Smart and AC PV Modules 2015-2020

Technologies, Value Propositions and Forecasts for Module-Integrated Power Electronics

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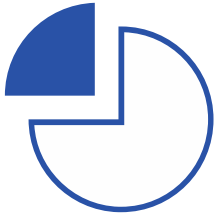

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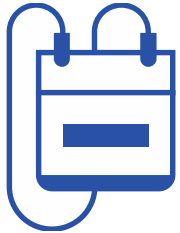

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Introduction and Key Findings

Introduction: A Brief History of Module Integration

Smart and AC modules were first widely introduced to the market in 2011 as an attempt for module manufacturers to differentiate in a massively oversupplied market. At the time, microinverters and DC optimizers were promising but unproven technologies. Through partnerships, these module-level power electronics (MLPE) vendors attempted to tap into the larger sales channels and stronger balance sheets of their module partners.

Since then, the MLPE sector has grown tremendously. Shipments of module-level power electronics totaled 1.3 GW in 2014 and are forecasted to continue growing at an average annual growth rate of 39% through 2020, faster than any other inverter product segment. However, microinverters and DC optimizers are far from ubiquitous. Module-level power electronics still require a higher upfront investment, and competing string inverters have plummeted in cost over the last several years. Additionally, increased labor costs associated with MLPE and the existence of only a few bankable suppliers keep module-level electronics from entirely taking over the market.

As a result, the second major market push for integrated smart and AC modules is beginning. This time, module manufacturers hope to ride the success of their MLPE vendor partners. Leading MLPE vendors Enphase, SolarEdge and Tigo are all working with select module partners; SunPower has acquired SolarBridge Technologies to develop AC modules on their own; Maxim Integrated has begun commercialization of its module string optimizer; and LG has brought the first fully embedded AC module to the market.

The bottom line is that the PV market is hungry for solutions that simplify labor, eliminate redundancy, and lower overall costs. Each of these objectives can be accomplished with smart and AC modules. The questions that remain are not new. Who will lead in bringing integrated modules to market at scale? What architectures and technologies are the most promising? How fast will costs come down? For whom does the value proposition resonate with the most? How big is the overall opportunity? These are the questions addressed in this report.

Key Findings: A Growing Market With Significant Upside

- **We forecast the market for integrated smart and AC modules to grow steadily from 73.3 MW in 2014 to 1.01 GW by 2020** largely due to the rapid growth in demand for module-level power electronics. This represents a market value of $603 million in 2020, up from $70 million in 2015. In our base-case scenario, growth in penetration as a percent of module-level power electronics shipments will be modest and gradual, rising from 3.0% in 2015 to 7.1% in 2020.

- **Forecast risk is significantly skewed to the upside.** Limited existing market penetration of integrated products means that downside risk is minimal. On the upside, the 2017 version of the National Electric Code in the U.S. will likely include module-level shutdown requirements, increasing the attractiveness of integrated solutions. A significant commitment to integrated modules for major players such as SolarCity/Silevo, SunPower/SolarBridge, Enphase, and SolarEdge could grow penetration levels to higher-than-expected levels.

- **Smart modules represent the greatest near-term market opportunity** due to the existing availability of embedded technologies that replace the junction box and strong momentum of DC optimization technologies, particularly those from SolarEdge. AC modules can offer a superior long-term value proposition for lowering overall installation labor costs, but short-term growth will be hindered by the limited value and increased cost of frame-attached AC modules, the minimal supply of embedded products, and the perceived risk to module manufacturers over warranties and questionable long-term reliability.

Key Findings: A Growing Market With Significant Upside (Cont.)

- **There remain several barriers to achieving high-volume sales of smart and AC modules.** 1) The greatest barrier has been significant product markup by smart and AC module vendors and distributors. Market growth will cause these markups to fall, and savings in relation to purchasing standalone modules and MLPE will eventually be passed on to customers. 2) Labor savings are currently difficult to recognize though they will become more valuable as the PV market matures. 3) Module vendors are inexperienced at dealing with customer service for implementation and troubleshooting of MLPE and microinverters in particular. Smart and AC module vendors must rely heavily on their MLPE partners in order to be successful. 4) Lastly, cheaper modules containing integrated safety features but lacking maximum power point tracking (MPPT), voltage control, and AC-to-DC inversion could undermine increased long-term demand for smart and AC modules that results from module-level rapid shutdown requirements in the 2017 version of the U.S. National Electrical Code.

- **Expect consistent new product introductions of smart and AC modules over the next several years.** We believe the most promising technologies will be fully embedded or cartridge-based and feature bankable module/MLPE providers. The smart-module market currently has only three notable MLPE suppliers: SolarEdge Technologies, Tigo Energy and Maxim Integrated. The success of SolarEdge has captured the attention of competing inverter manufacturers in particular, and we expect to see more relationships formed with Tigo and Maxim, as well as product introductions into the DC optimizer space. Due to the relatively small addressable market for standalone and OEM DC optimizers, entrants will look to capture a greater piece of the value chain and own the DC optimizer/inverter system or the entire smart module. For AC modules, both Enphase Energy and SolarBridge/SunPower will move beyond frame-attached AC modules to fully embedded solutions. Both companies have 2016 introduction timelines. Newcomers such as LG may struggle to overcome market incumbents, but a diverse group of microinverter manufacturers exists to help challenge the status quo.

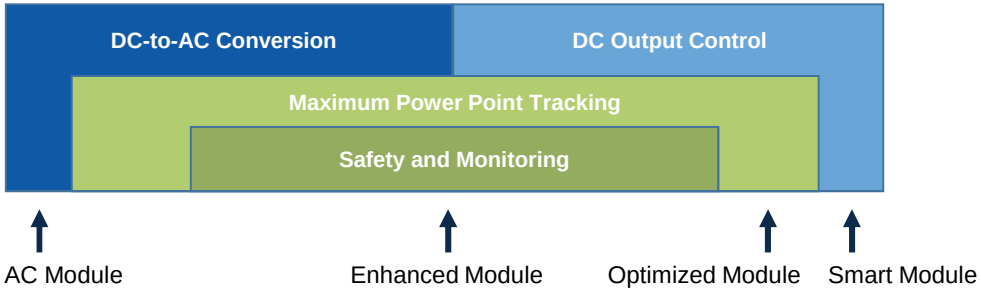
Module-Integrated Power Electronics Technology Overview

The Basics: What Is an Integrated Module?

We define an integrated module as any photovoltaic (PV) module that contains added power electronics, either embedded in the module or attached in the factory, that improve upon the basic functionality of a standard PV module. There are four primary architectures that an integrated module may have. Many of these terms are used interchangeably:

1. Integrated PV safety features that enable rapid shutdown. These products often have module-level monitoring as well. We refer to these as safety or **enhanced modules.**
2. DC-to-DC power optimization, which tracks the module's maximum power point. These are referred to as **optimized modules.**
3. Modules that perform DC-to-DC optimization and also control DC output voltage (enabling longer string lengths) are referred to as **smart modules**.
4. Modules that allow DC-to-AC inversion due to the embedding or attachment of a microinverter are commonly known as **AC modules.**

Integrated Module Types and Features



Source: GTM Research

Integrated Module Architectures

Frame-Attached AC Module

Source: Enphase Energy

Cartridge-Style Junction Box

Source: Shoals Technologies

Integrated modules come with module-level power electronics packaged in three primary architectures.

Frame-Attached Integrated Modules

- Module-level power electronics are attached to the module frame; junction box and DC wiring remain
- Currently most common architecture for AC modules
- No frame-attached smart modules are currently marketed
- Attachment can take place in the module manufacturer's facility, MLPE vendor facility or distributor/installer warehouse

Cartridge-Style Integrated Modules

- Modules with junction boxes that have attachment interfaces for optional added power electronics
- Shoals and Amphenol have introduced platforms designed for universal compatibility with power electronics; however, few MLPE partners exist for these products
- Tigo's new TS4 product creates a junction-box platform with added upgradable power electronics
- No microinverter manufacturer has introduced a product in this form factor as of October 2015
- Cartridge-based integrated modules can be installed off- or on-site with potentially minimal effect on overall costs

Integrated Module Architectures (Cont.)

Embedded Smart Module

Source: SolarEdge Technologies

Embedded Integrated Modules

- Embedded products are completely integrated into the module
- This is the most common form factor for smart modules, while only LG currently offers a fully integrated AC module
- There are two primary forms of embedded modules:
  - **Module level**, where the full output of the module is optimized by the integrated power electronics. The power electronics unit typically replaces the traditional junction box entirely.
  - **Cell-string level**, in which individual cell strings within the module are optimized by the integrated power electronics. These devices can either be implemented in the junction box (most typical) or embedded into the module encapsulant along the cell-string buses.

Value Propositions and Barriers for Smart and AC Modules

Why Use MLPE at All? The Benefits and Limitations of Module-Level Power Electronics

The Value Proposition of Module-Level Power Electronics

Increased Performance and Monitoring Granularity

- Increase system-level output by eliminating mismatch due to shading, power output tolerances, and degradation
- Monitor system at the module level to pinpoint problems during preventative and unscheduled maintenance

Simpler Design, Longer Strings, and Larger PV Systems

- DC voltage control for optimizers and parallel connected AC modules enable strings of varying lengths, simplifying design and allowing larger system sizes.
- These characteristics lower balance-of-system and customer acquisition costs.

Module-Level Safety

- The newest driver for MLPE is their ability to provide to module-level shutdown.
- NEC 2014 in the U.S. has favored MLPE vendors that already meet the code and NEC 2017 will likely require a module-level shutdown solution.

Limitations of Module-Level Power Electronics

Increased Cost

- Higher upfront pricing remains largest market barrier.
- Costs can be diminished through the recognition of backend performance gains, but material cost savings are limited to the electrical balance of systems.

Additional Installation Labor

- MLPE add labor, as every device must be manually installed, each ID must be recorded, and the communication must be configured.

Limited Bankability and Higher Warranty Risk

- Concern remains over the long-term viability of MLPE technologies and the health of MLPE suppliers.
- Increased electronics in the field heighten the reliance on warranties.

Supply Chain Complications

- Installing MLPE requires additional packaging and can complicate purchasing – especially if using DC optimizers that require a third-party inverter.
- Microinverters counter this limitation by being a one-size-fits-all solution whereby a single SKU functions for any project.

The Primary Benefits of Smart and AC Modules

Smart and AC modules improve upon the value proposition of module-level power electronics (MLPE) by overcoming several of their inherent limitations.

Current Smart and AC Module Benefits vs. Traditional MLPE by Level of Significance
1. Added bankability and simplified warranty when module manufacturers sells and warranties the integrated module as a single product. Eliminates multiple warranties from separate vendors and limits risk to the system owner.
2. Material savings from embedded MLPE that replace the junction box or frame-attached MLPE with shortened DC attachments. These savings typically are not passed on to the customer but could be as high as $0.03/W.
3. Lower installation labor costs from not having to individually install each microinverter or DC optimizer in the field. Integrated module vendors cite field installation times 30% to 50% faster than those for systems with standalone module-level power electronics. This can mean savings between $0.02/W and $0.05/W.
4. Simplified purchasing, packaging and inventory for installer by bundling MLPE with each PV module. Integrating MLPE into the module saves time in product unwrapping and site cleanup.
5. Enhanced module-level safety from frame-attached microinverters that enable rapid shutdown to within 1 foot of the module or embedded power electronics that offer module-level shutdown with no charged DC wiring.

