



2015 North American CO₂-to-Fuels
Technology Innovation Award



FROST & SULLIVAN



50 Years of Growth, Innovation & Leadership

Contents

Background and Company Performance	3
<i>Industry Challenges</i>	3
<i>Technology Attributes and Future Business Value of Joule Unlimited</i>	3
<i>Conclusion</i>	6
Significance of Technology Innovation.....	7
Understanding Technology Innovation.....	8
<i>Key Benchmarking Criteria</i>	8
Best Practice Award Analysis for Joule Unlimited.....	9
<i>Decision Support Scorecard</i>	9
<i>Technology Attributes</i>	10
<i>Future Business Value</i>	10
<i>Decision Support Matrix</i>	11
The Intersection between 360-Degree Research and Best Practices Awards.....	11
<i>Research Methodology</i>	11
Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices.....	12
About Frost & Sullivan	14

Background and Company Performance

Industry Challenges

Conventional 1st- and 2nd- generation biofuels require biomass as feedstock, which is converted to ethanol through a multi-step process that first requires the growth, collection, and processing of biomass, with subsequent further processing to obtain ethanol. The processes also require large amounts of land; Yield is also comparatively low (about 200 gallons per acre per year for corn ethanol, 2,000 gallons per acre per year for cellulosic ethanol, and about 7000 gallons per acre per year for algal ethanol). Moreover, this process has a significant constraint as it diverts valuable land away from agriculture towards fuel production and in the case of corn ethanol; it can divert actual valuable food output towards the development of fuels. Another drawback of the reliance on biomass is the dependence on the vagaries of weather conditions.

Biofuels obtained from non-food sources such as wood chips or algae have until now had a slow pace of progress. Moreover, most existing 1st- and 2nd-generation biofuels are not carbon-neutral, and in some cases, they can greatly increase the emission of greenhouse gases in the atmosphere.

Joule Unlimited, USA has developed a breakthrough photosynthetic system that can address the current challenges. The developed technology does not rely on biomass or agricultural land for inputs, to produce fuel in an efficient single-step conversion process using resources such as cyanobacteria, waste carbon dioxide and waste water for generation of products such as ethanol that can be used as alternative fuels.

Technology Attributes and Future Business Value of Joule Unlimited

Industry Impact

Joule Unlimited (Joule) has developed a unique process using genetically modified cyanobacteria that can convert carbon dioxide (CO₂) to liquid fuel such as renewable ethanol and diesel by harnessing the power of solar energy. The industrial photosynthesis process, commercialized under the name, Helioculture technology platform, effectively reverses combustion. The technology was developed after more than 5 years of research and is currently in the demonstration stage.

Best Practices example:

Most competing technologies in today's market require large amounts of arable land to grow crops for biomass, specific feedstock requirements, or require complex downstream processing to make the feedstock feasible for use. Joule's technology, by contrast, neither requires large amounts of land for crop cultivation, nor diverts land away from agricultural

production.

Moreover, Joule's technology platform can produce a drop-in fuel that is compatible with existing infrastructure, including storage, service, and distribution network. Most competing technologies require chemical upgrading before use. Joule's technology, however, requires no upgrading or further processing before blending directly at fuel depots that use standard processes and results in finished products that require no engine modifications.

Scalability

Joule's modular closed system enables easy upscaling through a simple replication process. Joule's technology, process and design mitigate scale-up risks by ensuring a continuous supply of fuel across a range of output scenarios, as confirmed by its demonstration plant over a 2-year pilot testing phase. The company has already identified about 1,000 worldwide locations to develop its plants, with the potential to increase the scale of operations if required. The company's locations are generally situated in areas that receive ample sunlight for optimal functioning of the system.

Best Practices example:

Joule has demonstrated best-in-class scale-up capabilities and is targeting, at full-scale production, yields of around 25,000 gallons per acre for ethanol and 15,000 gallons per acre for diesel. Competing technologies in the market are limited in their scale-up potential by variables such as proximity to and supply of feedstock, and a significant amount of arable land. Competing algal biomass technologies boast yields in the range of 7,000 gallons per acre, while cellulosic biofuels claim to yield about 2,000 gallons per acre, and fuels derived from corn demonstrate even lower yields.

Product Impact

Joule's technology platform is designed to convert CO₂ to a specific molecule of interest, including ethanol and hydrocarbons that comprise diesel, jet fuel, and gasoline in the presence of a catalyst. This platform can be tailored to produce a variety of products by simply changing the catalyst to the particular molecule in question.

