**Advanced Molten Salt for Solar Thermal Power Generation with Supercritical Steam Turbines**

**Commercialization Plan**

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# Market Opportunity

*Making the Sun the Solution*

We believe the sun is the ultimate source of energy. Solar thermal power, also called concentrating solar power or CSP, has the highest potential of any renewable electricity to displace fossil fuels. With Halotechnics thermal storage, concentrating solar power could become cheaper than natural gas or coal and able to provide electricity day and night.

It is imperative that we reduce our usage of natural gas and especially coal to address pressing societal concerns – climate change and environmental degradation, energy security, and price volatility. Solar thermal power, a compelling source of renewable electricity at large scale, represents a possible solution to fossil fuel use. Every day, the land areas of the Earth receive enough solar energy to power the world’s electricity demand for five years – if that energy could be collected and converted economically. The challenge is to concentrate the solar energy, store it for use when needed (day or night), and convert it to low cost electricity. Halotechnics is developing technology to enable this vision. The successful commercialization of our products would both reduce the cost of solar thermal power and enable economic thermal storage, bringing the society significantly closer to eliminating the use of coal. Figure 1 shows a CSP plant with mirrors focused on a distant receiver.



Figure : Concentrating solar power [image courtesy of Torresol Energy].

Halotechnics is the architect of advanced thermal storage. Halotechnics uses combinatorial chemistry techniques to screen thousands of materials and patent the most promising. Our thermal energy storage systems will be designed to achieve market-leading low installed costs due to our advanced designs enabled by our proprietary SaltstreamTM heat transfer and thermal storage materials. The subject of this Phase II proposal is Saltstream 700. This novel molten salt will enable the use of supercritical steam turbines in concentrating solar power plants, dramatically reducing the their cost of electricity and making thermal storage significantly cheaper.

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## Thermal Storage for Concentrating Solar Power – an Emerging Growth Market

The concentrating solar power market is an emerging industry showing high growth potential. A recent report published by Greenpeace and the European Solar Thermal Electricity Association projects an installed capacity over 68,000 MW by 2020, enough to power over 50 million households [[[1]](#footnote-1)]. Annual installed capacity is projected to be over 12,000 MW per year by 2020 with a typical plant size of approximately 250 MW. Each plant costs from $500 million to $2 billion.

Concentrating solar power plants generate electricity by focusing sunlight using mirrors onto a receiver, then passing a fluid through the receiver to collect the heat, and finally using the heated fluid to boil water and drive a steam turbine generator. There are two major varieties of solar thermal plants: the trough design which uses curved mirrors focused on long tubular receivers, and the tower design which uses a central receiver on top of a tower with a field of mirrors focused on one point. The trough systems have been proven in operation since the 1980’s but the tower designs are growing increasingly dominant due to their higher temperature operation and lower costs [[[2]](#footnote-2)].

Storing electricity directly is prohibitively expensive – large scale battery storage technology typically exceeds $400 per kilowatt-hour (kWh) electric [[[3]](#footnote-3)]. However, it is possible to store energy in the form of heat (thermal energy) and then convert it to electricity when needed. Thermal energy storage is dramatically cheaper due to its simplicity – less than $150/kWh with today’s technology. Halotechnics has identified a pathway to reduce these costs even further with advanced thermal storage materials – to as low as $25/kWh.

Thermal storage is growing increasingly valuable since it allows the power to be dispatched at will when demanded by the utility. As more photovoltaic (PV) solar capacity is installed on the power grid, utilities are increasingly coming to realize the value of thermal storage. A photovoltaic plant without storage, for example, results in an increased cost of electricity because it must be backed up by fossil fuel based plants that can turn on when a cloud passes [[[4]](#footnote-4)]. Figure 2 (a) shows actual data from a 5 MW PV plant in Arizona, with intermittent output. Figure 2 (b) shows the smoothed output that can be achieved in a CSP plant with thermal storage. This profile is preferred by utilities, who can rely upon it when needed (this makes CSP “dispatchable”). CSP with storage eliminates the intermittency problem, and with a large enough storage tank can provide power 24 hours a day (the Gemasolar plant shown in Figure 1operates this way for several months each summer).

The demand for thermal storage materials and systems is growing rapidly. Each 250 MW central receiver plant will typically have six hours of thermal storage (approximately 3,800,000 kWh), requiring over 45,000 tons of a molten salt heat transfer/thermal storage material (trough plants would require significantly more due to less effective use of thermal storage). The cost of such an inventory would exceed $45 million.