Understanding Labor Reduction Stemming From Module Integration

- Integrated module vendors claim that **integrated products take anywhere from 30% to 50% less time to install** compared to standard modules with MLPEs. These times typically refer to the time differentials in unpacking and installing modules and module-level electronics due to:
  - Single package (rather than dual packaging for module and MLPE)
  - Lack of need to install and secure MLPE to mounting structure or connect to each module
- In theory, this results in **installation labor savings of between $0.02/W and $0.05/W**
  - Savings depend on the experience and efficiency of installers using MLPE
  - A SolarBridge study from 2014 found labor savings to be as high as 20 man-hours on a 5 kW system (~$0.12/W) for AC modules versus standalone microinverters
- **Labor savings are greater in areas with higher unburdened wages** or requirements for electricians (e.g., Massachusetts)

Example Installation Comparison of Module + MLPE vs. Integrated Modules

	Prep and Installation Time (man-hours/kW)	Burdened Labor Rate, $/hr.	Module + MLPE Installation, $/W
Modules + MLPE	2.4	$30.00	$0.072
Integrated Modules	1.5	$30.00	$0.045
Savings			**$ 0.027**

Not including inverter installation for systems with DC optimizers; also excludes racking prep and installation

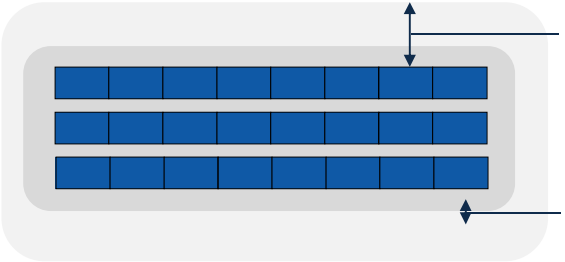
Source: GTM Research, GTM Research *Balance of Systems 2015*, Rocky Mountain Institute National Bureau of Labor Statistics

Whom Do Smart and AC Module Labor Savings Benefit Most?

- In theory, **non-fleet-level installers with less-efficient installation practices would save the most,** as they spend the most time on the roof.
  - However, less-sophisticated installation practices and operations often hinder the ability of small installers to recognize these savings
  - Additionally, spending an hour or two less on multi-day installations does not necessarily reduce install time enough to do multiple jobs per day or radically change installation practices
  - Small installers benefit the most from the simplified design aspects of systems using MLPE and are the most accepting of MLPE technologies for this reason
- **Major national installers already using MLPE point to minimal labor savings from using integrated products** due to the high levels of efficiency already achieved by installing with current MLPE technologies.
  - Integrated modules seemed more attractive to installers currently using string inverters, which would enable them to make a switch to MLPE without adding labor costs, an increase that averages to $0.03/W, according to a December 2013 Rocky Mountain Institute survey of installers

Module-Level Safety and the Coming of the 2017 NEC

National Electrical Code Rapid Shutdown Requirements



NEC 2014
Output within 10 feet can be 600 V or 1,000 V. Must be 30 V and 240 VA beyond when disconnected.

NEC 2017 [Proposed]
Output within 1 foot of array must be 80 V or less in case of disconnection. Shortening of 10-foot rule to 1-foot.

Source: GTM Research *Global PV BOS Price and Technology Trends 2015*

- In the United States, the 2014 version of the National Electrical Code (NEC) is a major driver for MLPE, as its rapid shutdown requirement establishes a 10-foot barrier around the array.
- The 2017 version of the NEC will likely minimize the rapid shutdown requirement to 1 foot, essentially mandating MLPE.
- Introduction of NEC 2017 with current expectations would promote strong MLPE growth, as well as promote the use of all types of integrated PV modules.
- NEC 2017 would take place first in the states that were earliest to adopt NEC 2014 – Massachusetts, Maryland and Colorado being the largest of these state solar markets. Other states would follow in the three years following the introduction.
- Many installers would, however, look to the cheapest option for code compliance, which would likely be a string inverter and modules with embedded rapid shutdown ($0.05/Wdc to $0.06/Wdc) and a rapid shutdown box ($0.05-$0.08W/dc).

The Primary Barriers for Smart and AC Modules

There remain many significant market barriers that somewhat erode the value proposition of smart and AC module and are likely to keep penetration levels modest.

Current AC and Smart-Module Barriers by Level of Significance
1. High upfront pricing in comparison to traditional solutions. Embedded solutions do not yet pass on material savings for junction boxes and DC cabling, which theoretically are as high as $0.03/W. Instead, module manufacturers currently mark up integrated solutions by 3 percent to 5 percent. This currently adds costs between $0.04/W and $0.07/W.
2. Labor savings are too small to drive growth. Inability to overcome product markups means that integrated module value proposition is built upon difficult-to-recognize benefits such as simplified inventory and improved product warranties.
3. Only a limited number of bankable MLPE suppliers have aggressively pursued integrated modules as a primary path to the market. Those most aggressively targeting integrated modules – Tigo and SolarBridge prior to its acquisition by SunPower – have long suffered from a perception of poor bankability.
4. Concern from installers and developers around poor interchangeability of integrated products. Failures require replacements to come from the same power electronics vendors. This increases the potential impact to a project owner if the vendor exits the market.
5. Partnership sales model has kept integrated-module growth slow. Module manufacturers, used to selling large portfolios of relatively simple products, have approached integrated module sales less aggressively than their fast-moving, often-venture-funded MLPE partners would implore them to do.

Specific Barriers: Smart Modules and AC Modules

AC-Module-Specific Barriers

- Most AC modules are frame-attached, meaning little material savings can be found for AC modules. Only LG's AC module has an embedded microinverter (ArrayPower was the first to attempt this strategy before its market exit), and the product remains too expensive to truly impact the market.
- Module vendors fear heat damage and mechanical wear from the addition of power electronics, even for frame-attached products.
- Imported AC modules are also subject to a 2.5% import tariff that conventional "dumb" modules avoid. This tariff applies to all AC modules, not just those from Chinese vendors, and is not related to the U.S. tariffs on Chinese and Taiwanese PV products.

Smart-Module-Specific Barriers

- Customers of smart modules are not beholden to their use, as DC optimizers do not replace any part of the system and a customer can just as easily install with a standard module (unless they use the optimizer for rapid-shutdown compliance or use SolarEdge for all inversion needs). While this is fine for the module company, which makes money no matter what type of module is sold, this is a significant burden for the power electronics vendor that relies on the module company to make the sale.
- Conversely, the leading DC optimizer provider, SolarEdge, requires that SolarEdge-enabled smart modules be paired with a SolarEdge inverter. While this enables a lower-cost inverter, it creates smart-module inventory tied to that inverter. This was a commonly cited burden among PV installers interviewed for this report.

The Costs of Module Integration

Theoretically, integrated modules should have a lower upfront cost than comparable modules and MLPE solutions for three reasons:

1. Less packaging required and lower shipping costs for integrated products
2. Shorter DC wiring for frame-attached MLPE
3. Replacement of junction box for embedded solutions

In reality, these currently do not result in significant savings to customers because:

1. Modules and MLPE typically are not manufactured in the same location, and this adds complexity to the supply chain
2. Most frame-attached integrated modules are built with standard modules that do not shorten DC wiring from the junction box. However, even if optimized, savings on DC wires are quite small (~$0.001/W).
3. Junction-box replacement theoretically can save up to $0.03/W; however, module manufacturers currently do not pass these savings on to the customer. In fact, they actually increase price to make up for the complexities of selling an integrated product.

Additionally, smart and AC modules must recertify to UL 1741 standards in order to maintain UL listing, even when both the module and microinverter are already listed. These tests only incur a one-time cost, but the impact can be substantial for integrated modules not shipped at significant scale.

Caught in the Crossfire of Country-Specific Customs Practices

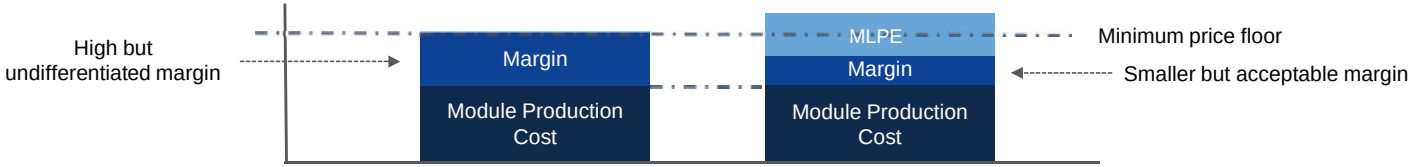
U.S. Customs' duties are a hindrance for products shipped from and integrated outside of the U.S.

- The integration of a microinverter transforms a PV module into a generator, according to U.S. Customs, subjecting AC modules to a modest 2% to 3% tariff on top of any other duties the PV module would incur
- Smart modules may also be subject to the tariff
- Cartridge-based solutions that are attached in the field can avoid the added tariff by shipping components separately, but this minimizes some of the benefits associated with reduced integration costs
- Since U.S. tariffs on Chinese and Taiwanese PV products are based on declared value, higher pricing/cost of AC and smart modules results in higher duties paid

In Europe, the EU module price floor implemented in 2013 has inadvertently benefited integrated modules

- Integrated modules are not differentiated from standard PV modules in the EU and thus the cost of the attached MLPE can be covered by the artificial price increase of Chinese modules needed to reach the price floor
- This enables integrated DC optimizers and microinverters essentially to be offered for free, with the module company selling the base module below the price floor.

EU Price-Floor Effect on Smart and AC Module Price Competitiveness



Source: GTM Research

Module Vendor Challenges With Smart and AC Modules

Module vendors have faced difficulties selling and supporting smart and AC modules in their portfolios. Two issues exist:

1. The partnership sales relationships between large, established module vendors and the typically startup-phase MLPE companies looking for rapid growth have not developed smoothly. Module companies may heavily market smart and AC modules to differentiate and draw in customers, but the objectives of making a sale and providing the lowest cost to the customer are deeply ingrained in module sales teams. This often pushes them away from the more complex products in their portfolio. Distributors have similarly little incentive to push smart and AC module products in their catalogs.

2. Smart and AC module companies are often inexperienced with the customer service requirements and reliability demands associated with MLPE, especially those of microinverters. These issues begin during the presales process (e.g., explaining the value propositions of each product line), and persist through post-sale and implementation (e.g., system design and commissioning) and throughout the product life (e.g., troubleshooting, warranty servicing, O&M). As a result, module companies must heavily rely on their MLPE partners in order to be successful.

Module companies will overcome these issues as the market demands more MLPE and integrated module products. To get there, module vendors and their MLPE partners must work together very closely on initial sales. MLPE vendors must take a consultative approach to educate their module partners and ease reliability and service concerns on the part of their end-use customers. Over time, module vendors can control more of this process.

This is a significant challenge for module vendors with their own MLPE solution – notably ReneSola and LG – which have had to build customer-service infrastructures themselves. Startup MLPE vendors faced significant difficulty in overcoming this requirement. Although ReneSola and LG are large, global companies, the demanding requirements of system-by-system customer service could prove to be an existential threat to their AC technologies.

Stakeholder Market Drivers and Partnership Selection Criteria

Drivers for MLPE Suppliers, Module Companies, and Customers

The benefits of integrating power electronics into standard PV modules also vary along the PV system value chain.

MLPE Supplier Benefits

Power electronics vendors benefit from module integration for a few reasons.

- They gain the sales and service channel of their module partners without necessarily having to vastly grow their own teams.
- They are able to take advantage of the bankability of the module vendor and broaden their warranty through the partnership.

Module Vendor Benefits

The module company benefits from integration by taking advantage of growing demand for MLPE and differentiating among the commoditized module supply environment. The added cost of the power electronics contributes to the module company's top line while enabling it to offer the product as a premium, potentially higher-margin product.

Customer Benefits

For the system owner, the benefit lies in having only one supplier serving the warranty for the module and the power electronics. For the installer, the benefit comes from savings on installation labor, as well as from simplified inventory and site logistics.

Drivers of Module Integration Across the Value Chain

MLPE Supplier	Module Company	Customer
• Channel leverage • Bankability via module company	• Differentiation • Expanded revenue opportunity	• Improved product warranty • Improved bankability • Installation labor efficiency • Inventory/supplier efficiency

Source: GTM Research

Selecting Partners for Smart and AC Module Products

Module companies have varying approaches for selecting their partners. However, the overall criteria are similar from company to company. Module company partnership criteria are more particular than MLPE company partnership criteria for a few specific reasons:

- Module companies have difficulty marketing multiple integrated solutions and thus can only work with a very limited number of MLPE suppliers.
- Marketing integrated products is beyond the typical sales scope of most module manufacturers. As a result, close participation of the MLPE vendor during the sales and implementation process is required, and thus a strong brand and relationship is desired.

