FROST & SULLIVAN

# FROST & SULLIVAN BEST PRACTICES AWARD

## INDUSTRIAL POWER ELECTRONICS - GLOBAL

## Company of the Year 2019

TMEIC
We drive industry

FROST & SULLIVAN
2019 BEST PRACTICES AWARD

# Contents

# Background and Company Performance

## *Industry Challenges*

We are in a day and age where digital transformation has taken center stage in all industries leading to a fourth industrial revolution. Industry 4.0 implies that industrial machinery will have smart product processing capability and will also have the ability to communicate with other machinery without human aid by bridging the physical and virtual worlds. While various industries embrace this trend, it is crucial that ICT semiconductors, central processing units, digital signal processors, integrated circuits etc. are not only highly advanced, but also offer high quality and reliability. This highly depends on the production processes of these devices as they are extremely sensitive to the power supply disturbances and require fine manipulation, strict room conditions, detailed process line control and so on. The key to addressing this challenge is advanced power electronics solutions.

On the other hand, demand for solar power systems are increasing, as economics vs. conventional power continue to improve and the global need to limit emissions becomes more urgent. Key components play a role in this and project developers are looking for solar inverter solutions that enable farms to maximize electrical output (harvest) and therefore revenues. One main challenge in the solar inverter industry is the potential differential harvests that can be achieved. The string and central inverters face a challenge from the perspective of partial shading, which can cause a reduced energy harvest. Partial shading can be caused by dust, debris, a chimney, and branches of trees, which may come between sunlight and the solar panel.

PV power generation is one of the alternative energy generations for $CO_2$ abatement leading to a sustainable future. For $CO_2$ abatement, the major challenge is from an energy efficiency perspective. The first energy efficiency challenge caused because of digital transformation, where the ICT facilities are rapidly increasing in number and also in energy consumption. For the ICT facilities, stable electric power supply is crucial for reliable operation to support the digital transformation including Industry 4.0. So, the power electronics, especially UPSs and DC power supplies, face a challenge to supply highly efficient and stable power to the ICT facilities. Efficient energy usage also benefits the owners to obtain good evaluations from viewpoint of SDGs. The challenge for energy efficiency has forced manufactures to improve their products and systems.

More significant challenge to energy efficiency is found in the motor systems, which consume around half of global electric power. The motor system efficiency improvement requires advanced design of the motors. In addition the motor drive inverters also face this challenge.

## *Visionary Innovation and Performance/Customer Impact*

**Excellence in Addressing Unmet Needs**

The most intriguing aspect about TMEIC is its rock solid determination and relentless pursuit for technology innovation and excellence. Its comprehensive product portfolio represents the next generation of power electronics solutions that are not only truly end-

to-end, but also state of the art future ready solution set. When it comes to anticipating future market needs and addressing unmet needs, TMEIC has time and gain maintained its position at the forefront of the industry. Furthermore, it has gained a reputation of raising the bar higher every time with its innovations, making it difficult for its competitors to catch up. TMEIC's excellence in addressing unmet needs in the industrial power electronics market can be attributed to its truly holistic approach. This is demonstrated by its visionary product innovations and technology incubations in four distinct product groups – PV inverters, uninterruptible power systems (UPS), energy storage systems (ESS) and motor drive inverters (MD)

TMEIC's cutting edge PV inverter product line is second to none in the global market. It not only offers industry leading efficiencies, but also optimizes the cost of power generation to the highest magnitude. The company's excellence in PV inverters can be characterized by three unique technology aspects – 3 level circuit technology, which plays a crucial role in enhancing efficiency and reliability levels; innovative control technology that allows high-precision maximum power point tracking (MPPT) (with at recorded MPPT efficiency at 99.9% in a third-party test at Fraunhofer institute); and finally a cutting edge cooling technology that employs a fan-less cooling system for large capacity inverters. This cooling technology is specifically designed to reduce the power consumption, increase reliability and reduce the need for periodic replacement of parts. Furthermore, TMEIC's custom made IGBT perfectly complements the 3 level inverter circuit and significantly reduces the dimensions while increasing power density substantially. One of the other key elements born out of TMEIC's initiative to address unmet needs is the "AC Station". It is a pre-engineered integrated solution comprising of Solar Ware® PV inverter series, DC recombiner system, an interconnection circuit breaker and a medium step-up transformer. TMEIC offers this highly cost effective and reliable solution in an E-House package design or as a pre-assembled open skid, depending on customers' selection of indoor or outdoor product series.