The company's 1st commercial products will be Joule Sunflow-E, solar-derived ethanol, and Joule Sunflow-D, the world's 1st hydrocarbon diesel fuel produced directly from waste CO₂ and sunlight.

Visionary Innovation

Joule's technology aims to use CO₂ emitted from an industrial flue or other polluter as an energy source, thereby contributing towards carbon capture and utilization. A big

advantage of the company's technology is that it uses brackish or waste water as its circulating agent, eliminating the need for fresh water. This not only increases the potential locations for the company's plants but also greatly reduces the environmental impact of its technology.

Best Practices example:

Joule's technology can yield fuels with minimal environmental impact compared to competitors. It embodies Frost & Sullivan's Mega Trend of "innovating to zero." This has been proven in lab environments, where a conversion rate of 95% has been realized. This is about 5 times the conversion rates attained by existing 1st- and 2nd-generation biofuels, which are intrinsically less energy efficient.

Further, Joule's renewable fuels meet ASTM (American Society for Testing and Materials) for blends with traditional fossil fuels in concentrations of up to 50% for diesel blends and up to 25% in jet fuel blends. The blending of the company's fuel with conventional fuels can improve combustion quality, reduce sulfur and particulate content and also reduce carbon emissions of the fuel blend.

Further demonstrating Joule's commitment to sustainability and to manufacturing a lower cost product, the company has entered into a Memorandum of Understanding (MoU) with Scatec Solar ASA, Norway (Oslo) to reach specific terms for a partnership in support of the rollout of Joule's plant with photovoltaic power. This partnership would reduce Joule's carbon footprint even further, by more than 90% over conventional fuels.

Technology Licensing

The German automaker, Audi, after extensive evaluation of Joule's proprietary technology and commercial plans, has entered into a strategic partnership with the company for developing renewable ethanol and diesel. The agreement complements Audi's vision of carbon-neutral mobility in the realm of personal transportation. The automaker has also invested in Joule's demonstration plant in New Mexico in support of Joule's production of its Sunflow-E and Sunflow-D sustainable transportation fuels. This exclusive partnership will help Audi gain a 1st-mover advantage in the auto industry as Joule's exclusive partner in the automotive sector; Joule, in return, would benefit from Audi's established brand value, expertise, and global presence.

Joule is also actively involved with various other technology partners for accelerating product development and site partners with access to capital and CO₂ for expediting product deployment. Joule is also working on commercial plant design with engineering, procurement, and construction (EPC) companies.

Best Practices example:

Joule has demonstrated commitment to its technology and long-term vision by aggressively protecting its intellectual property in this area. This is evidenced by its filing of more than 50 patents in this space and with more than 100 patent applications.

Brand Loyalty

In May 2014, Joule demonstrated the commercial readiness of its fuel by complying with the standards of the American Society of Testing and Materials (ASTM).

Joule also became one of the 1st companies to ever receive clearance from U.S. Environmental Protection Agency (EPA) for the commercial use of a modified organism. This was done after extensive review of the company's Microbial Commercial Activity Notices by the EPA. The voluntary consent order entered into by Joule and EPA allows Joule to use the modified microbial strains at its plant in Hobbs, New Mexico, while also continuing to provide the EPA with further data resulting from this use.

Joule Unlimited has also earned recognition for its brand through various accolades in the Cleantech and energy industries.

Customer Acquisition

Joule has acquired more than \$160 million in funding with an active support from Flagship Ventures. The company plans to use the funding for further industrialization of its technology platform. The company is also working toward strategic partnerships with oil companies and international original equipment manufacturers (OEM's) looking for more sustainable alternatives to traditional fuels. Another avenue for Joule to expand its customer base includes off-take partners such as fleet owners, railways, airlines, and fuel blenders that are looking for drop-in fuels that reduce their carbon emissions. Local governments looking to localize fuel production, increase local employment, and reduce dependence on imports could also benefit from Joule's technology platform.

Best Practices example:

Joule's strategy with expansion is also dependent on the location of its infrastructure partnerships and land availability. Joule's technology is targeting a price point of \$1.20 per gallon or \$50 per barrel for both its Sunflow-E and Sunflow-D products.