MLPE companies' partnership criteria differ from each other based on the companies' primary go-to-market strategy

- For those whose primary route is through module manufacturers, such as Tigo and SolarBridge prior to its acquisition by SunPower, partnerships are seen as additional sales channels, and thus volume is the most important factor.
- Those with strong standalone businesses (Enphase, SolarEdge, APS) can be more selective and develop longer timelines with their module partners.

These requirements differ from the demands of end-use customers as well.

Selection Criteria of Stakeholders in the Smart and AC Module Market

Source: GTM Research

Partnership Selection Criteria: Module Vendor Perspective

- Module manufacturers must weigh a number of criteria for potential MLPE partners and choose carefully.
- Vendors note that it is difficult to market multiple integrated modules. There are a few – notably Jinko, JA, and ET Solar – that sell multiple smart modules or both smart and AC modules.
- DC optimizers are far simpler devices than microinverters and are more suitable for embedded module integration due to their smaller form factor and lower costs. However, there are a very limited number of DC optimization partners to choose from.
- There are far more microinverter suppliers in the market; however, module manufacturers remain wary of the complication of microinverters. Module vendors are primarily concerned over potential heat damage to module backsheets for embedded and even frame-attached microinverters.

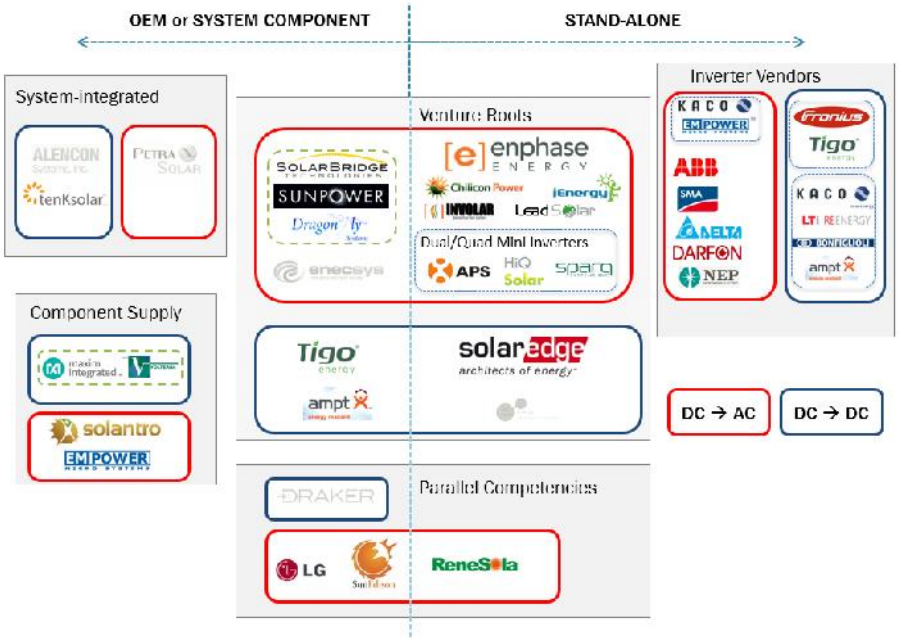
Criteria for Selecting a Module-Level Electronics Partner

Criterion	Description	Notable Leaders	Notable Laggards
Cost	MLPE must minimally impact cost of integrated module	SolarEdge, APS, Maxim	SunPower/SolarBridge, SMA
Form Factor	Electronics must have size profile to meet integration (embedded or frame-attached) requirements	Maxim, Tigo, KACO (Empower), SolarEdge, LG, tenKSolar	All other microinverters
Worldwide Compatibility	Microinverters must be compatible with global grid requirements and optimize with multiple inverters	Tigo, SolarEdge, KACO (Empower), Enphase, ABB, SMA, I-Energy	SunPower/SolarBridge
Thermal Characteristics	Power electronics should have minimal heat generation on the back of the PV module	Tigo, Maxim, SolarEdge, KACO (Empower)	Microinverters
Market Momentum	MLPE product has significant market presence and field experience	SolarEdge, Enphase, APS	Tigo, ABB, SMA
Bankability	Financial standing and brand of MLPE company or parent is strong, with limited short-term debt, and long track record	ABB, SMA, Enphase, SolarEdge, SunPower/SolarBridge, Maxim	Tigo, APS, tenKsolar

Source: GTM Research, Folsom Labs

Partnership Selection Criteria: MLPE Vendor Perspective

Module-Level Power Electronics Landscape by Primary Market Approach



Source: GTM Research

While we deem integrated module associations as partnerships, these are sales relationships. The strategy of each MLPE supplier determines the approach that is taken in forming these relationships.

OEM and System Component Vendors: The Integrated Module Pioneers

- MLPE companies that take an exclusively or primarily integrated approach, such as Tigo and SolarBridge, historically have had to work with a broad range of module manufacturers in order to meet their sales targets and diversify their customer base.
- These companies typically target the largest module providers with the greatest reach in residential and commercial markets.
- Additionally, dependence on single or limited partners increases the cost of a poorly executed relationship.
- This model has proven difficult to pull off, as the most aggressive MLPE vendors are typically fast-moving startup companies in relation to their module partners.

Standalone MLPE Vendors

- Companies with significant standalone businesses, such as SolarEdge, Enphase, and APS, have the luxury of being more selective in choosing module partners for their integrated offerings.
- These companies can often look to work with select partners for long-term development of embedded or optimized products.

Integrated Module Landscape

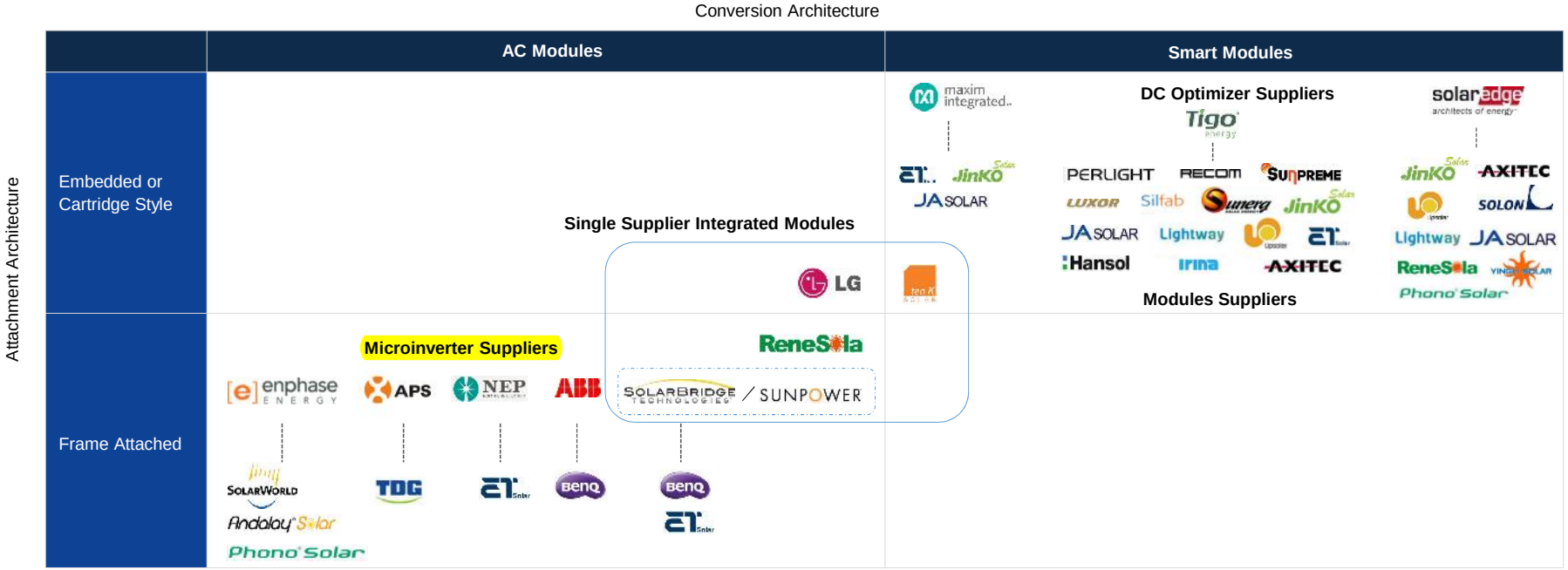
The Signal and the Noise: Understanding Module/MLPE Partnerships

There a few important items to understand when assessing the current integrated module landscape.

1. **Announcements of partnerships often do not mean full commercial availability** of an integrated module or proper certification. Press releases are often used to hype the brands of one or both parties in the partnership. This was a larger issue in 2012 and 2013 when module manufacturers were attempting to differentiate from their competitors during a period of oversupply.
2. **Many frame-attached integrated modules are not official partnerships**. These typically take the form of microinverters purchased through distribution or from the manufacturer that are then attached to a standard module. These products generally lack certification by a nationally recognized testing laboratory and come with warranties from both the module manufacturer and the MLPE vendor.
3. **Many integrated modules are marketed by only one party**, typically the module manufacturer. While companies like Tigo list all applicable partners, SolarEdge and others are more discreet about detailing those with which they have partnered.
4. **Module vendors often market integrated modules heavily while not pushing their sales**. MLPE vendors have long had difficulty convincing module companies to fully commit to selling smart and AC modules. Many module companies continue to offer integrated products in their portfolios, while focusing primarily on selling customers their cheapest solutions.
5. **Companies do not make announcements when partnerships or products have been discontinued**, unlike when products are introduced. Integrated modules typically are discontinued for one of two reasons: either the product was not selling or a partner company has gone out of business or been acquired.

The Current Integrated Module Partnership Landscape

Currently Marketed Integrated Module Partnerships



Source: GTM Research

MLPE Suppliers of Smart and AC Modules

The paths to market have varied greatly among module-level power electronics vendors:

- In the past, there were a number of vendors taking hybrid paths to market with both integrated module and standalone products.
- As the market matured, most vendors committed to a single path, and thus the market came to be clearly divisible into OEM vendors and standalone suppliers.
- While many vendors still sell both standalone and integrated products, we expect the full hybrid business model to return as standalone vendors begin the implementation of integrated products as part of their long-term growth plans.

Leading MLPE Vendors' Approaches to Smart and AC Modules

Full OEM/Module Integration Model

Tigo energy
maxim integrated
SolarBridge Technologies
SunPower

Primarily Standalone With Some OEM/Module Sales

APS
enphase ENERGY
ABB
solaredge architects of energy
ReneSola

Fully Standalone Model

jEnergy
SMA

Source: GTM Research

Leading MLPE Integration Partners: Tigo Energy

Company: Tigo energy

Key Statistics	
Headquarters	Los Gatos, Calif.
Products	DC Optimizers, Safety Switches
Estimated Cumulative DC Optimizer Shipments Year End 2014	173 MWdc
Estimated Cumulative Integrated Module Shipments Year End 2014	70 MWdc

Note: GTM lists shipments in their native voltage (Wdc for DC optimizers and Wac for microinverters) whenever possible. We use a standard AC:DC ratio of .87 when needed for comparison.

Module Partners:

Trina, RECOM, Sunerg Solar Energy, Upsolar, Hansol, JinkoSolar, Perlight, Lightway, Luxor, JA Solar, Silfab Solar, Sunpreme, Axitec

Background: Tigo Energy is the No. 2 provider of DC optimizers and the leading smart-module supplier. Unlike rival SolarEdge, Tigo only produces the DC optimizer and not the entire inversion system. Tigo transitioned from a standalone business model to an OEM/module integration strategy in 2012 and has been the leading advocate for smart modules since that time. Its latest product, the TS4, is a cartridge-based system with varying feature levels.