Figure 2: (a) Photovoltaic power output with no storage. (b) CSP plant with thermal storage.

Thermal storage capital costs are measured by cost per kilowatt hour of thermal energy stored (a kWh of thermal energy must be converted to electricity, typically at an efficiency of 35-50%, in order to be compared to battery storage costs). At an average installed capital cost of $25/kWh (equivalent to roughly $60/kWh electric), the market for thermal energy storage in CSP plants is projected to reach $3.7 billion by 2015, at a compound annual growth rate of 49% from 2010 [[[5]](#footnote-5)]. Figure 3 shows the projected growth of this market. This is an international market, with the U.S. one of the primary regions (1000 MW of CSP plants currently under construction). Spain is also a very large market (1300 MW of plants under construction), with potential growth markets in Australia, South Africa, and elsewhere. Halotechnics will target the U.S. and Spanish markets first and will expand our sales to wherever our customers do business.



***CAGR from 2010 to 2015: 49%***

Figure : Market growth of thermal storage (total installed capital cost of thermal storage systems, including salt inventory, tanks, pumps, and associated hardware).

*Halotechnics Positioned to Lead Thermal Storage Market*

Halotechnics stands poised to capture a significant portion of the emerging thermal storage market. Our strategy is to gain first-mover advantage, build a name for the company by establishing a presence at industry conferences and trade shows, and to get out in front and keep innovating. We intend to become the world expert in molten salt and molten glass – chemistry, procurement, manufacturing, and use in full-scale plants. We intend to build our brand by establishing credibility at technical conferences and trade shows (publishing papers, presenting, and sitting on panel discussions). We have trademarked the product name “Saltstream” and are in the process of increasing our profile in the industry. By building our presence in the industry we believe that customers will come to view Halotechnics as the “go-to company” for thermal storage technology. We use conferences as an opportunity for direct customer engagement. We are regular attendees at conferences such as SolarPACES, CST Power, CSP Summit, and ASME Energy Sustainability. We have written several peer-reviewed scientific papers which have been published at the 2010 and 2011 SolarPACES conferences [[[6]](#footnote-6)], [[[7]](#footnote-7)].

Our position along the value chain of thermal storage is between the producers of the raw materials (salt producers such as SQM and Haifa) and before the end users (solar companies such as Abengoa and Siemens). We will enable high performance applications by developing and commercializing our proprietary materials and thermal storage system designs. Figure 4 shows the position of Halotechnics along the thermal storage value chain.



Figure : Thermal storage value chain.

# Company / Team

## Company Profile and History

Founded in 2009 by Dr. Justin Raade as a spin-out from pioneer Symyx Technologies, Halotechnics draws upon a rich heritage in combinatorial chemistry extending back to 1996. Dr. Raade began his research with molten salt in 2007 and received a $1.5 million grant from the DOE in 2008 to develop advanced molten salt heat transfer fluids for CSP plants. He led a multidisciplinary team at Symyx for one year under this program. During this program his team made an important breakthrough in novel eutectic salt mixtures, and in late 2009 he founded Halotechnics to spin out of Symyx and commercialize the result of this early work. Halotechnics has acquired from Symyx the powerful scientific equipment and software necessary for high throughput materials science research. Halotechnics has also acquired the IP related to molten salts from Symyx and is poised to continue innovative work in this field. As part of the spin-out Symyx acquired a 19% ownership stake in Halotechnics. See Figure 5 for a timeline of the company history.

Halotechnics, Inc. is a Delaware C-corporation, founded on December 24, 2009. General legal counsel is provided by Stephen Clinton at Foley & Lardner, LLP. Intellectual property legal counsel is provided by Dr. Alex Trimble at Kilpatrick Townsend & Stockton LLP. Barry Wertheimer provides contract drafting and negotiation services on a consulting basis as an independent attorney. See capitalization table below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Owner** | **Shares** | **Percentage** | **Notes** |
| Justin Raade | 5,000,000 | 67.82% |  |
| Symyx Technologies, Inc. | 1,172,840 | 15.91% | Symyx is now owned by Accelrys, Inc. |
| Stock option pool | 1,200,000 | 16.28% | Approx. 70% of option pool has been issued |
| *Total* | 7,372,840 | 100.00% |  |

Table : \* Pro forma capitalization table of Halotechnics, Inc. Common Stock. \*



Figure : Timeline of events in Halotechnics history.