Conclusion

Joule Unlimited has demonstrated its ability to add value to business, society, and the environment through cost-effective, sustainable, and high-volume production of renewable fuels and chemicals by means of its Helioculture technology platform. The company's platform continuously and directly converts solar energy to drop-in fuels compatible with the existing infrastructure, including fungible diesel and ethanol, unlike the costly, multi-step production of traditional 1st- and 2nd-generation biofuel technologies. The technology targets productivities that are exponentially greater than comparable

technologies by using breakthroughs in genome engineering, solar capture, and conversion and process engineering.

With its strong overall performance, Joule Unlimited has earned Frost & Sullivan's 2015 Technology Innovation Award in the CO₂-to-fuels industry.

Significance of Technology Innovation

Ultimately, growth in any organization depends upon finding new ways to excite the market, and upon maintaining a long-term commitment to innovation. At its core, technology innovation or any other type of innovation can only be sustained with leadership in three key areas: understanding demand, nurturing the brand, differentiating from the competition. This three-fold approach to nurturing innovation is explored further below.



Understanding Technology Innovation

Technology innovation begins with a spark of creativity that is systematically pursued, developed, and commercialized. That spark can result from a successful partnership, a productive in-house innovation group, or the mind of a singular individual. Regardless of the source, the success of any new technology is ultimately determined by its innovativeness and its impact on the business as a whole.

Key Benchmarking Criteria

For the Technology Innovation Award, we evaluated two key factors—Technology Attributes and Future Business Value—according to the criteria identified below.

Technology Attributes

- Criterion 1: Industry Impact
- Criterion 2: Product Impact
- Criterion 3: Scalability
- Criterion 4: Visionary Innovation

Criterion 5: Application Diversity

Future Business Value

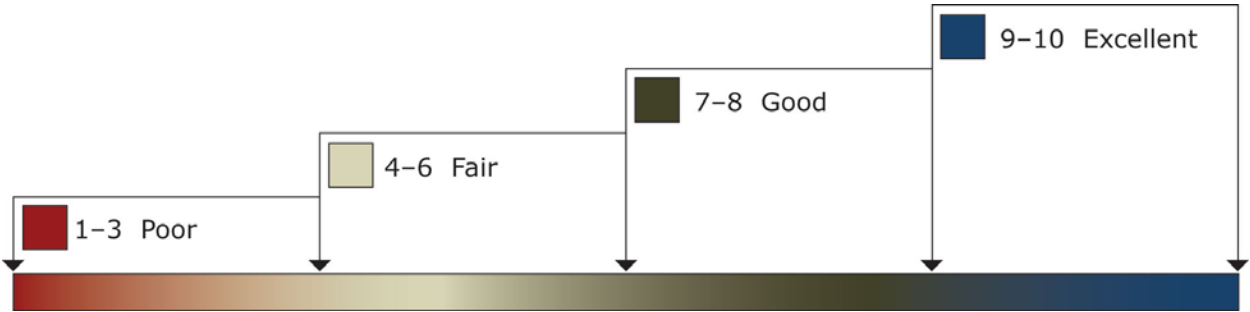
- Criterion 1: Financial Performance
- Criterion 2: Customer Acquisition
- Criterion 3: Technology Licensing
- Criterion 4: Brand Loyalty
- Criterion 5: Human Capital

Best Practice Award Analysis for Joule Unlimited

Decision Support Scorecard

To support its evaluation of best practices across multiple business performance categories, Frost & Sullivan employs a customized Decision Support Scorecard. This tool allows our research and consulting teams to objectively analyze performance, according to the key benchmarking criteria listed in the previous section, and to assign ratings on that basis. The tool follows a 10-point scale that allows for nuances in performance evaluation; ratings guidelines are illustrated below.

RATINGS GUIDELINES



The Decision Support Scorecard is organized by Technology Attributes and Future Business Value (i.e., the overarching categories for all 10 benchmarking criteria; the definitions for each criteria are provided beneath the scorecard). The research team confirms the veracity of this weighted scorecard through sensitivity analysis, which confirms that small changes to the ratings for a specific criterion do not lead to a significant change in the overall relative rankings of the companies.

The results of this analysis are shown below. To remain unbiased and to protect the interests of all organizations reviewed, we have chosen to refer to the other key players in as Company 2 and Company 3.