Analyst Take: Tigo has struggled to gain significant momentum with its OEM model. The company has never achieved consistent sales growth in spite of earning notable customers such as Vivint Solar, Clean Power Finance, and Anesco in the U.K. Its flagship module partner, Trina Solar, has begun to market the varying levels of performance of the TS4 with the introduction of the Trinaflex (using various TS4 levels throughout the system), Trinaswitch (monitoring and rapid shutdown) and the existing Trinasmart (full DC optimization). This flexibility should hedge against introductions of competing rapid-shutdown solutions; however, it adds complexity to an already-complex product. There is demand for these functions, but execution will be key, and it will be difficult with such a large network of partners. Time is running out for Tigo, now in its eighth year of existence. The company would be an attractive acquisition target for an inverter vendor hoping to challenge SolarEdge's DC optimization/inverter system or for its flagship partner, Trina Solar.

Leading MLPE Integration Partners: Enphase Energy

Company: enphase ENERGY

Key Statistics	
Headquarters	Petaluma, Calif.
Products	Microinverters
Cumulative Microinverter Shipments Year End 2014	1,541 MWac
Estimated Cumulative Integrated Module Shipments Year End 2014	24 MWac

Module Partners:

Andalay Solar Phono Solar SolarWorld

Background: Enphase is the leading global microinverter manufacturer and leading MLPE vendor by cumulative shipments. Enphase began working with a variety of module manufacturers as recently as 2010 but has scaled back its AC module focus as its standalone business grew. Enphase partners publicly with Andalay Solar, which has a rail-less integrated racking solution with built-in cabling, and Phono Solar, which sells frame-attached AC modules through distribution. In September 2015, Enphase announced a partnership with SolarWorld to develop an integrated AC module for introduction in late 2016.

Analyst Take: Enphase rightly scaled back its AC module partnerships as the business model proved far less capable than its standalone sales efforts. However, Enphase values simplicity, and we expect the company to very aggressively re-enter the AC module market with a cartridge-based or fully embedded AC module from a recognizable module supplier. Enphase's next generation S-series microinverter also promises higher efficiency and less heat dissipation, which should ease the minds of its module partners.

Leading MLPE Integration Partners: SunPower/SolarBridge Technologies

Company: SUNPOWER SOLARBRIDGE TECHNOLOGIES

Key Statistics	
Headquarters	Santa Clara, Calif./Austin, Texas
Products	AC Modules
Estimated Cumulative Shipments Year End 2014	42 MWac
Estimated Cumulative Integrated Module Shipments Year End 2014	42 MWac

Known Module Partners:

SUNPOWER BenQ ET Solar

Background: SolarBridge Technologies was a microinverter manufacturer established in Austin, Texas in 2010. The company took an exclusively AC module path to market, offering a premium, highly reliable product. However, the product's price premium and limited market for AC modules limited growth, and the company was acquired by its partner and investor SunPower in November 2014.

Analyst Take: SolarBridge did more than any other manufacturer to popularize the idea of an AC module. In spite of lackluster growth, the brand was strong and well respected, and the new ownership by SunPower will only improve that image. Sales in 2014 took a hit as the company relocated manufacturing in response to the U.S./China solar trade case. SunPower now controls exclusive international sales of SolarBridge AC modules and permits sales of SolarBridge in North America to a few legacy module partners. Moving forward, the integration with SunPower should enable the creation of a reliable AC module product. Cost will be a major factor, as both SunPower and SolarBridge can be seen as premium brands. We do expect the next generation of SolarBridge microinverters to be fully embedded, and thus costs will come down as the solution is scaled.

Leading MLPE Integration Partners: SolarEdge Technologies

Company: solaredge architects of energy

Key Statistics	
Headquarters	Hod Hasharon, Israel
Products	DC Optimizer/ Inverter System
Cumulative Shipments Year End 2014	1,406 MWdc
Estimated Cumulative Integrated Module Shipments Year End 2014	23 MWdc

Module Partners:

JA SOLAR, AXITEC, Upsolar, ReneSola, Lightway, Phono Solar, YINGLI SOLAR, JinKO Solar, SOLON

Background: SolarEdge is the leading DC optimization vendor and has overtaken rival Enphase to become the leading MLPE company by megawatts shipped in 2015. The vast majority of sales are standalone DC optimizers sold as part of the company's inversion system. Nevertheless, SolarEdge has offered integrated smart modules for over five years through a variety of module partners.

Analyst Take: While SolarEdge makes the most compelling market case for DC optimization, it has not made a major impact in the smart module market. The company has no flagship partner, nor has it fully devoted itself to the partnership sales model. The module price floor in the European market has been a positive for smart-module sales, but its U.S. business remains primarily standalone. Installers cite a resistance to having module inventory tied to SolarEdge inverters, and prices have not been low enough to justify the risk. The company is well positioned to capitalize on increasing demand for smart modules due to its existing technology, bankability, and expected growth. However, SolarEdge will need to build its partnerships in order to scale its smart-module product and exceed baseline growth forecasts.

Leading MLPE Integration Partners: Maxim Integrated

Company: maxim integrated™

Key Statistics	
Headquarters	Fremont, Calif.
Products	DC Optimizers
Estimated Cumulative Shipments Year End 2014	Pilot Testing (~5 MWdc)
Estimated Cumulative Integrated Module Shipments Year End 2014	~5 MWdc

Module Partners:

ET Solar JA SOLAR JinKO Solar

Background: Maxim Integrated offers a DC-stage chipset that it acquired from Volterra Semiconductor in late 2013. Maxim began commercial sales with three major module manufacturers in 2015.

Analyst Take: The market has shown considerable excitement for a third DC optimizer solution. Maxim's optimizers are installed with three to six devices at the cell-string level in every module and enable elimination of the bypass diode in the junction box. The buck architecture also offers increased yield and a low theoretical price point. Additionally, the string-level design gives Maxim the largest advantage for systems with cross-banked shading. However, Maxim optimizers feature no communications and no rapid shutdown capability. The lack of communication can be seen as a positive due to the limited value and added cost that module-level communication offers, but the absence of rapid shutdown can be seen as a legitimate negative. Maxim has been smart to enter the market by working closely with three highly bankable partners. However, all three partners offer additional smart or AC modules that directly compete with the Maxim solution.

Up-and-Coming MLPE Vendors to Watch for Module Integration

Empower Micro is a Santa Clara, Calif.-based chipset manufacturer founded by alumni of Array Power, which formerly developed embedded AC module technologies. Empower began commercialization of its series-connected system labeled as the KACO New Energy Ultraverter System in 2015. The KACO partnership gives Empower the bankable partner and sales channel it needs to scale. Though not fully exclusive, having a single partner with a limited U.S. track record is a risk for the company. Additionally, in spite of excellent reliability, the Empower system faces a difficult value proposition due to the limited design flexibility allowed from its series design. However, Empower's architecture results in the lowest heat emissions of any microinverter, and we expect the module market to heavily court the company for this reason.

Altenergy Power Systems is the third-largest vendor of MLPE. The company has reached significant scale and manufactures in both the U.S. and China. APS is heavily focused on the commercial market, but as a low-cost supplier with high volume, it is an attractive partner for module suppliers yet to explore the AC module market.

NEP is a small microinverter manufacturer based in China. NEP was recently announced as the AC module partner of ET Solar (which previously worked with SolarBridge internationally and still does in North America) for the Japanese market. While NEP has been a minor player in the MLPE space, the Japanese market is currently nascent with respect to module-level power electronics, and thus the entrance to that market is a major opportunity.

Sparq Systems is a Toronto, Ontario-based startup developing a quad-type 1,000W microinverter, as well as a single module microinverter for systems requiring odd-numbered configurations. In July 2015, Sparq announced it had partnered with GE Global Research to construct an embedded next-generation AC module. Sparq inverters lack electrolytic capacitors, making the company an attractive alternative to module manufacturers wary of reliability concerns of Enphase rooted in their use of those devices.

SineWatts is a Charlotte, North Carolina-based startup that is developing a microinverter product. Formed in 2011, the company has raised $1.6 million over two rounds of funding in 2013 and 2014. SineWatts remains very quiet regarding its technology, but all signs point to an embedded "inverter molecule" for use in AC modules.

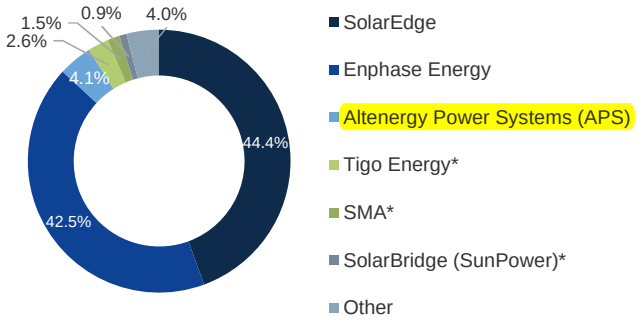
Assessing the Smart and AC Module Landscape: Notable MLPE Suppliers

MLPE Vendor	Cumulative Global MLPE Shipments (MWac)	2014 Total MLPE Shipments (MWac)	Product	Primary Business Model	Current Integration Technology	Number of Current Publicly Disclosed Module Partners	Company Notes
SolarEdge Technologies	1223	601	DC Optimizer	Standalone	Embedded	9	Leading DC optimizer vendor. Wide range of smart module partners. No partner has emerged as leading provider.
Enphase Energy	1567	575	Microinverter	Standalone	Frame-Attached	3	Leading microinverter supplier with diminishing emphasis on frame-attached AC module. Next-gen likely embedded or cartridge style.
APS	123	56	Microinverter	Standalone	Frame-Attached	1	Low-cost supplier of microinverters. Sells frame-attached dual AC modules in Australia. Growing U.S. presence.
Tigo Energy	150*	35*	DC Optimizer	OEM	Embedded	13	Leading smart module provider. Fully OEM model. Leading partner is Trina, though the relationship is non-exclusive.
SMA	48*	20*	Microinverter	Standalone	Frame-Attached	0	Leading inverter vendor worldwide. No module integration plans publicly announced.
SolarBridge Technologies	42*	12*	Microinverter	OEM	Frame-Attached	3	Owned by SunPower since November 2014, additional relationships limited to North America.
ABB	32*	10*	Microinverter	Standalone	Frame-Attached	1	Frame-attached AC module sold by BenQ Solar with former Aurora microinverter product sold by Power-One before 2013 acquisition.
Maxim Integrated	4*	4*	DC Optimizer	OEM	Embedded	3	Began commercial production of cell-string level DC optimizer in 2015 with Jinko, JA and ET Solar.
Empower Micro	-	-	Microinverter	Standalone	Embedded	0	Series-connected microinverters with lowest-in-class heat emissions. Microinverter licensed through KACO; no publicly announced module partners.
Sparq Systems	-	-	Microinverter	Standalone	Frame-Attached	0	Early-stage manufacturer with quad and eventually single microinverters. Announced R&D program for AC modules with GE.
SineWatts	-	-	Microinverter	OEM	Embedded	0	Stealth-mode company developing an "inverter molecule" for module integration.