On the other hand, TMEIC's PV inverters are designed to offer highly optimized power generation throughout the day, even under adverse weather conditions. On an average, it has been able to achieve 3-5% higher annual power output when compared to its competitors. Its products also feature 99.99% availability, demonstrating reliability of the highest magnitude. The highly efficient MPPT of TMEIC's products is one of its key strengths and also a differentiating factor that sets TMEIC apart from its competitors. Furthermore, with its advanced control capabilities, TMEIC's inverters are able to maintain maximum active power generation even during cloud-edge phenomenon passing though the PV panels, which is dangerous and may damage PV inverters.

TMEIC's unique 3 level circuit technology is also applied in UPSs and in motor drive inverters. The technology pushes TMEIC UPS efficiency up to the highest in the world and contributes for higher energy efficiency in ICT facilities. In its motor drive systems, TMEIC applies the 3 level technology to the medium-voltage and high-capacity drive inverters. The medium voltage motors themselves operate with high efficiency since they output large power with smaller current. For the medium voltage motors, TMEIC developed the

motor drive inverters with the bi-directional 3 level circuit technology. This regenerates electric power form the motors while powering the motors as well. This bi-directional function further contributes to energy efficiency in the motor systems. The advanced motor drive can also reduce the reactive power consumption in the AC power supply systems of industries. This reduction of the reactive power results in the power loss reduction in the transmission/distribution lines/cables in the electric power networks.

**Visionary Scenarios Through Use of Mega Trends**

TMEIC's ongoing effort to study and analyze mega trends is highly commendable. These efforts have enabled TMEIC to capitalize on trends that would have an impact not only on itself, but also across the value chain of the solar PV ecosystem. Its futuristic approach towards product development has placed it in the forefront of this highly competitive industry. It constantly strives to be a step ahead of its competitors with respect to technology and innovation and has been successful thus far. This is primarily driven by its high focus on tracking and analyzing mega trends. A vivid testament to demonstrate TMEIC's thought leadership is its conception of a visionary concept called Power Electronics in Everything (PEiE) which it developed to capitalize on the fourth industrial revolution, Industry 4.0. The PEiE concept proposes that the integration of power electronics on devices has increased tremendously and will continue to do so until it reaches a stage of "Power Electronics in Everything".

The company has implemented PEiE concept in three distinct system levels. The first is on a product level, where it has developed a highly innovative product called "Universal Inverters". This cutting edge product deploys inverter modules in parallel where the converter has the ability to larger power with higher efficiency and the inverters have the ability to continue operation without any disruption even when a particular inverter module fails. Interestingly, TMEIC has also applied the PEiE concept at a product level in "Uninterruptible Power System (UPS)", "MV drive inverters", "Medium voltage MPC" and "MMC convertors". The second one is the implementation of PEiE at a plant level. As we know, TMEIC's proprietary "main site controller (MSC)" is a control system for integrating multiple PV inverters. It provides functions to stop and restart operations, control the output and power factor via remote command by independent system operators and so on. As a part of its PEiE initiative the company has developed a more advanced controller called the power plant controller (PPC) that works in conjunction with the MSC. The PPC is designed to take a wider role to stabilize the AC power network. The PPC plays a key role in optimizing control systems such as renewable integration, where its energy storage systems (ESS) support grid stability by compensating the output power variations from renewable generations (PV, wind and etc.). The other example is load shaving, where ESS helps shave and shift the load connected to the grid, thus contributing to demand response optimization. The third aspect is the implementation of PEiE at a network level. With this initiative, TMEIC aims to significantly enhance the level of customer experience offered by current conventional systems by implementing PEiE in smart grids and virtual power plants. Frost & Sullivan finds this initiative highly commendable.