DECISION SUPPORT SCORECARD FOR TECHNOLOGY INNOVATION AWARD (ILLUSTRATIVE)

<i>Measurement of 1-10 (1 = poor; 10 = excellent)</i>			
Technology Innovation	Technology Attributes	Future Business Value	Average Rating

Joule Unlimited	9.5	9	9.25
Competitor 2	8.5	8.5	8.50
Competitor 3	8	8	8.00

Technology Attributes

Criterion 1: Industry Impact

Requirement: Technology enables the pursuit of groundbreaking new ideas, contributing to the betterment of the entire industry

Criterion 2: Product Impact

Requirement: Specific technology helps enhance features and functionality of the entire product line for the company

Criterion 3: Scalability

Requirement: Technology is scalable, enabling new generations of products over time, with increasing levels of quality and functionality

Criterion 4: Visionary Innovation

Requirement: Specific new technology represents true innovation based on a deep understanding of future needs and applications

Criterion 5: Application Diversity

Requirement: New technology serves multiple products, multiple applications, and multiple user environments

Future Business Value

Criterion 1: Financial Performance

Requirement: High potential for strong financial performance in terms of revenues, operating margins and other relevant financial metrics

Criterion 2: Customer Acquisition

Requirement: Specific technology enables acquisition of new customers, even as it enhances value to current customers

Criterion 3: Technology Licensing

Requirement: New technology displays great potential to be licensed across many sectors and applications, thereby driving incremental revenue streams

Criterion 4: Brand Loyalty

Requirement: New technology enhances the company's brand, creating and/or nurturing brand loyalty

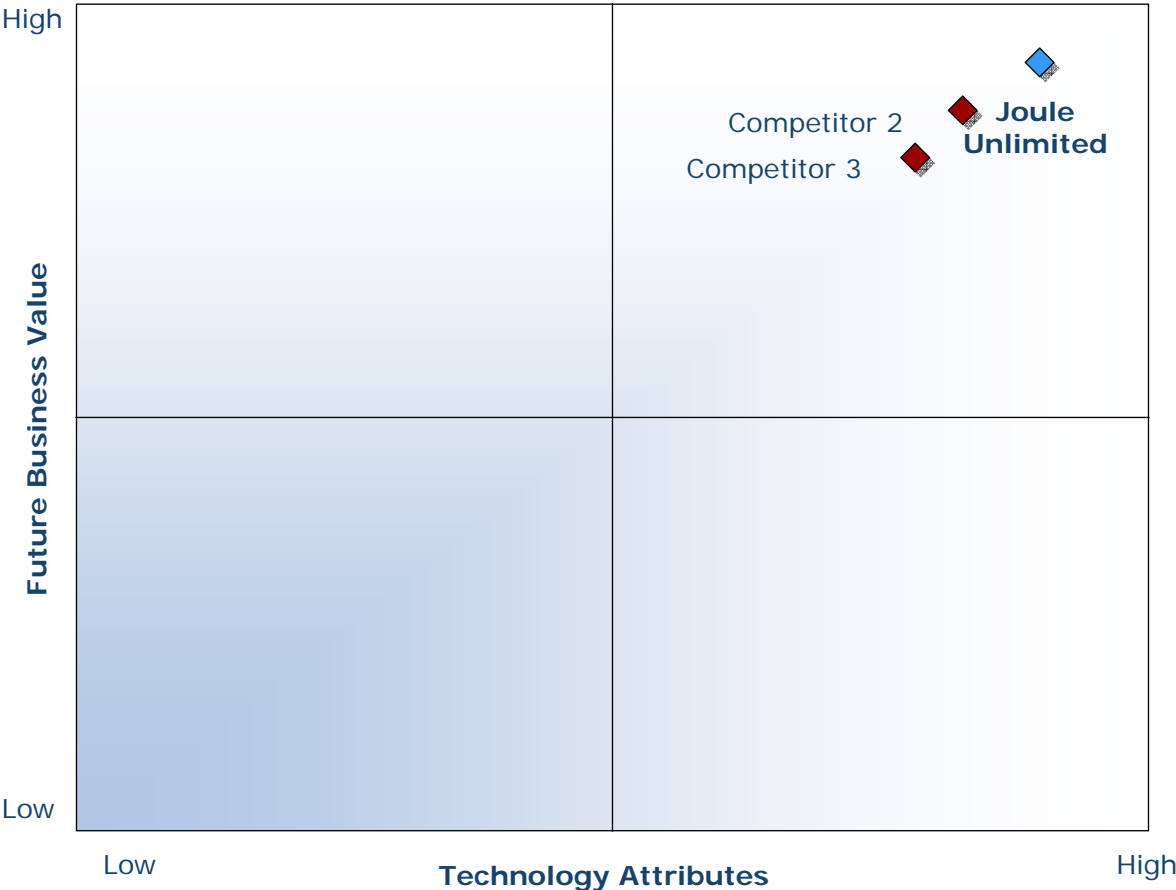
Criterion 5: Human Capital

Requirement: Customer impact is enhanced through the leverage of specific technology, translating into positive impact on employee morale and retention