The innovation proposed for this NSF SBIR Phase II project fits squarely into our company mission: to develop and commercialize advanced thermal energy storage systems enabled by our proprietary materials. Receiving the Phase II award would be instrumental in making our vision a reality, since the project cannot justify venture investment or traditional corporate R&D funds. We must prove that the Saltstream 700 is feasible before securing traditional funding to scale it up for commercial deployment.

Halotechnics has a proven track record of early stage product development and is currently commercializing the results of R&D. Our core expertise leverages high throughput materials discovery methods to rapidly develop novel materials. We have developed powerful software tools and experimental apparatus for synthesizing and characterizing materials. Halotechnics has the chemistry and materials science expertise to synthesize and screen thousands of candidate materials for desirable properties and low cost. We have the informatics know-how to design, analyze, and store the data resulting from our materials screening. We have the engineering expertise to take the hits from our materials screening and build them into advanced thermal energy storage systems, validating their performance under realistic operating conditions at the laboratory scale and larger.

We have received $6 million in research grants to date, plus additional funds from angel investors.

* $1.5 million grant from the Department of Energy (for Saltstream 565 development)
* $150,000 NSF SBIR Phase I (for preliminary Saltstream 700 development, to be completed in Phase II)
* $3.3 million from ARPA-E (for 1200 °C thermal storage system with novel molten glass)
* $1 million from NREL (for 700 °C thermal storage system engineering)

Table 2 shows the revenue by type for 2010 and 2011. The bulk of our revenue comes from the federal awards described above. We have performed research services measuring the properties of molten salt for a large CSP company. This small project allowed us to build a relationship with the company, who is a potential customer of our proprietary Saltstream products.

|  |  |  |
| --- | --- | --- |
| **Income type** | **2010** | **2011** |
| Sales | $0 | $0 |
| Licensing | $0 | $0 |
| Contracts (R&D grants) | $300,000 | $850,000 |
| Research services | $0 | $60,000 |
| Other | $0 | $0 |
| *Total revenue* | $300,000 | $910,000 |

Table 2: \* Halotechnics 2010 and 2011 revenue. \*

## Multidisciplinary Team

We have assembled a multidisciplinary team of experts: inorganic chemists, thermal/fluids engineers, experienced entrepreneurs, and business professionals. There are currently six employees of Halotechnics and several part time consultants and advisors. Advisors include experts from the high-tech and chemicals industries. We currently have a board of directors with three seats. We intend to expand the board to five in the near future and to fill it with industry veterans who can provide strategic value with their relationships and guidance.

Dr. Justin W. Raade | CEO and Founder (PI)

* PhD, Mechanical Engineering (University of California, Berkeley)
* B.S., Mechanical Engineering (Massachusetts Institute of Technology)

Dr. Raade founded Halotechnics in 2009 with a vision of ubiquitous solar power. Dr. Raade is an expert in applied thermodynamics. He has experience in leading multidisciplinary R&D teams and in commercializing the results of high-impact research. His research with molten salt began in 2007 when he was a Staff Scientist at Symyx Technologies. Dr. Raade received an NSF Graduate Research Fellowship to support his doctoral research in Mechanical Engineering at UC Berkeley. His work there focused on applied thermodynamics and energy storage with hybrid systems using fuel cells and lithium polymer batteries. He has an undergraduate degree in Mechanical Engineering from MIT.

Darren Hickey | Director of Engineering

* M.S., Mechanical Engineering (University of Arizona, Tucson)
* Bachelor of Eng. in Mechanical Engineering, University of Melbourne, Australia

Mr. Hickey has 19 years of experience in high temperature materials and thermal engineering in applications up to 1000 °C. He was formerly the Principal Engineer at Bloom Energy, where he led the development of their solid oxide fuel cell stack, scaling it from a 1 kW prototype to the first commercial 100 kW energy server. Recently he was a Director and Co-Founder at EnerVault developing a unique flow battery concept for grid scale energy storage. At EnerVault he built the engineering team from scratch and scaled up the size of the battery by two orders of magnitude. At Halotechnics Mr. Hickey leads the engineering team focused on building our thermal storage technology.

Grady Hannah | Director of Business Development

Mr. Hannah has 10 years of experience in Silicon Valley technology companies. He sold enterprise Linux solutions and Open Source cluster technology and later transitioned into the video game software market. Later his sales led directly to a $10 million B Round while he was at Replay Solutions. Mr. Hannah leads customer-facing messaging and strategy at Halotechnics.