**Implementation of Best Practices**

TMEIC places tremendous emphasis on three core aspects of its product development process – quality, reliability and efficiency. Its solutions are embedded with a wide range of features and functionalities that enhance end user value multi-fold where most of these features are unique in the industry. Its innovation excellence has catapulted it significantly in the technology curve, placing it way ahead of its competitors. The company's best-in-class strategy implementation is characterized by processes, tools, and activities that generate a consistent and repeatable level of success. Frost & Sullivan finds TMEIC's manufacturing excellence second to none. The company has gone to great lengths to ensure product quality of the highest magnitude by leveraging cutting edge processes and tools in its manufacturing facilities. It is highly intriguing to see the company going above and beyond the traditional manufacturing approach with its digital manufacturing initiative underpinned by best-in-class engineering. This has provided TMEIC with a unique edge in this highly competitive market.

One of the fine examples that demonstrate TMEIC's excellence in digital manufacturing is its use of "3D working model visualization", where the factory employees are provided instructions via 3D visualization techniques to create a zero error assembly line to a microscopic detail. The other unique manufacturing best practice employed by the company is the use of "kaizen" principles in its factories; aiming at continuous improvement with a vison to enhance and improve the system/process on a regular basis. TMEIC's global production/supply strategy is also highly commendable, where the basic product design is developed in Japan, while the final specifications are determined by the design division of each plant, based on the needs of each region. The other key aspect of this strategy is to maintain product quality at the highest levels even while manufacturing in plants outside Japan.

**Excellent Financial Performance**

TMEIC's tremendous focus on power electronics has propelled it to one of the leading positions in the global market in terms of market share. The company achieved above market average growth rate by registering 10% year-on-year revenue growth rate; it is also noteworthy that TMEIC recorded a 10% growth rate on its operating income in 2018 compared to the previous year. The company currently holds the largest market share in the large-capacity PV inverters (100kW and above) and is taking serious measures to increase its overall global market share, where its main strategy is to increase its overseas sales percentage. In an effort to strengthen its Americas operations and market share, TMEIC has built a second power electronics factory in Houston, Texas as a supplement to its already existing factory. This new factory became fully operational in August 2017. These production facilities will not only manufacture PV inverters but also other high-quality competitive products such as inverters for driving motors by leveraging its power electronics technology. With the addition of this new factory, the company aims to increase its production capacity of its PV inverters by nearly 300%. It is Frost & Sullivan's finding that TMEIC is poised for a steady growth over the next two to three years which will be primarily driven by its innovative PEiE concept backed by an extremely

strong product/technology innovation strategy and manufacturing excellence with a strong focus on quality and reliability.

**Outstanding Customer Ownership Experience**

TMEIC has high potential to further strengthen its position in the market with its cutting edge PE solutions, enabled by its long-range, macro-level innovation strategies. As a result of its meticulous mega trend scenario analysis, the company has been able to develop products that not only satisfies the current needs but also addresses anticipated future needs of the end user. Frost & Sullivan finds TMEIC's sincere effort towards constant product developments and technology enhancements aimed at customer value enrichment is highly commendable.

TMEIC offers an industry leading UPS product line designed with cutting edge power electronics. It employs an innovative circuit concept by leveraging an all CSTBT (Carrier Stored Trench Bipolar Transistor) Circuit (IGBT) Topology and uses an advanced 3-level bi-directional conversion technology in its UPS systems. With this state-of-the-art design, TMEIC is able to deliver industry-leading efficiency, reliability, performance and flexibility to meet today's critical power demands. Other key functionalities that enhance customer ownership experience include a DC-to-DC chopper charging circuit which extends battery and capacitor life and the high-speed digital control that ensures stable power supply to the critical load even with 100% unbalanced load and regenerative loads.

TMEIC's excellence in motor drives for high voltage and high power applications is unparalleled. Its motors offer superior efficiency, low electrical losses and high power conversion; this is mainly the result of TMEIC's detailed analysis of the electromagnetic field patterns and ventilating air flows and incorporating the results in its product design. The company's excellence in this field can be directly attributed to its vast exposure and pedigree in heavy industries such as iron, metal, power networks and so on. This complemented by its technology know-how in power electronics and semiconductor applications has further propelled its ability to deliver motor drives that offer industry leading customer ownership experience. Its high voltage motor drives are known for significantly increasing the energy efficiency in factories. Furthermore, its motor shafts are made of forged steel with high tensile strength, thereby minimizing mechanical deflection and vibration. TMEIC's drives have been developed by incorporating cutting edge design aspects that offer high reliability, low harmonics distortion, regenerative operation and reactive power control operation to a broad range of industrial applications.