Decision Support Matrix

Once all companies have been evaluated according to the Decision Support Scorecard, analysts can then position the candidates on the matrix shown below, enabling them to visualize which companies are truly breakthrough and which ones are not yet operating at best-in-class levels.

DECISION SUPPORT MATRIX FOR TECHNOLOGY INNOVATION AWARD (ILLUSTRATIVE)



The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS



Frost & Sullivan's 360-degree research methodology represents the analytical rigor of our research process. It offers a 360-degree-view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often, companies make important growth decisions based on a narrow understanding of their environment, leading to errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry players and for identifying those performing at best-in-class levels.

Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Our awards team follows a 10-step process (illustrated below) to evaluate award candidates and assess their fit with our best practice criteria. The reputation and integrity of our awards process are based on close adherence to this process.

STEP	OBJECTIVE	KEY ACTIVITIES	OUTPUT
1 Monitor, target, and screen	Identify award recipient candidates from around the globe	<ul style="list-style-type: none"> • Conduct in-depth industry research • Identify emerging sectors • Scan multiple geographies 	Pipeline of candidates who potentially meet all best-practice criteria
2 Perform 360-degree research	Perform comprehensive, 360-degree research on all candidates in the pipeline	<ul style="list-style-type: none"> • Interview thought leaders and industry practitioners • Assess candidates' fit with best-practice criteria • Rank all candidates 	Matrix positioning all candidates' performance relative to one another

STEP	OBJECTIVE	KEY ACTIVITIES	OUTPUT
3 Invite thought leadership in best practices	Perform in-depth examination of all candidates	<ul style="list-style-type: none"> • Confirm best-practice criteria • Examine eligibility of all candidates • Identify any information gaps 	Detailed profiles of all ranked candidates
4 Initiate research director review	Conduct an unbiased evaluation of all candidate profiles	<ul style="list-style-type: none"> • Brainstorm ranking options • Invite multiple perspectives on candidates' performance • Update candidate profiles 	Final prioritization of all eligible candidates and companion best-practice positioning paper
5 Assemble panel of industry experts	Present findings to an expert panel of industry thought leaders	<ul style="list-style-type: none"> • Share findings • Strengthen cases for candidate eligibility • Prioritize candidates 	Refined list of prioritized award candidates
6 Conduct global industry review	Build consensus on award candidates' eligibility	<ul style="list-style-type: none"> • Hold global team meeting to review all candidates • Pressure-test fit with criteria • Confirm inclusion of all eligible candidates 	Final list of eligible award candidates, representing success stories worldwide
7 Perform quality check	Develop official award consideration materials	<ul style="list-style-type: none"> • Perform final performance benchmarking activities • Write nominations • Perform quality review 	High-quality, accurate, and creative presentation of nominees' successes
8 Reconnect with panel of industry experts	Finalize the selection of the best-practice award recipient	<ul style="list-style-type: none"> • Review analysis with panel • Build consensus • Select winner 	Decision on which company performs best against all best-practice criteria
9 Communicate recognition	Inform award recipient of award recognition	<ul style="list-style-type: none"> • Present award to the CEO • Inspire the organization for continued success • Celebrate the recipient's performance 	Announcement of award and plan for how recipient can use the award to enhance the brand
10 Take strategic action	Share award news with stakeholders and customers	<ul style="list-style-type: none"> • Coordinate media outreach • Design a marketing plan • Assess award's role in future strategic planning 	Widespread awareness of recipient's award status among investors, media personnel, and employees

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best in class positions in growth, innovation and leadership. The company's Growth Partnership Service provides the CEO and the CEO's Growth Team with disciplined research and best practice models to drive the generation, evaluation and implementation of powerful growth strategies. Frost & Sullivan leverages almost 50 years of experience in partnering with Global 1000 companies, emerging businesses and the investment community from 31 offices on six continents. To join our Growth Partnership, please visit <http://www.frost.com>.