - Parent/Subsidiary - Common Ownership - No common relationship - Other	Strategic partnership based on a joint development agreement between WattJoule and BCL. No common ownership.	
Number of previous BIRD projects	1	0

Israeli Company Registration Number	510273394
U.S. Company DUNS Number	078748708

Expected project title	Vanadium Bromine Flow Battery
Estimated project budget	\$ 4 Million
Expected project duration	30 months

1. **Abstract:** A summary, **no more than 15 lines**, describing the essence of the project and its expected outcome. The abstract should be self-explanatory to someone who has no previous knowledge in the field.

WattJoule and BCL jointly propose to carry out a follow-on Phase II joint development program, over a 30- month period, to commercialize the results of their successful and ongoing Phase I program. In our Phase I program we have proven the core feasibility of a vanadium bromine redox flow battery, that is our second generation (Gen II) electrolyte with improved cost and performance goals over existing battery systems for large-scale energy storage. This product platform is targeted for low cost, high performance, energy storage applications such as renewables integration and peak shaving as examples. Today, the energy storage market is desperately seeking these kinds of cost effective solutions, and we have demonstrated a breakthrough technology platform that can meet this need. WattJoule and BCL have complementary expertise and IP in this area that when combined will result in a unique and compelling product offering. With continued funding and focused effort the result will be a product platform that can be utilized by a large number of energy storage system integrators worldwide.

2. **Company Background:** Describe the major technical, marketing and financial assets and strong-points of each one of the two companies that are relevant to the successful completion of the proposed development project, and to its successful commercialization. Describe the characteristics and qualities possessed by each company that would make it a good strategic partner to the other company.

WattJoule stores electrical energy in liquids, to support a rapidly growing global market for cost effective stationary energy storage. WattJoule is a startup company that has a highly experienced entrepreneurial team to execute the development of its flow battery energy storage product platform, ElectriStor™. The company has a unique, proprietary set of core innovations that together form a game changing foundation for our Gen I all-vanadium platform. Based on these innovations, we have demonstrated substantial cost and performance improvements over the competition, incorporated in our 10 kWh prototype storage system; this substantially de-risks future investments in Gen II (discussed below) and future chemistries that can be built on this platform. WattJoule has secured \$2M of seed funding from a Fortune 50 energy company, a leading energy storage system provider, a large chemical company and a real estate venture firm to successfully execute our early development plan over the last 3 years. We are raising additional funding at this time for both our Gen I and Gen II efforts. The Gen II platform builds upon the Gen I platform investment.

ICL Industrial Products ("ICL-IP") is producing elementary bromine from an end-brine that is created as a by-product of the production process of potash in Sodom and produces other compounds, mainly bromine-based. ICL-IP is the world's leading producer of elementary bromine. ICL-IP produced approximately a third of the world's production of this product. Approximately 70% of the bromine produced by ICL-IP is used for its own production of bromine compounds in its production facilities in Israel, the Netherlands and China. Additionally, ICL-IP produces various salt, magnesia, and chlorine products in Israel, as well as other phosphorus-based products at production sites in the United States and Germany and chlorine-based products in the United States and Ireland. ICL-IP markets its products worldwide. ICL-IP services a wide range of industries including: plastics and polymers, intermediates for the pharmaceutical, agrochemical and electronics industries, oil drilling chemicals, soil and space fumigation, flame retardants, paints and dyes, food additives, water treatment chemicals and photographic materials. BCL has established market presence and core expertise in the development and high volume manufacture of bromine based compounds, especially bromine complexing agents that are critical to the WattJoule Gen II platform.

3. **The Innovation:** Provide a concise description of the product / technology to be developed within the project, including its uniqueness, its innovation, and how it will satisfy market needs that are not met today.

Beginning in 2008, early development work was done on the vanadium-bromine system by V-Fuel, an Australian company which was a spin-out of technology developed at the University of New South Wales (UNSW). WattJoule now owns the two core U.S. patents on the vanadium-bromine system, based on the original IP of UNSW. Despite the potential advantages of lower cost and higher energy density, V-Fuel was not able to carry this system forward to commercial production. Technical issues that prevented this advance include the following: limited current density, low round trip efficiency, no suitable bromine complexing agent and multiple material limitations. The essence of the present proposal is that WattJoule and BCL have a combined set of unique and innovative solutions to each of these major problems. This enables the commercialization of a next-generation DC energy storage platform that can be taken by OEM's and integrated into a complete AC energy

storage product for end users. The target volume cost point that the market needs at breakout is \$150/kWh, and this can be met by our Gen II platform. UNSW will have no role in the proposed program.

Technical Progress on Phase I Effort

During the first two quarters of the WattJoule-ICL Phase I joint development project, the following activities were pursued in accordance with the Phase I Work Plan Schedule:

1. Develop/Qualify Small Test System
2. Define Electrolyte Composition and Preparation
3. Perform Materials Compatibility Study
4. Select and Test Complexing Agents
5. Design, Build and Test Scaled System

Task 1 was completed with the development and qualification of a 25-cm² test cell with a design based on proven WattJoule technology. A unique bromine equilibration component to obtain well-defined and low bromine activity in the circulating aqueous phase was designed, built by an external contractor, and proven out to complete Task 1. WattJoule defined a viable electrolyte composition and a procedure for its preparation to complete Task 2. Initial materials for the 25-cm² cell and balance-of-plant components were chosen based on previous compatibility testing for the WattJoule all-vanadium redox flow battery; these functioned flawlessly during initial system tests. To complete Task 3, additional tests will be carried out during the second half of the Phase I effort. Based on WattJoule specifications for the complexing agent, ICL supplied three proprietary bromine complexing agents for testing. One of these was found to give very good performance in initial system tests, and these preliminary results will provide guidance for the completion of Task 4 in the second half-year. Work has commenced on the design of a 250-cm² scaled-up system according to the Work Plan Schedule.