Dr. Robert Bradshaw | Corrosion Chemistry Consultant

* PhD, Chemical Engineering (Stanford University)

Dr. Bradshaw is recognized as the leading expert in molten salt chemistry and corrosion. He was Principal Member of Technical Staff at Sandia National Laboratories. Dr. Bradshaw has authored many peer reviewed articles and holds several patents on molten salt science and technology. He oversees work with corrosion and high temperature chemistry of molten salt at Halotechnics.

Dr. Michael Tenhover | Chemicals and Energy Advisor

* PhD, Applied Physics (Caltech)

Dr. Tenhover performs analytical research on the economics and operational aspects of a wide array of chemical processes. He is a consultant to the oil and gas industry and has extensive experience in senior management positions at Hosokawa Micron (CTO) and BP (Chief Scientist for Advanced Materials).

Dr. David Kearney | CSP Technology Consultant

* PhD, Mechanical Engineering (Stanford University)

Dr. David Kearney is widely regarded as an international expert in CSP technology and maintains consulting relationships with many industry leaders. He currently advises the World Bank on CSP technology projects. He played a key role at Luz International during the building of the Solar Electric Generating Systems (SEGS). Dr. Kearney held a leadership role at the Solar Energy Research Institute (now NREL), and was instrumental in the commercialization of parabolic trough technology through his many contributions to industrial developments.

Xavier Helgesen | Director

Mr. Helgesen is a serial social entrepreneur in energy, software and e-commerce. His is currently CEO and Co-Founder of Off.Grid:Electric, a revolutionary solar micro-utility that generates and sells the world's most valuable electricity: 24/7 power beyond the electrical grid. Off.Grid:Electric is based in Arusha, Tanzania and sells power as a service throughout East Africa, with a special focus on the mobile telephone industry. Mr. Helgesen is also Chairman and Co-Founder of Better World Books, the online bookstore with a soul, which he grew from the back of a community center to a member of the Internet Retailer 500 with $65 million in revenue. He holds an MBA from Oxford University as a Skoll Scholar and a BA from the University of Notre Dame.

Will Davies | Director

Mr. Davies has founded several ventures in the mortgage, real estate, and fitness industries. Mr. Davies founded, managed, and sold Scope Lending, a mortgage broking business operating in Australia. He has since gone on to co-found Keypoint Holdings which invests in real estate opportunities and Southport Studios which owns and manages a gym in the Gold Coast of Australia. He also works with a group that organizes conferences building youth leadership skills. Mr. Davies has a Bachelor of Commerce degree in Economics and Finance from Sydney University.

## Facilities and Equipment

The work for the proposed project will take place at Halotechnics facilities in Emeryville, California. Halotechnics leases 6000 square feet of lab and office space in two locations in Emeryville. The chemistry lab is in the state of the art life science research facility, Emerystation North, at 5980 Horton St. Completed in 2001, this facility is home to a variety of life science and biotech tenants including Halotechnics. Our lab includes specialized equipment for rapidly synthesizing and screening thousands of materials and testing their properties at temperatures up to 1200 °C. The engineering lab is at 1601-B 63rd St. This facility is an open floorplan engineering space equipped with adequate ventilation, electrical service, and office space.

# Product / Technology and Competition

## Saltstream Product Line

Our strategy is to deliver a near term product to existing plants, producing enough revenue to remain a viable business until our breakthrough products are ready for the next generation of concentrating solar power plants. We are developing a suite of branded products for heat transfer and thermal energy storage in applications ranging from 565 °C to 1200 °C.

* Saltstream 565 is a drop-in replacement for central receiver CSP plants operating at 565 °C. It has similar physical properties as previous molten salt materials but 20% lower cost due to our use of earth abundant components. The prospect of saving millions in capital costs is generating sigfinicang interest from potential customers. This product will generate near-term revenue since it will be compatible with plants currently in operation and under development, allowing us to strengthen our position for follow-on products.
* Saltstream 700 will be designed for next generation central receiver CSP plants using efficient supercritical steam turbines. It consists of chloride salts stable to 700 °C and targets an unprecedented low melting point near 200 °C. This material will be further developed and commercialized under this Phase II award.
* Molten Glass GT will be a tailor-made fluid for the requirements of commercially available gas turbine combined cycle power blocks. It is a novel earth abundant material suitable for pumped heat transfer and thermal energy storage applications at extremely high temperatures up to 1200 °C. This product represents a step change that could make CSP cheaper than coal.