**Brand Equity**

It is intriguing to see the pace at which TMEIC's brand image has made a unique and iconic mark for itself among the value chain of the highly competitive power electronics industry. Customers perceive TMEIC as a company that stands out in technology excellence, innovation, and most importantly, customer focus. It has gained a reputation of delivering services and solutions of the highest standard that specifically addresses customers' unmet needs. The company's tremendous effort towards building and strengthening brand equity is clearly evident in the company's year on year revenue

growth where it has been constantly achieving above market growth rates. It is also characterized by its intimate relationship with its customers and partners.

## *Conclusion*

TMEIC's visionary innovations and technology excellence places it at the forefront of the Global power electronics industry. Its strong R&D culture combined with extensive intellectual property provides it with a unique edge in the market. Simplicity, efficiency and reliability are the three cornerstones of TMEIC's power electronics products. The driving force behind TMEIC's success is its astronomical perseverance and commitment to pursuing its vision of creating cutting edge PE solutions that not only address customers' current needs, but also evolving future needs.

With its strong overall performance, TMEIC has earned Frost & Sullivan's 2019 Company of the Year Award.

## Significance of Company of the Year

To receive the Company of the Year Award (i.e., to be recognized as a leader not only in your industry, but among non-industry peers) requires a company to demonstrate excellence in growth, innovation, and leadership. This excellence typically translates into superior performance in three key areas—demand generation, brand development, and competitive positioning—that serve as the foundation of a company's future success and prepare it to deliver on the 2 factors that define the Company of the Year Award: Visionary Innovation and Performance, and Customer Impact).


## Understanding Company of the Year

Driving demand, brand strength, and competitive differentiation all play critical roles in delivering unique value to customers. This three-fold focus, however, must ideally be complemented by an equally rigorous focus on Visionary Innovation and Performance to enhance Customer Impact.

## *Key Benchmarking Criteria*

For the Company of the Year Award, Frost & Sullivan analysts independently evaluated each factor according to the criteria identified below.

**Visionary Innovation and Performance**

Criterion 1: Addressing Unmet Needs
Criterion 2: Visionary Scenarios through Mega Trends
Criterion 3: Implementation of Best Practices
Criterion 4: Blue Ocean Strategy
Criterion 5: Financial Performance

**Customer Impact**

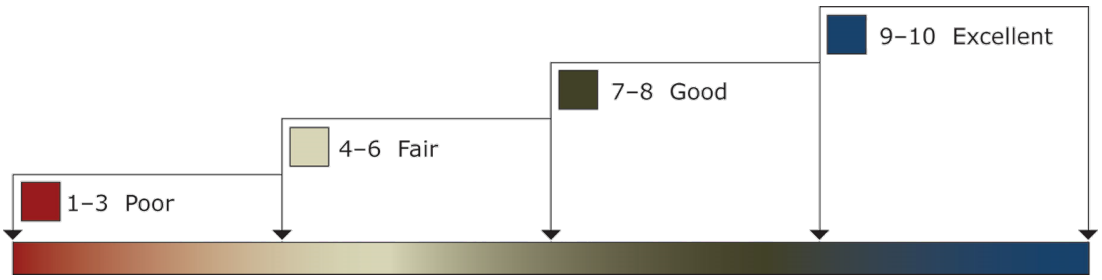
Criterion 1: Price/Performance Value
Criterion 2: Customer Purchase Experience
Criterion 3: Customer Ownership Experience
Criterion 4: Customer Service Experience
Criterion 5: Brand Equity

# Best Practices Award Analysis for TMEIC

## *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 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 considers Visionary Innovation and Performance and Customer Impact (i.e., the overarching categories for all 10 benchmarking criteria; the definitions for each criterion 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, Frost & Sullivan has chosen to refer to the other key participants as Competitor 1 and Competitor 2.