Initial results from the 25-cm² cell have been very promising for the overall success of the program. Specifically, the results of cell cycling and polarization measurements have shown a 20-fold improvement in current density over the technology licensed by WattJoule from University of New South Wales. Further improvements are expected as the system is optimized during the second half of the Phase I Effort.

4. **Collaborative Relationship:** Describe the anticipated role of each company during the development project and during product commercialization. Indicate approximately how the development budget will be split between the two companies, and from where the non-BIRD portion of the project expenses will be obtained. Describe what the expected basis and arrangement between the two companies regarding sharing of profits and other benefits during commercialization.

WattJoule and BCL are currently engaged in a Phase I vanadium-bromine joint development program. The companies already have a joint development agreement in place at this time with defined IP rights. BCL has funded this key initial program with \$500,000 for a 12-month period that started 1/1/16. Substantial progress has been made to date, and initial feasibility has been established. We are now proposing a \$4 Million follow-on program over the next 30 months. WattJoule would be performing 70% of the work and BCL 30%. WattJoule's non-BIRD portion would be supplied by a combination of BCL's and WattJoule's own internal resources. The present commercialization plan has WattJoule manufacturing the hardware components utilizing large scale contract manufacturers, and BCL manufacturing the liquid electrolyte in high volume utilizing its in-place chemical infrastructure. The apportionment of benefits and profits has not been decided at this time, since it is still too early in the process.

Proposed Phase II Follow-on Program

Based on the successful results of Phase I, we plan to execute a de-risked Phase II program. In Phase II we intend to build an initial full-scale cell design based on the 250 cm² cell developed in the Phase I program described above. This proven vanadium bromine scaled-up single cell design will be used as the basis of the design of a five-cell stack with a power capability on the order of 1 kW. This will be then be scaled up to a full-scale prototype energy storage system operating at 20 kW (or more) based on Generation I platform but fully adapted for vanadium bromine. This will serve as the basis for the core power module that can be offered as our first OEM product based on Gen II technology. All of the work involving bromine complexation, material compatibility, corrosion studies, and bromine handling will be done in collaboration with BCL. The full description of the Phase II program will all be explained in more detail in a full proposal.

Commercial Potential: State the estimated relevant market size for the developed product, and the expected market share after 1-3 years of commercialization. (Please indicate the sources employed in deriving this forecast.) Estimate the volume and the total \$ value of direct sales revenue expected to result from the developed products over each one of the first 3 years of commercialization.

Many sources of market research have estimated the size of the energy storage market. In summary, these numbers are all in the billions and span the range from \$5 to 20 Billion by 2020. So we have picked a mid-range value of \$10B. Suffice it to say, that there is general agreement that this market is a rapidly emerging market and estimated to grow into the GWh/year deployment range of storage capacity when the market reaches wide adoption within the next decade. WattJoule product is directly addressing this market. Scaling to meet this demand will be through the development of a strategic consortium both upstream and downstream in the value chain. WattJoule is already developing the relationships to enable the scaling required for cost effective commercialization.

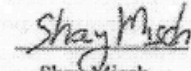
Calendar year:	2019	2020	2021
Target market size for developed product (M\$):	7,000	10,000	15,000
Estimated market share (%):	0.1%	0.2%	0.3%
Estimated sales quantity (kWh of storage):	20,000	100,000	300,000
Estimated representative unit price (\$/kWh):	300	200	150
Estimated sales revenue (K\$):	6,000	20,000	45,000
Estimated cumulative sales revenue (K\$):	6,000	26,000	71,000

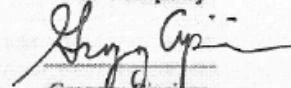
Authorized Company Officials:

Israeli Company

U.S. Company

Signature:





Typed Name:

Shay Misch

Gregory Cipriano

Typed Title:

VP Business Dev.

VP Business Dev.

Date:

6/29/16

6/29/16

Tel. no.:

972-8-6296631

508-942-8995

Typed Email address:

shay.misch@iclgrou.com

greg@wattjoule.com

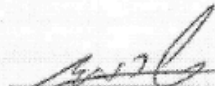
Cell phone no.:

972-52-47108700

508-942-8995

Contact Person Details:

Signature



Typed Name:

Sharona Atlas

Same as above

Typed Title:

Bus. Dev. Manager

Tel. no.:

972-8-6297696

Typed Email address:

sharona.atlas@iclgrou.com

Cell phone no.:

972-52-4718070

Please note that all Israeli company email addresses above actually end in "@iclgrou.com", we could not enter these into the fields provided above.

Signatures above do not constitute a legal commitment on the part of either party to undertake the project herein described. Such commitment, if made, will be subject to a separate agreement.