Our products exhibit unparalleled operating range (low melting point, high maximum temperature) which will enable our customers to develop viable thermal storage and reduce their levelized cost of electricity. Our products utilize novel eutectic (low-melting) mixtures of stable inorganic materials. Figure 6 shows the operating range and application of our products in central receiver CSP plants.

Intellectual Property Strategy

Halotechnics has filed five patent applications covering the composition of matter and use of the products described above. We expect to file more patents in 2012. Expected patents fall in the following general categories:

* Composition of matter. These patent claims cover the proportion of each constituent in the preferred mixtures; the formula.
* Synthesis process. These patent claims will specify the temperature, duration, and other steps and techniques for synthesizing the proprietary materials.
* Novel use. It may be possible to develop an existing material for a novel use, analogous to a pharmaceutical firm patenting a previously known chemical compound to treat a disease.
* Related equipment. We will expand our IP portfolio to include related technology for wetted components in the plant: coatings, pumps, tanks, system design.

We are working with the Silicon Valley IP law firm Kilpatrick Townsend & Stockton to file patents covering the composition of our novel materials. The attorneys at Kilpatrick Townsend have extensive experience in protecting compositions of matter, and in particular inorganic materials like molten salt and glass. We believe we will be able to defend our products in commercial applications by covering the broad application and composition as well as the specific mixture of the product. A recent patent granted to Sandia National Laboratories [[[8]](#footnote-8)] covering a novel molten salt mixture shows that there is precedent for issuing patents in this space. We believe we have freedom to operate and commercialize our novel molten salt materials. We will file both domestic patents as well as international patents in countries we expect our products to be used (for example, Spain, Australia, South Africa, and others). We will protect the enabling details of our product development capabilities as trade secrets.



Figure : Halotechnics products and operating ranges.

## Value Proposition – Low Cost Thermal Storage

There is a general trend over time in the concentrating solar power generation industry to increase operating temperature of the plants, thereby reducing the levelized cost of electricity (cents per kilowatt-hour) by two routes: (1) increasing efficiency in the turbines that turn heat into electricity, and (2) reducing the cost of thermal storage. Our products will enable this trend for CSP to continue from 400 °C in the 1980s, to 565 °C today, and to 700 °C with Saltstream 700 and eventually 1200 °C with molten glass in future plants.

We will leverage the performance our proprietary materials to offer thermal energy storage systems with market-leading low installation costs. Figure 7 shows the capital cost of the thermal storage fluid inventory for a given plant size of 150 MW with 6 hours of thermal storage. Saltstream 700 and molten glass dramatically reduce the cost versus previously available technology. Concentrating solar power plants are typically built by EPC (Engineering, Procurement, and Construction) firms, such as Bechtel and Fluor. Halotechnics will provide engineering designs for the thermal energy storage system to project developers who hire EPC firms to build the plants. These designs include the pumps, pipes, tank design, materials selection, and preferred suppliers. This is the ‘E’ in EPC.

When a customer buys our thermal storage design, we will provide a non-exclusive license for the use our proprietary salt and glass materials at the heart of the system. We will leverage our relationships with salt suppliers to identify the lowest cost components. We understand the chemistry of our proprietary salt products and know how they behave at large scale during long term operation. We will coordinate the logistics to deliver the raw material components to the customer’s site. We will set up mobile manufacturing facilities to crush, mix, melt, and install our products into the thermal storage tanks of the customer’s plant. And finally we will offer complete maintenance, diagnostic, and repair services for the molten salt inventory.

We have developed a capital efficient business model since our main proprietary product is the know-how for building a competitive thermal energy storage system. We do not intend to build salt factories from scratch or reinvent the wheel if there is existing capacity available for utilization. The manufacturing equipment necessary for the installation of the molten salt inventory is readily available and can be set up under tents in temporary facilities at each plant site. We intend to partner with existing firms who have this know-how, such as Durferrit.



Figure : Halotechnics slashes thermal storage costs. Cost shown is for molten salt or glass inventory capable of storing 6 hours of heat for a 150 MW plant.

## Barriers to Entry

Significant barriers to entry for competitors arise from our combination of compelling prototypes with IP protection, high throughput product development capabilities, a top-notch team, and strategic business relationships.

We have patents pending on each of the proprietary materials described above. We intend to use this IP protection to give us a competitive advantage in achieving high performance thermal energy storage systems that cannot be duplicated by any competitor.