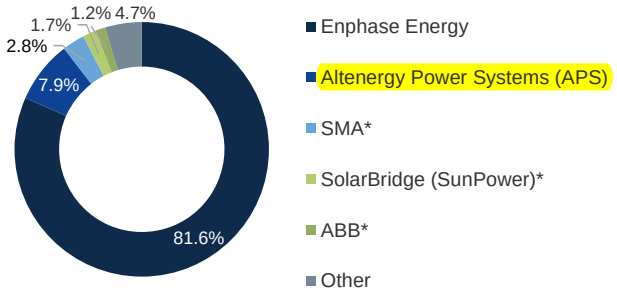
Source: GTM Research

*Estimate

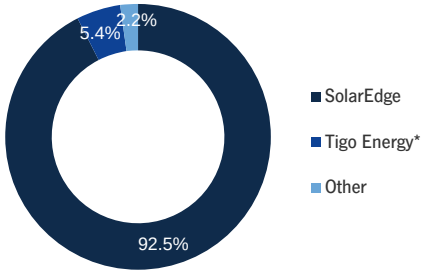
2014 Global Market Share of MLPE Suppliers by Shipments (MWac)



2014 Global Market Share of Microinverter Suppliers by Shipments (MWac)



2014 Global Market Share of DC Optimizer Suppliers by Shipments (MWac)



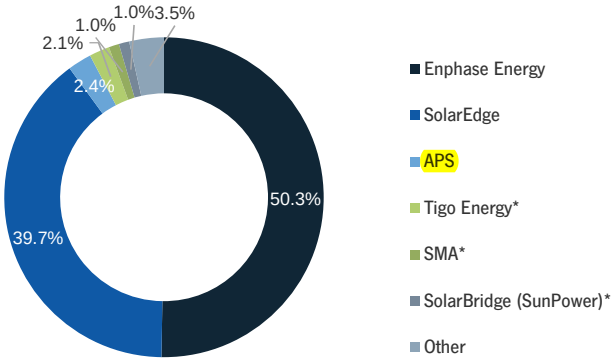
Source: GTM Research's *Global PV Inverter Landscape 2015*

*Estimate

- The MLPE market consolidated at the top in 2014 as Enphase and SolarEdge supplied a combined 87% of the market, up from 77% in 2013 and 76% in 2012 and 2011. Altenergy Power Systems (APS) has additionally displaced Tigo Energy as the third-leading MLPE supplier on strong growth in the U.S. market.
- The long tail of microinverter challengers has slowly faded, with SolarBridge's acquisition by SunPower and ABB's and SMA's limited commitment to achieving substantial growth in sales of their microinverter products.
- Additionally, the DC optimization landscape has become a one-vendor affair as Tigo transitions to its TS4 platform. SolarEdge has strengthened this position through 2015.

2014 U.S. Module-Level Power Electronics Leaders

2014 U.S. MLPE Market Shares by Shipments (MWac)



*Estimate

Source: GTM Research's *Global PV Inverter Landscape 2015*

- Enphase maintained its leadership in the U.S module-level power electronics landscape in 2014, accounting for more than half of all MLPE shipments in 2014.
- SolarEdge has closed ground through strategic supply deals with leading installers SolarCity and Vivint Solar. SolarEdge has the momentum and the cost advantage – especially in Northeast markets requiring rapid shutdown – and we expect its market share to match or exceed Enphase's over 2015. Both will continue to show strong shipment growth in line with 50% year-over-year growth in the residential sector.
- Altenergy Power Systems (APS) has emerged as the No. 3 MLPE vendor in the United States. APS has found a niche in the Pacific Northwest, where its manufacturing center is located.

MLPE Vendor Positions: Leaders Continue Rise to the Top

Though the tail of MLPE vendors is long, the AC and smart-module market is led by just a handful of MLPE vendors and their partners. The market will remain top-heavy. The emergence of a market for smart and AC modules – where module vendors look for the most bankable and advanced products – will mean higher barriers to entry, not lower.

Outlook for Leading Smart and AC Module MLPE Vendors

Company	Integrated Module Outlook	Analyst Take
Tigo Energy	Neutral	Tigo is the leading smart module advocate and has marketed itself aggressively in 2015. However, the company's future is uncertain, and the TS4 has yet to significantly impact the market. The smart-module market does not entirely hinge on Tigo's success, though it is strongly correlated in the near term. In the absence of sustained growth, Tigo would be an attractive acquisition for an inverter vendor looking to compete with SolarEdge, or for Trina if it chose to make itself the exclusive TS4 provider.
Enphase Energy	Positive	Enphase will be a marginal player in the near-term AC module market. However, its announced relationship with SolarWorld is the right strategy for the leading microinverter supplier. The NEC code will be a major driver for Enphase and will help it get beyond the 2017 U.S. market dip.
SolarEdge Technologies	Positive	SolarEdge has market momentum in the MLPE market, embedded technology, and an existing network of smart-module partners. A flagship partner would accelerate smart-module growth, but the company is set up well in the short term regardless.
Maxim Integrated	Neutral	Maxim offers the highest performance increase for module mismatch and cross-banked shading. However, lack of rapid shutdown functionality is a major concern and limits the long-term outlook.
SunPower/SolarBridge	Positive	SolarBridge was able to reset after its acquisition and focus on the future. Next-generation embedded product should be able to leverage SunPower's dealer network to contribute to AC module market growth.
APS	Neutral	APS' growth and cost structure are attractive, but the focus on dual/quad module microinverters is not optimal for AC-module leadership.
SMA	Negative	SMA has experienced rebounding growth in 2015 as a company after hitting rock-bottom in 2014. However, its microinverter product is only used to serve niche customers. SMA's product is undifferentiated and the company has not sought AC module partnerships.
ABB	Negative	Similar to SMA, ABB will not make an impact in the AC module market due to its focus on string and central products.
Empower Micro (KACO)	Positive	We believe that of all newcomers to the market, Empower is best positioned for smart and AC modules due to its low-heat, series-connected design. Though market entrance is through a standalone system, the company is actively courting module vendors for AC module offerings.

Potential for M&A and New Entrants

The MLPE market has high barriers to entry with the existence of a dominant microinverter vendor, Enphase, and DC optimizer supplier, SolarEdge. However, the success of these companies and impending NEC requirements will cause others to consider entering the space, either through acquisition or new product developments. Due to the low relative value of the DC optimization market, we believe market entrants will look to capture a larger piece of the value chain and own the DC optimizer/inverter system, own the entire smart module, or simply partner with an existing DC optimizer vendor.

Competitors: Inverter vendors have long looked to acquisition to fill their portfolios, as ABB did with Power-One in 2013 and SMA did with microinverter vender OKE-Services in 2009. The microinverter market is rather saturated, but the DC optimization space is ripe for a buyer to acquire DC optimization IP or the established brand of Tigo Energy. SolarEdge's rapid growth increases the likelihood of this scenario.

SMA ABB OMRON Fronius SOLECTRIA RENEWABLES YASKAWA

Entrants from adjacent market segments: The U.S. residential market could be an attractive place for commercial and utility inverter vendors, in spite of very competitive pricing. Utility PV markets have proven volatile, and the upcoming step-down in the federal Investment Tax Credit in the U.S. will least affect the U.S. residential market. Exceptionally low residential string inverter prices and rapid shutdown requirements make it more likely that new market entrants will introduce products with module-level capabilities.

HUAWEI SUNGROW CHINT POWER

Module vendors: Extensive customer-service requirements for microinverters make DC optimization solutions more attractive than fully owned AC modules. Ambitious firms seeking vertical integration, such as Silevo/SolarCity, are the exception to this. Further acquisitions are possible, and we would not be surprised by LG introducing a smart-module product to ease the troubles it has faced with its AC module.

LG Trina silevo SolarCity

Integrators of Smart and AC Modules

Over 20 module companies offer smart and integrated modules. The leading partners are those with the broadest reach that have championed smart and AC modules. Others simply lack the scale, the price-competitiveness, or the differentiation from other smart and AC module providers to be truly impactful in the market. We expect other leading vendors to jump in to the mix in the next few years, even as MLPE suppliers still look to smaller regional vendors or those with heavy residential-market focuses.

Leading AC and Smart Module Partners

Leading Vendors Without Smart or AC Modules

Single-Supplier Smart and AC Module Vendors

Source: GTM Research

Assessing the Smart and AC Module Landscape: Leading Module Vendors

While nearly every leading module supplier has at some point announced a smart or AC module partnership, it is notable that of the 10 leading module suppliers, only two currently offer AC modules while five offer smart modules. While this shows how little traction smart and AC modules have found in the market, it represents opportunities for MLPE vendors that have yet to form strong partnerships.

Module Vendor	Headquarters	2014 Cumulative Module Shipments (MWdc)*	2015E Year-End Internal Module Capacity (MWdc)*	Internal Tariff-Free Supply	Number of Public Smart Module Partnerships	Number of Public AC Module Partnerships	Company Notes
Trina Solar	China	3,664	4,800	Yes	1	0	Leading global module supplier and leading partner of Tigo. No current AC module partnership.
Yingli Solar	China	3,361	2,450	No	1	0	Announced SolarEdge partnership in 2012, with little marketing follow-up.
Canadian Solar	China	3,041	3,470	No	0	0	Formerly partnered with Array Power and Enecsys on AC modules before both companies' insolvencies. Largest manufacturer without current smart and AC module offerings.
Jinko Solar	China	2,862	3,770	No	3	0	Like JA, markets all three major smart-module solutions.
JA Solar	China	2,407	3,700	Yes	3	0	Sells all three major smart-module solutions though does not offer an AC module.
ReneSola	China	1,970	1,200	Yes	1	1	ReneSola sells an AC module with its own Replus microinverter frame-attached, as well as SolarEdge smart modules. Sales have been minimal.
Hanwha Q CELLS	South Korea	1,466	3,500	Yes	0	0	Diversified supply and no current partnerships make Hanwha a target for MLPE vendors. Growing U.S. volume. However, achieved little success with four historical integrated-module offerings.
SunPower	United States	1,255	605	Yes	0	1	SunPower acquisition shores up AC module offering. Previous acquisition of Dragonfly could result in a smart module or string-level optimizer.
SolarWorld	Germany	849	1,580	Yes	0	1	U.S. manufacturing means tariff-free supply. Announced AC module development partnership with Enphase in Sept. 2015 for 2016 introduction.

*Source: GTM Research PV Pulse

Assessing the Smart and AC Module Landscape: Other Notable Module Vendors

A few vendors are notable for MLPE suppliers due to:

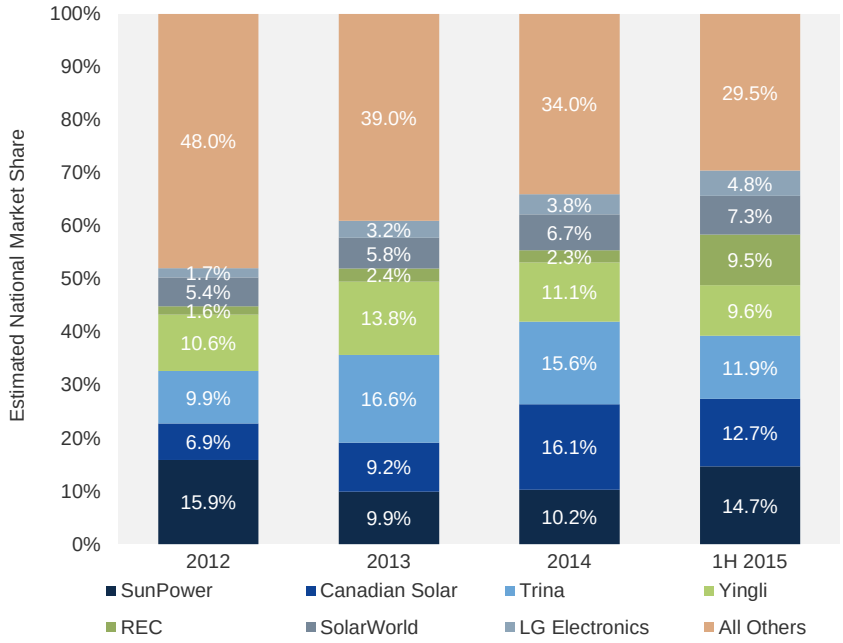
1. Tariff-free supply (Suniva, Silevo, Kyocera and other Japanese vendors)
2. Early adoption and continued inventory of smart and AC modules (ET Solar and Phono Solar)
3. Attractive parent company and the possibility of sales channels opened by that parent (Silevo: parent company SolarCity)

Module Vendor	Headquarters	2014 Cumulative Production*	2015E Capacity	Tariff-Free Supply	Number of Public Smart-Module Partnerships	Number of Public AC Module Partnerships	Company Notes
Suniva	United States	127 MWdc	200 MWdc	Yes	0	0	U.S. based vendor with U.S. manufacturing. No current MLPE partnerships. Recently acquired by China based Shunfeng.
Silevo	United States	-	-	Yes	0	0	Owned by leading U.S. residential installer SolarCity since 2014. New module facility in New York will provide tariff-free supply for the installer.
Kyocera	Japan	1,400 MWdc	1,400 MWdc	Yes	0	0	Leading Japanese vendor with reach to Japanese market. Mitsubishi, Sharp, Sanyo/Panasonic, and other Japanese vendors are similarly positioned.
ET Solar	China	828 MWdc	1,000 MWdc	No	2	2	Perhaps the leading AC module vendor to date. A leading SolarBridge partner prior to acquisition and early adopter of Maxim optimization technology.
Phono Solar	China	580 MWdc	800 MWdc	No	1	1	Currently Enphase's most significant AC module partner, though product only sold through distribution.