| *Measurement of 1–10 (1 = poor; 10 = excellent)* | | | |
|---|---|---|---|
| **Company of the Year** | Visionary Innovation & Performance | Customer Impact | **Average Rating** |
| | | | |
| **TMEIC** | **9.0** | **9.0** | **9.0** |
| Competitor 1 | 7.0 | 7.0 | 7.0 |
| Competitor 2 | 7.0 | 6.0 | 6.5 |

## *Visionary Innovation & Performance*

### Criterion 1: Addressing Unmet Needs

Requirement: Implementing a robust process to continuously unearth customers' unmet or underserved needs, and creating the products or solutions to address them effectively.

### Criterion 2: Visionary Scenarios through Mega Trends

Requirement: Incorporating long-range, macro-level scenarios into the innovation strategy, thereby enabling first-to-market growth opportunity solutions.

### Criterion 3: Implementation of Best Practices

Requirement: Best-in-class strategy implementation characterized by processes, tools, or activities that generate a consistent and repeatable level of success.

### Criterion 4: Blue Ocean Strategy

Requirement: Strategic focus on creating a leadership position in a potentially uncontested market space, manifested by stiff barriers to entry for competitors.

### Criterion 5: Financial Performance

Requirement: Strong overall business performance in terms of revenue, revenue growth, operating margin, and other key financial metrics.

## *Customer Impact*

### Criterion 1: Price/Performance Value

Requirement: Products or services offer the best value for the price compared to similar offerings in the market.

### Criterion 2: Customer Purchase Experience

Requirement: Customers feel they are buying the optimal solution that addresses both their unique needs and their unique constraints.

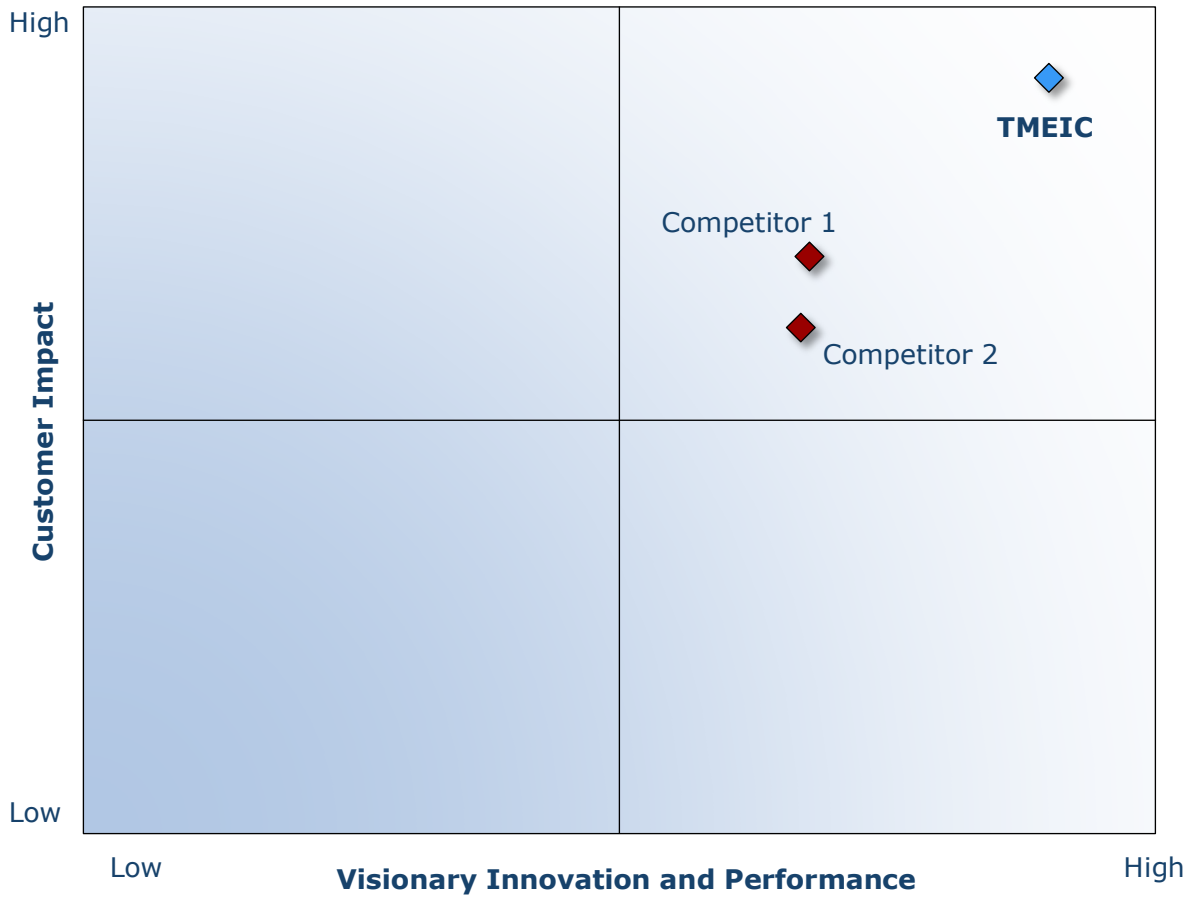
**Criterion 3: Customer Ownership Experience**
Requirement: Customers are proud to own the company's product or service and have a positive experience throughout the life of the product or service.