Our technology has a key differentiating aspect that provides us with a competitive advantage: our proprietary materials that enable our designs to operate at high temperature. By developing and patenting our molten salt formulas we have erected significant barriers to entry for a competitor wishing to develop low-cost thermal energy storage at high temperatures. No other labs can match our capability for rapid product development and combinatorial chemistry. By enhancing our engineering capability we will further increase the value proposition from our advanced materials and provide a complete solution for advanced thermal energy storage.

Our unique combinatorial chemistry abilities enhance our product development capabilities. We have developed a high throughput materials discovery workflow at Halotechnics which is capable of screening 100 unique mixtures of salt each day. This workflow is capable of discovering novel materials orders of magnitude faster than traditional lab techniques, as well as customizing and optimizing existing mixtures. This capability to rapidly produce innovative products and to continue to improve them based on customer’s needs puts Halotechnics in a strong position relative to potential competitors. By applying the techniques of combinatorial chemistry, originally developed for the pharmaceutical industry, we have screened over 14,000 unique mixtures of salt to date. We have developed powerful software tools to efficiently design constrained sets of experiments with up to six components of salt. These experiment designs are fed into automated machines for dispensing the mixtures and measuring their properties rapidly. We also have proprietary software tools for analyzing up to six dimensional data resulting from the experiments and rapidly using the results to iteratively discover the lowest melting point mixtures possible.

## Product Development Schedule

The concentrating solar power industry is constrained by the requirements of project finance; every aspect of a $1-2 billion plant must have a 20 year track record of proven performance, or have the guarantee of a company with a big balance sheet willing to back the technology. Halotechnics plans to form strategic alliances with leading engineering firms in order to achieve performance guarantees (“bankability”) with our technology. We will construct a pilot scale thermal energy storage system with our partner firm to build confidence in the performance of our products. We will then do the detailed engineering for a full scale commercial plant. We must establish a strong relationship with our engineering partner and they will then provide a guarantee on the performance of our designs. Potential EPC partners include Bechtel, Fluor, Sener, Abener, and others who are active in CSP project development.

We plan to leverage federal investment in pilot testing facilities to validate the performance of our products at relevant scale. The data obtained from pilot testing will give our customers confidence of our product’s performance at full commercial scale in their plants. We plan to begin pilot scale testing our Saltstream 565 product in Q3 2012 with Sandia National Labs in their newly constructed Molten Salt Test Loop. This facility requires a salt inventory of 50 tons and uses commercially relevant pumps, valves, and other salt handling components. We have preferred access to this facility at Sandia due to our DOE-funded R&D program to develop Saltstream 565. Sandia works on behalf of the U.S. Government with many industry leaders in solar thermal power and will provide reliable 3rd party validation of our products long term thermal stability and corrosion properties. We are also in discussion with Sandia regarding 700 °C flow and receiver testing with Saltstream 700. See Figure 8 for a timeline of our pilot testing and commercial product deployment.



Figure : Product development schedule and target customers.

## Target Customers

Our target customers are market leading solar power plant developers who need to store their energy in order to produce power on demand, including at night. They must reduce their costs in order to remain competitive and since there are no materials that will allow them to achieve these goals, Halotechnics will provide them with products that will allow them to reduce capital costs in the near term (Saltstream 565) as well as enable significant increases in plant efficiency for the next generation of plants (Saltstream 700 and molten glass).

Torresol is our early-adopter lead customer. They have built and deployed concentrating solar power plants using molten salt for thermal storage. They have a pipeline of four plants in Spain, two in California, and two more in Abu Dhabi. If we can provide them pilot scale data of Saltstream 565, we believe we can sign a licensing deal to get our product into the plants they are currently developing. We are targeting deals to use Saltstream 565 in one 100 MW plant in 2013 and two 100 MW plants in 2014. Torresol uses technology developed by the Spanish engineering firm Sener, who has written a letter of support for Saltstream 700, showing they support both our near term products as well as our technology roadmap.

SolarReserve is currently constructing a 110 MW CSP plant in Nevada with 10 hours of molten salt thermal storage (approximately 30,000 tons). We have spoken to the CTO of SolarReserve and we believe that if we can show them data from pilot testing Saltstream 565, they will sign a deal to license the salt in early 2013. We are targeting deals to use Saltstream 565 in one 100 MW plant in 2013 and two 100 MW plants in 2014. SolarReserve has written a strong letter of support for our advanced high temperature materials.