*Source: GTM Research PV Pulse

Assessing the Smart and AC Module Landscape: Other Notable Module Vendors

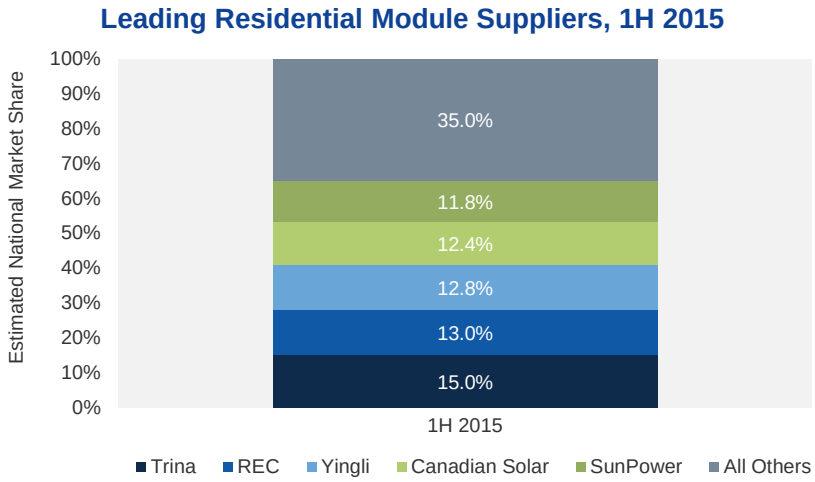
Leading Module Suppliers, Residential and Non-Residential Markets

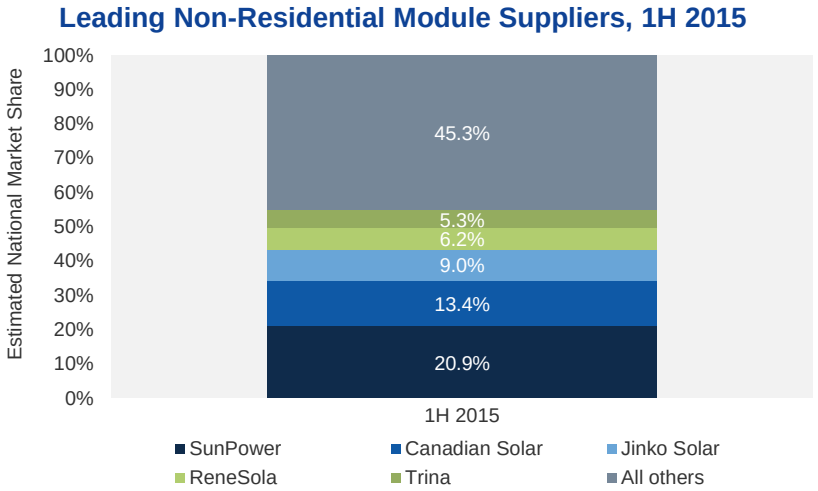


Source: GTM Research U.S. PV Leaderboard, Q3 2015

- Trina, Yingli, SunPower, and Canadian Solar were again the leading DG module suppliers in 2014. SunPower has surpassed Trina for the leading spot for the first half of 2015.
- Yingli was the top supplier to the commercial market in 2014, However, the company has experienced a drastic downturn to #12 in that market in the first half of 2015. Amid the company's financial troubles, which include substantial amounts of debt, developers have become wary of procuring Yingli modules with such uncertainty surrounding the company's future.
- Trina's market share in the non-residential market has also taken a hit recently, but this appears to be the result of a shift in the company's focus to the stable, larger residential market.
- Rounding out the top five non-residential suppliers in 2014 was SunEdison, due in large part to the systems the company develops itself.
- SolarWorld, LG Electronics, and REC each have a growing presence in the residential market, while Jinko and ReneSola have had strong first halves of the year in the non-residential market.

Breakdown of Leading Module Suppliers to the U.S. Residential and Non-Residential Markets, 1H 2015





- The module landscape is much more consolidated in the residential market than in the non-residential market, reflecting the fact that the residential market is controlled by several large installers that procure modules from a few primary suppliers.
- REC has grown significantly in the U.S. residential market over the past year due to its tariff-free supply. Its major customers include SolarCity and Sunrun.
- Vivint Solar primarily purchased Yingli and Trina modules in 2014 but signed a supply agreement with Jinko Solar in June 2015.

Source: GTM Research U.S. PV Leaderboard Q3 2015

Who Needs a Partner? Single-Supplier Integrated Modules

Several module manufacturers have ventured to develop their own integrated solutions. These products have the advantage of wrapping the bankability of the module manufacturer into the MLPE, alleviating warranty concerns, and can theoretically diminish the margin stack to bring a lower price to the customer.

Frame-Attached Single-Supplier Solutions

ReneSola Micro Replus Microinverter

Source: ReneSola

ReneSola was the first module manufacturer to self-develop a microinverter product, the Micro Replus. The product is sold standalone, but is also sold frame-attached in ReneSola's AC module offering. Product sales have been minimal, though this is as much a reflection of market demand for frame-attached AC modules as it is of ReneSola's ability to market the product.

Canadian Solar Microinverter

Source: Canadian Solar

Canadian Solar initially partnered with ArrayPower to develop a fully integrated, series connected AC module. Canadian was unable to sell the value proposition of the series connected microinverter and dropped it in favor of a frame-attached AC module with a Canadian Solar-labeled microinverter built by Enecsys. The module was taken off the market when Enecsys entered administration in early 2015.

Single-Supplier Integrated Modules: Embedded Solutions

Embedded Single-Supplier Solutions

LG Mono X ACe Module

Source: LE Electronics

LG is the first company to bring a fully embedded AC module to market with its Mono X ACe Module. LG self-developed the microinverter and wiring system to maximize labor savings for installers, claiming a 40% reduction in installation labor time. The product was released commercially in early 2015 and currently incurs a significant material premium over standard module and microinverter systems. Additionally, the product warranty is only 10 years, well behind the 25 years that has become standard in the module and microinverter industry.

TenKsolar RAIS XT Module Architecture

Source: TenKsolar

TenKsolar, like Maxim Integrated, utilizes a chipset optimizer. However, its device optimizes at the cell level rather than the string level and connects those cells in parallel rather than in series. TenK differentiates itself by manufacturing the entire PV system. TenK's smart module is incorporated into an optimized design that looks to achieve maximum performance across the PV system. TenK's module, which is manufactured with JA Solar cells, is not available for external sale and is only implanted in its proprietary system.

Risks and Opportunities for Single-Supplier Smart and AC Modules

Many have expected module manufacturers with power electronics experience such as LG, Panasonic, Mitsubishi, and others to move into the smart and AC module game for some time. Some have tried, but no solution has scaled. However, there is currently considerable excitement regarding LG's AC module. The product is aesthetically pleasing and well marketed, but LG will have to prove it has brains as well as beauty if it hopes to succeed where others have faltered.

Opportunities/Benefits

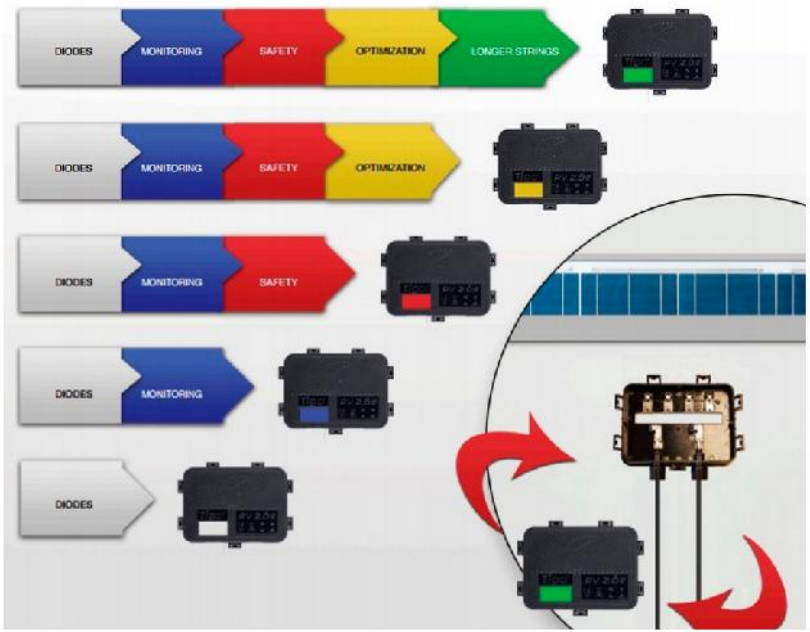
- Single-supplier, integrated modules alleviate warranty risk and simplify the sales process
- A single manufacturer can theoretically optimize its manufacturing and supply chain to create the lowest-cost device
- Solutions create exceptional differentiation from other module manufacturers, even those with competing smart and AC module solutions

Risks

- Module vendors introducing MLPE solutions still have to earn the bankability that can only be gained through time and deployments
- AC modules in particular require significant resources for customer support. This is an added cost, as AC module providers cannot outsource support to competing MLPE suppliers. DC solutions are superior in this regard.

Enhanced PV Modules With Safety and Monitoring: MLPE Vendor Landscape

Tigo TS4 Platform Functionality Levels



Source: Tigo Energy

The growing focus on safety and cost means there are also a growing number of solutions meeting only rapid shutdown needs.

MLPE Suppliers Exclusively Offering Safety and Monitoring

- **Mersen** offers enhanced junction boxes in conjunction with Huber+Suhner that feature rapid shutdown with optional monitoring.
- **Tigo's** TS4 platform prioritizes monitoring over safety, but similarly offers a platform from which to choose features. For Tigo, the idea is to be the total solution – from standard junction box up to DC optimization. So far, customers seem to be most interested in gaining either rapid shutdown – the 3rd level in the graphic to the right - or full functionality.
- **Shoals Technologies'** MultiLink platform enables addition of any type of MLPE; however, the initial partner, Ampt (which had developed similar platforms with Amphenol, Huber+Suhner, and Multi-Contact), has transitioned to string-level monitoring. SolarEdge is compatible with the platform, but as of late, Shoals has not pushed sales of the system.
- **GreenPeak Technologies** introduced a device featuring rapid shutdown and monitoring in 2012. The product, however, is not currently on the market.

Additional junction box vendors will begin to offer these solutions with chipsets from vendors such as Solantro, TI, and Maxim Integrated.

Enhanced PV Modules With Safety and Monitoring: Module Vendor Landscape

Nascent but Anticipated Market for Modules With Only Rapid Shutdown and Monitoring

- Demand for rapid shutdown has stirred interest for module vendors looking to add these capabilities to their product portfolios.
- Junction boxes with rapid shutdown currently are priced at $0.05/W to $0.06/W (compared to $0.02/W to $0.03/W for simple diode junction boxes). These prices mean that module vendors should be able to offer rapid shutdown capabilities for less than inverter/BOS vendors that currently sell rapid shutdown boxes at a retail price of $300 to $500 per unit ($0.05/W to $0.08/W).
- The 2014 National Electrical Code in the United States requires rapid shutdown within 10 feet of the array. Many vendors have introduced rapid shutdown boxes to meet these needs where required. These products would not meet the expected 1 foot requirements of the 2017 version of the code. Far more module vendors with junction-box-integrated rapid shutdown capabilities will emerge as a result.