**Criterion 4: Customer Service Experience**
Requirement: Customer service is accessible, fast, stress-free, and of high quality.

**Criterion 5: Brand Equity**
Requirement: Customers have a positive view of the brand and exhibit high brand loyalty.

## *Decision Support Matrix*

Once all companies have been evaluated according to the Decision Support Scorecard, analysts 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.



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

Frost & Sullivan analysts follow a 10-step process to evaluate award candidates and assess their fit with select best practice criteria. The reputation and integrity of the awards 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 world | • Conduct in-depth industry research<br>• Identify emerging industries<br>• Scan multiple regions | Pipeline of candidates that potentially meet all best practices criteria |
| 2 | **Perform 360-degree research** | Perform comprehensive, 360-degree research on all candidates in the pipeline | • Interview thought leaders and industry practitioners<br>• Assess candidates' fit with best practices criteria<br>• Rank all candidates | Matrix positioning of all candidates' performance relative to one another |
| 3 | **Invite thought leadership in best practices** | Perform in-depth examination of all candidates | • Confirm best practices criteria<br>• Examine eligibility of all candidates<br>• Identify any information gaps | Detailed profiles of all ranked candidates |
| 4 | **Initiate research director review** | Conduct an unbiased evaluation of all candidate profiles | • Brainstorm ranking options<br>• Invite multiple perspectives on candidates' performance<br>• Update candidate profiles | Final prioritization of all eligible candidates and companion best practices positioning paper |
| 5 | **Assemble panel of industry experts** | Present findings to an expert panel of industry thought leaders | • Share findings<br>• Strengthen cases for candidate eligibility<br>• Prioritize candidates | Refined list of prioritized award candidates |
| 6 | **Conduct global industry review** | Build consensus on Award candidates' eligibility | • Hold global team meeting to review all candidates<br>• Pressure-test fit with criteria<br>• 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 | • Perform final performance benchmarking activities<br>• Write nominations<br>• 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 practices award recipient | • Review analysis with panel<br>• Build consensus<br>• Select winner | Decision on which company performs best against all best practices criteria |
| 9 | **Communicate recognition** | Inform award recipient of recognition | • Present award to the CEO<br>• Inspire the organization for continued success<br>• 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** | Upon licensing, company able to share award news with stakeholders and customers | • Coordinate media outreach<br>• Design a marketing plan<br>• Assess award's role in strategic planning | Widespread awareness of recipient's award status among investors, media personnel, and employees |

# The Intersection between 360-Degree Research and Best Practices Awards

## *Research Methodology*

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of the 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, resulting in 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 participants and for identifying those performing at best-in-class levels.

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS


## About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, helps clients 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 practices models to drive the generation, evaluation, and implementation of powerful growth strategies. Frost & Sullivan leverages nearly 60 years of experience in partnering with Global 1000 companies, emerging businesses, and the investment community from 45 offices on 6 continents. To join Frost & Sullivan's Growth Partnership, visit http://www.frost.com.