BrightSource Energy is the industry leading CSP firm with over 2,600 MW of signed power purchase agreements with California utilities. They recently announced that their plants for Southern California Edison will incorporate molten salt thermal storage. We are in the process of quantifying the savings in operations and maintenance costs that Saltstream 565 may bring, which is of particular importance to BrightSource. BrightSource has also indicated to us their interest in Saltstream 700 for enabling their future plans with supercritical steam turbines.

Other potential customers include CSP technology companies such as Siemens, Abengoa Solar, Acciona, AREVA Solar, Pratt & Whitney Rocketdyne, and eSolar. In addition to solar power plant builders, our products have demonstrated traction with leading turbine manufacturers and materials companies. GE has expressed interest in using our fluids to provide solar input to their combined cycle turbines. 3M has written a letter of support for using our materials in their high temperature solar collector work. We have letters of support for our products from six companies. Figure 9 shows the target customers we are currently in discussions with about our products.



Figure 9: Customer traction for Saltstream.

## Outpacing the Competition

One form of competition we have identified is overcoming the inertia of existing molten salt products with years of performance data. Commodity salt-based heat transfer fluids have been in use for decades. Their composition is public knowledge and is not protected by any current patents. The currently used salt is called “solar salt” and consists of 60 weight percent sodium nitrate, 40 weight percent potassium nitrate. Our first product, Saltstream 565, will be judged in comparison to solar salt. We are confident that the value proposition of significant capital savings offered by Saltstream 565 will entice potential customers to adopt the material in their plants.

There are several companies that supply solar salt and similar salt mixtures and are considered competitors to Halotechnics. Coastal Chemical supplies a salt under the brand name Hitec [[[9]](#footnote-9)]. Dynalene supplies a salt called MS-1 [[[10]](#footnote-10)]. We believe both of these salts are the same chemical composition as solar salt, with no performance or cost advantages. Durferrit offers molten salt installation services and a range of products for heat treating applications. BASF produces synthetic sodium nitrate and has a research project on low melting point nitrate salts for CSP applications. We believe that our innovative product development capabilities will allow us to outpace these competitors with higher performance materials. Furthermore, we know of no commercialization efforts from any other company focused on molten salt products for CSP at temperatures higher than 565 °C. We intend to drive aggressively into this high temperature sector and establish a leading position.

Our main competition with thermal storage engineering designs are existing engineering, procurement, and construction firms who have established a presence in CSP project development and in particular thermal energy storage systems. These companies include Bechtel, Sener, Bertrams-Heatec, Fluor, ACS-Cobra, and others. We intend to turn these competitors into potential partners by offering an advanced product that complements their existing portfolio and will allow them to bid on projects that would otherwise be beyond their capability. For example, we may partner with Sener, the EPC firm who built Torresol’s Gemasolar plant. We could offer them use of our patented materials and a design that enables 700 °C thermal storage, something currently beyond their reach. A partnership with this firm would prospectively have mutual benefit for both companies: a path to market for Halotechnics, and access to advanced thermal energy storage technology for Sener. This example illustrates our approach to managing competitive risk.

# \* Finance and Revenue Model \*

## Revenue Model

We have developed a model with two revenue streams:

1. Salt and glass licensing
2. Thermal storage engineering fees

We will license the use of Saltstream 565 for near-term applications. We are not projecting any thermal storage system sales for 565 °C systems since this is already proven technology than can be purchased off the shelf from established firms. Solar salt currently sells for approximately $1000 per ton. We are projecting a savings of $200 per ton with Saltstream 565 due to our use of earth abundant and low cost salt components. Our model includes a license fee of $50 per ton. In other word, we propose to save our customers 20 cents and charge them a nickel. We anticipate structuring the licensing agreements to include some up-front payments as well as recurring payments based on quantity of material used. For Saltstream 700 we are targeting the same cost as solar salt: $1000 per ton. We anticipate a higher license fee of $100 per ton since there are no currently available alternatives in the market. We do not anticipate significant revenue from our proprietary molten glass materials before 2016 due to the longer development timeline. The gross margins of our licensing model are projected to be very high (90%) since the main costs will be the patenting fees and costs associated with drafting and enforcing licensing agreements.

Detailed engineering designs of power plants typically sell for some fraction of the total construction cost. We are projecting a technology fee for our designs of 10% of the total installed capital cost of the thermal energy storage system. Based upon feedback from industry experts this fee is reasonable for innovative systems that are not simply duplicated from “off the shelf” designs. The gross margins of this revenue are projected to be 30%, typical for labor-based engineering design services.