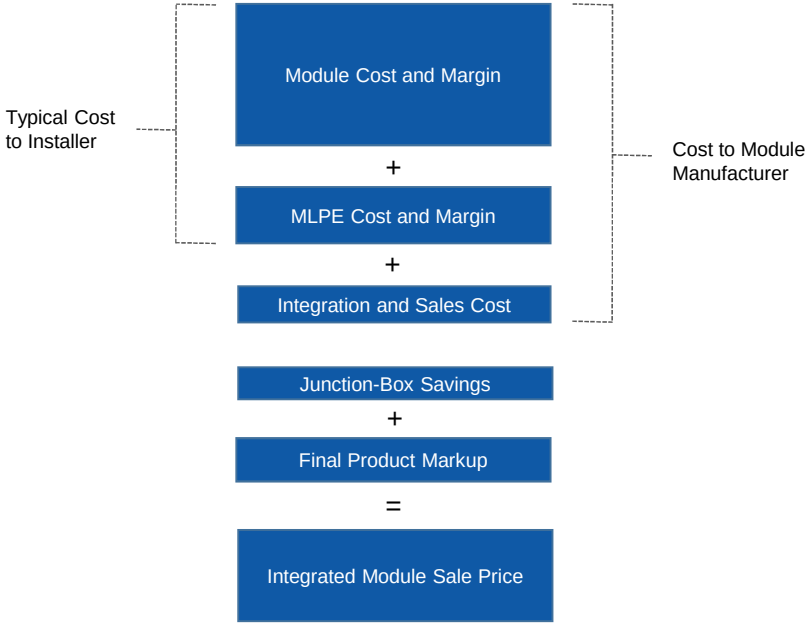
Module Vendors Offering These Capabilities

- Technically, any module manufacturer that advertises Tigo's TS4 product is able to sell PV modules with only safety and monitoring rather than full-functioning smart modules. However, only Trina and ET Solar currently market the full functionality of Tigo's product.
- ET Solar also markets a module that exclusively features rapid shutdown and monitoring capabilities.

Smart and AC Module Pricing

The Anatomy of Smart and AC Module Pricing

Smart and AC Module Price Makeup

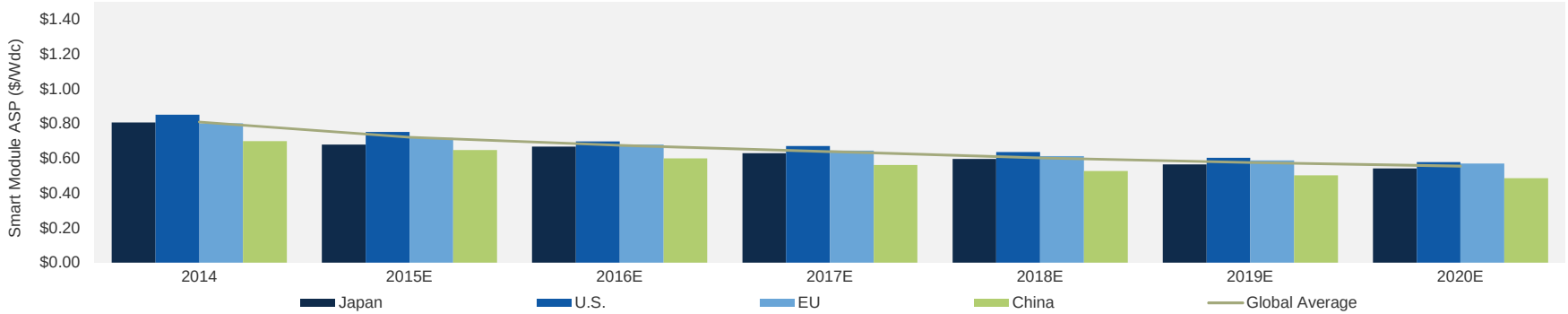


Source: GTM Research

- Smart and AC module pricing is primarily dependent on the price for PV modules and MLPE components.
- For products that are embedded, there are additional material savings up to the cost of the junction box ($0.02 to $0.03/W in 2015). Currently, all smart modules sold have embedded DC optimizers, meaning those savings currently exist for the module vendor.
- The share of AC modules sold with embedded microinverters will grow steadily until 2018, at which time we expect all AC modules to be fully embedded or cartridge-based.
- Most smart and AC modules currently have final product markups of 3 percent to 5 percent. This means integrated-module sale prices typically exceed the cost to the installer of buying standalone PV modules and MLPE. We expect integrated module markups to shrink rapidly in the near term to enable market share growth.
- As the market matures, we expect that markups will decline steadily such that integrated module ASPs fall between the typical cost to the installer and the cost to the module manufacturer after the junction box savings, with the module vendor taking the majority of these savings.

Current and Forecasted Pricing of Smart Modules, 2014-2020E

Smart Module Price Forecast by Market, 2014-2020E ($/Wdc)

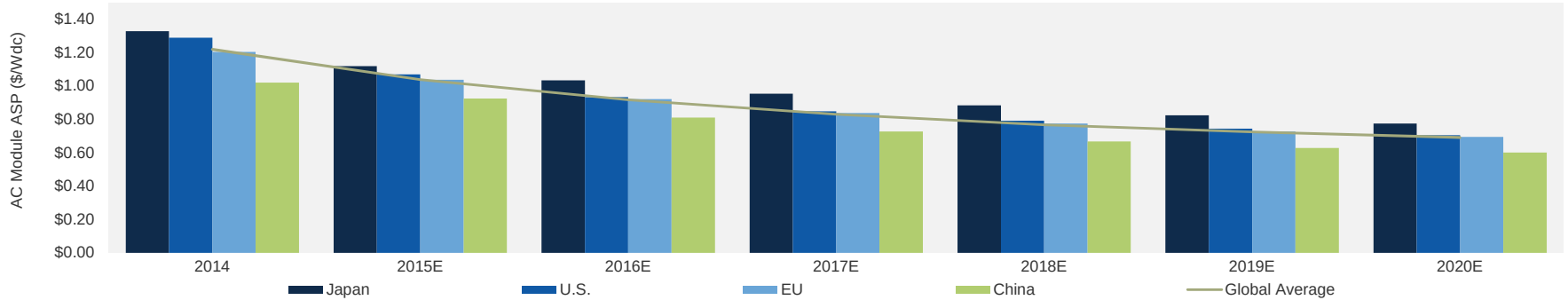


Smart Module ASP Forecast by Market, Nominal USD/Wdc	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.81	$0.68	$0.67	$0.63	$0.60	$0.56	$0.54
U.S.	$0.85	$0.75	$0.70	$0.67	$0.64	$0.60	$0.58
EU	$0.80	$0.72	$0.68	$0.64	$0.61	$0.59	$0.57
China	$0.70	$0.65	$0.60	$0.56	$0.53	$0.50	$0.48
Global Average	**$0.81**	**$0.72**	**$0.68**	**$0.64**	**$0.60**	**$0.58**	**$0.56**

Source: GTM Research

Current and Forecasted Pricing of AC Modules, 2014-2020E

AC Module Price Forecast by Market, 2014-2020E, ($/Wdc)



AC Module ASP Forecast by Market, Nominal USD/Wdc	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$1.33	$1.12	$1.03	$0.95	$0.88	$0.82	$0.77
U.S.	$1.29	$1.07	$0.93	$0.85	$0.79	$0.74	$0.70
EU	$1.20	$1.04	$0.92	$0.84	$0.77	$0.73	$0.69
China	$1.02	$0.92	$0.81	$0.73	$0.67	$0.63	$0.60
Global Average	**$1.22**	**$1.04**	**$0.92**	**$0.83**	**$0.77**	**$0.72**	**$0.69**

Source: GTM Research

Levers for Cost Reduction

Beyond manufacturing scale and reducing costs for the PV module and module-level power electronics themselves, there are several ways that manufacturers of integrated smart and AC modules can reduce costs and improve the value proposition of the technology.

Material Reductions

- The largest opportunity for cost reduction lies in fully embedding the MLPE into the junction box. All smart-module products are currently embedded, and thus this is an opportunity primarily for microinverter vendors.
- Use of larger microinverters for larger modules (72- and 96-cell) is another opportunity, as cabling and housing remain fixed for higher wattages, and only the sub-components are more expensive.

Manufacturing and Installation Labor

- Co-location of manufacturing to minimize shipping and packaging costs. This would be most easily accomplished by fully integrated suppliers such as LG or by module vendors such as ReneSola that the utilize original equipment manufacturers (OEMs).
- Integration of module frame as well as the power electronics. Andalay Solar is the first to take this approach, offering an integrated racking system with Enphase microinverters custom-wired to the frame.
- The addition of scannable barcodes for each integrated module, reducing manual cataloging of each module and microinverter/DC optimizer.

Overhead

- Greater cooperation earlier in the product-development phase among MLPE and module companies has been frequently cited as a way to optimize product, streamline sales, and reduce the cost of goods sold.
- MLPE/module relationship exclusivity is another potential opportunity. Working with fewer partners promotes collaborative R&D and ensures that partners are not monopolized with sales support for competing vendors.

Global MLPE and Module Price Benchmarks

Module DDP (Deliver, Duty, Paid) Average Sale Price ($/Wdc)							
Location	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.66	$0.57	$0.59	$0.56	$0.54	$0.51	$0.50
U.S.	$0.72	$0.65	$0.63	$0.61	$0.59	$0.56	$0.54
EU	$0.67	$0.62	$0.61	$0.58	$0.55	$0.53	$0.51
China	$0.57	$0.55	$0.54	$0.51	$0.49	$0.47	$0.45
India	$0.57	$0.48	$0.47	$0.45	$0.43	$0.41	$0.40
Global Average	**$0.64**	**$0.58**	**$0.57**	**$0.54**	**$0.52**	**$0.50**	**$0.48**

Source: GTM Research PV Pulse

DC Optimizer Average Sale Price ($/Wdc)							
Location	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.13	$0.11	$0.09	$0.08	$0.07	$0.07	$0.06
U.S.	$0.10	$0.09	$0.08	$0.07	$0.06	$0.05	$0.05
EU	$0.10	$0.08	$0.08	$0.07	$0.07	$0.07	$0.06
China	$0.10	$0.08	$0.07	$0.05	$0.04	$0.04	$0.04
Global Average	**$0.11**	**$0.09**	**$0.08**	**$0.07**	**$0.06**	**$0.06**	**$0.06**

Source: GTM Research

Microinverter Average Sale Price ($/Wac)*							
Location	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.68	$0.58	$0.50	$0.45	$0.41	$0.37	$0.33
U.S.	$0.57	$0.43	$0.34	$0.27	$0.25	$0.22	$0.20
EU	$0.54	$0.43	$0.35	$0.30	$0.26	$0.23	$0.22
China	$0.45	$0.38	$0.31	$0.24	$0.21	$0.19	$0.17
Global Average	**$0.56**	**$0.43**	**$0.35**	**$0.29**	**$0.25**	**$0.23**	**$0.21**

*Note: Inverter prices are shown in $/Wac, not $W/dc as with module and integrated modules pricing forecasts. Assumed AC:DC ratio of .87

Global String Inverter Price Benchmarks

Single-Phase String Inverter Average Sale Price ($/Wac)*							
Location	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.33	$0.31	$0.28	$0.26	$0.24	$0.22	$0.20
U.S.	$0.22	$0.17	$0.14	$0.12	$0.10	$0.09	$0.08
EU	$0.24	$0.20	$0.17	$0.15	$0.13	$0.12	$0.10
China	$0.17	$0.14	$0.12	$0.10	$0.08	$0.07	$0.07
Global Average	**$0.26**	**$0.22**	**$0.18**	**$0.16**	**$0.14**	**$0.12**	**$0.11**