## Revenue Projections

We have taken a bottoms-up approach to build a revenue model as described above. We have identified customers by name and reached out to them to find information regarding their project pipelines and when they could potentially buy our products. The revenues we project from this effort results in capturing 0.5% of the total thermal energy storage market by 2016. See Table 3 for projected revenue and income resulting from all of our products. Saltstream 700 is broken out on a separate line to show projected revenues resulting from the product to be developed under this Phase II award. We are projecting signing licensing deals with Saltstream 700 for a royalty of $100 per ton: 15,000 tons in 2014 (one plant), 45,000 tons in 2015 (three plants), and 90,000 tons in 2016 (six plants).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *All values in $k* | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Revenue: |  |  |  |  |  |  |
| Product sales (minus Saltstream 700) | 15,000 | 1,120,000 | 2,500,000 | 7,500,000 | 7,500,000 | 7,250,000 |
| Saltstream 700 sales | 0 | 0 | 0 | 1,500,000 | 4,500,000 | 9,000,000 |
| Grant income | 850,000 | 2,154,000 | 1,104,000 | 1,104,000 | 0 | 0 |
| *Total revenue* | 865,000 | 3,274,000 | 3,604,000 | 10,104,000 | 12,000,000 | 16,250,000 |
| Cost of revenue | (423,850) | (1,604,260) | (1,765,960) | (4,950,960) | (5,880,000) | (7,962,500) |
| *Gross profit* | 441,150 | 1,669,740 | 1,838,040 | 5,153,040 | 6,120,000 | 8,287,500 |
| Operating expenses: |  |  |  |  |  |  |
| Research and development | (396,000) | (1,494,500) | (2,782,700) | (4,425,000) | (4,445,660) | (4,467,353) |
| Sales, general, and administrative | (158,000) | (737,000) | (804,000) | (828,000) | (830,000) | (840,000) |
| *Total operating expenses* | (554,000) | (2,231,500) | (3,586,700) | (5,253,000) | (5,275,660) | (5,307,353) |
| Net income | (112,850) | (561,760) | (1,748,660) | (99,960) | 844,340 | 2,980,147 |

Table : \* Halotechnics revenue and income projections. \*

## Capital Required for Commercialization

We are projecting a total venture investment of $12-15 million in order to build out our sales and business teams, expand our engineering and scientific capabilities, and provide for materials and construction costs of pilot scale plants. There are significant federal grant funds available for pilot testing advanced concentrating solar power technology that we intend to pursue and which may reduce the total amount of venture capital required. Potential federal programs include the recently announced SunShot Initiative from the Department of Energy, many opportunities from ARPA-E, the SunShot Incubator program from NREL, and others. After successfully completing pilot scale testing we anticipate that we will have sufficient data and proven performance with our system designs that we will be able to secure an EPC partner and a bankable guarantee for our designs. At this point we anticipate receiving an increasing number of contracts to sell our guaranteed designs to project developers who are building advanced CSP plants with thermal energy storage. We anticipate being cash flow positive and profitable due by 2015 to our capital efficient business model. Our most likely exit scenario would be acquisition in 5-6 years by a large EPC firm or solar technology firm who wishes to gain exclusive access to our must-have thermal energy storage technology. Figure 10 shows a timeline of anticipated venture investments building toward an acquisition in 2016.



Figure 10: Capital required for product commercialization and investment milestones.

We are currently raising a Series A investment of $2 million from leading venture capital firms. These funds will be used to pay for a 50 ton inventory of Saltstream 565 and usage of the Molten Salt Test Loop at Sandia. Invested funds will also be used to meet the cost share requirements of our federal R&D grants over the next 24 months.

*Conclusion and Path Forward*

We see an opportunity to take a leading position in high temperature thermal energy storage at operating temperatures greater than 565 °C. Halotechnics identified a pathway to breakthrough heat transfer fluids enabling operation at 700 °C. We have additional products under development for even higher temperatures up to 1200 °C. There are currently no commercially available materials suitable for heat transfer at 700 °C. Receiving the proposed NSF award would provide a jump-start on developing our advanced fluids. At the current level of technology readiness, the technology for thermal energy storage at high temperature is too risky for traditional venture capital investment or corporate R&D budgets. The NSF SBIR program provides a crucial role in funding high impact R&D at this stage.

If successful this project will be both transformative and disruptive. We propose to use combinatorial chemistry methods to transform a new sector – solar thermal power. If successful, our technology will provide thermal energy storage at significantly lower cost and make solar generated electricity competitive with fossil fuels.

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