Source: GTM Research

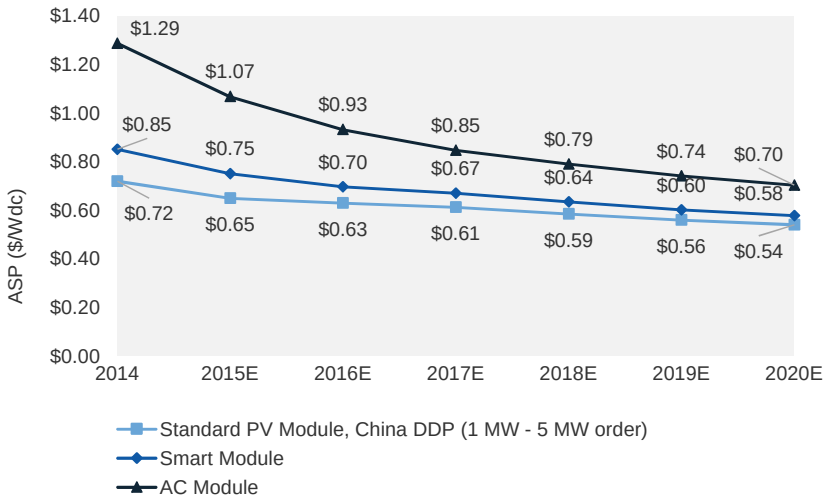
Three-Phase String Inverter Average Sale Price ($/Wac)*							
Location	2014	2015E	2016E	2017E	2018E	2019E	2020E
Japan	$0.29	$0.26	$0.24	$0.15	$0.14	$0.12	$0.10
U.S.	$0.18	$0.14	$0.12	$0.10	$0.09	$0.07	$0.06
EU	$0.15	$0.13	$0.12	$0.11	$0.10	$0.09	$0.08
China	$0.13	$0.11	$0.09	$0.07	$0.07	$0.06	$0.05
Global Average	**$0.19**	**$0.16**	**$0.13**	**$0.11**	**$0.10**	**$0.08**	**$0.08**

Source: GTM Research

*Note: Inverter prices are shown in $/Wac, not $W/dc as with integrated modules pricing forecasts. Assumed AC:DC ratio of .87

U.S. Smart, AC and Standard PV Module Price Comparison

U.S. Smart, AC and Standard PV Module Prices 2014-2020E ($/Wdc)



Source: GTM Research, GTM Research PV Pulse

- Microinverters and DC optimizers will fall in price more rapidly than PV modules over the next five years.
- In the United States, microinverter ASPs will decline at an annual rate of 14.1%, DC optimizers will decline at 10.8% and PV module prices will fall at an average annual rate of 3.6% from 2015 to 2020. Globally, these rates of decline will be 13.5%, 8.7% and 3.7%, respectively.
- More rapidly falling MLPE prices will shrink the relative pricing between standard and integrated PV modules.
- These pricing differentials will be further compressed by falling product markups that enable junction box savings to be passed on to the customers.

Smart and AC Module Market Forecasts

Smart and AC Module Forecast Methodology and Accounting

- Our base-case forecast for integrated module demand reflects the most likely demand scenario without serious deviations from expected market drivers.
- The forecast model is built upon GTM Research's global demand expectations, historical and forecasted MLPE shipments, and historical smart and AC module penetrations.

Note: Though our inverter and module-level power electronics forecasts are in MWac, our smart module and AC module forecasts are in MWdc. MWdc is the standard advertising and pricing wattage for PV modules. We utilize a DC-to-AC ratio of .87 in our accounting.

Context: The Global Market Outlook for Module-Level Power Electronics

The outlook for integrated modules hinges strongly on the outlook for module-level power electronics shipments in general. Growth for companies supplying these products will allow scale, bankability, and advancements in the power electronics that enable module integration.

GTM Research's forecasts see microinverters and DC optimizers as the two fastest-growing inverter segments between now and 2020. We forecast microinverter and DC optimizer shipments to build at annual growth rates of 32.6% and 42.1% between 2015 and 2020, respectively. This implies a continued, but more gradual rise in the overall global MLPE inverter penetration percentage from 4.9% in 2015 to 10.1% in 2020. However, there are downside and upside risks to our forecasts.

Negative Trends and Downside Market Risks

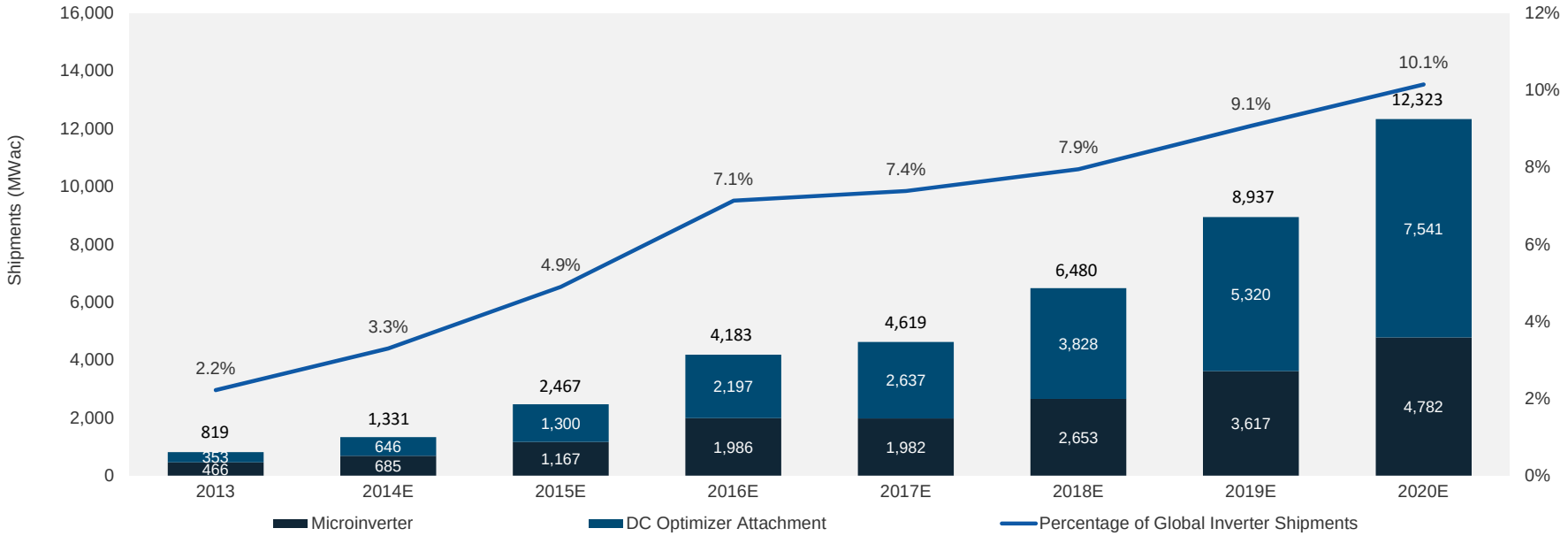
- The market has consolidated such that Enphase and SolarEdge controlled 87% of the global market in 2014. No other startup challengers have achieved consistent growth. Additionally, inverter incumbents with microinverters have been minimally committed to these products, which remain in their portfolios mainly to satisfy niche customers.
- Residential and commercial string-inverter pricing have fallen faster than expected, and these market segments are growing in competiveness, meaning prices will continue to fall.
- Low-cost devices that enable rapid shutdown without optimization have begun to emerge. These devices could become the preferred choice of U.S. installers in the tight economic conditions of the post-ITC world.

Positive Trends and Upside Market Risks

- NEC 2017 will likely require module-level rapid shutdown, further encouraging growth of MLPE in the U.S. in 2018-2020.
- Several new and less-expensive microinverter products, as well as the emergence of new smart and AC module technologies, could win over many string inverter enthusiasts.
- Commercial market expansions by Enphase and SolarEdge, the continued introduction of less-expensive dual module- and quad-level power electronics, as well as utility focus from Maxim Integrated, could help to expand the market for MLPE beyond the residential market.

Global Module-Level Power Electronics Shipments, 2013-2020E

Global Module-Level Power Electronics Shipments 2013-2020E (MWac)

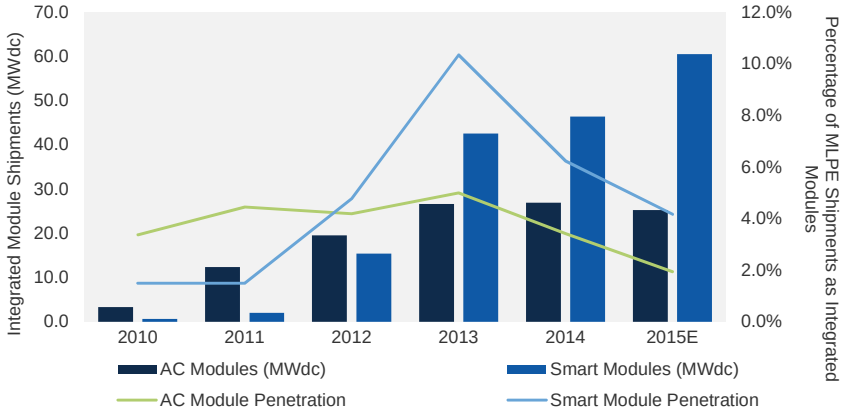


Source: GTM Research

Assumed DC-to-AC ratio of .87

Historical Integrated Module and Smart Module Shipments, 2010-2015E

Historical Global Smart and AC Module Shipments, 2010-2015E (MWdc)



Integrated Module Shipments	2010	2011	2012	2013	2014	2015E
AC Modules (MWdc)	3.3	12.3	19.5	26.6	26.9	25.2
Smart Modules (MWdc)	0.6	2.0	15.3	42.5	46.4	60.5
AC Module Penetration	3.4%	4.4%	4.2%	5.0%	3.4%	1.9%
Smart Module Penetration	1.5%	1.5%	4.8%	10.3%	6.2%	4.2%

Source: GTM Research

Assumed DC-to-AC ratio of .87

As a percentage of MLPE shipments, smart and AC module shipments have historically been quite small. AC modules gained traction before smart modules due to the relatively higher number of microinverter companies, greater microinverter demand, and the efforts of microinverter companies in using module vendors as a path to market.

The percent of microinverters shipped as AC modules has fallen from a high of 5.0%in 2013 to an expected 1.9% in 2015. There a few specific reasons for the decline beyond the general market barriers facing smart and AC modules.

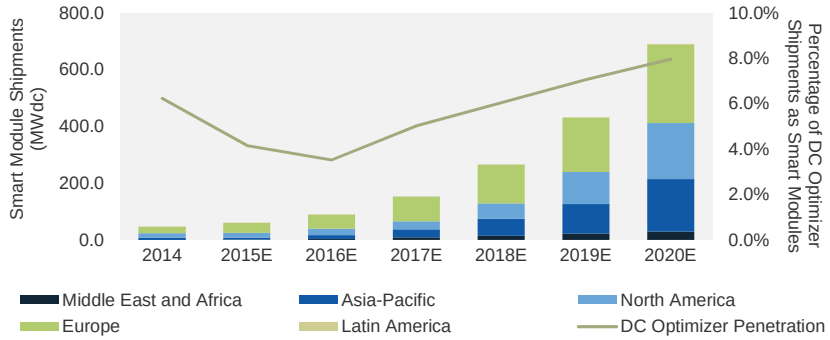
- SolarBridge, which exclusively took an AC module path to market, underperformed prior to its acquisition by SunPower.
- Microinverter leader Enphase has focused nearly entirely on its standalone business since 2012.

Smart modules slowly gained momentum as embedded products entered the market. Two trends are apparent when looking at historical shipments of smart modules

- Tigo's shift to a completely OEM strategy enabled higher smart-module penetration levels beginning in 2012. However, 2014 and 2015 were down years for the company as it transitioned to its new cartridge-based system.
- SolarEdge has had a broad selection of smart-module offerings and partners, but its explosive growth as a standalone DC optimization and inverter vendor has tempered smart-module market penetration levels in recent years.

Smart Module Forecasts, 2015-2020E: Base Case Scenario

Smart Module Base-Case Forecast, 2015-2020E (MWdc)



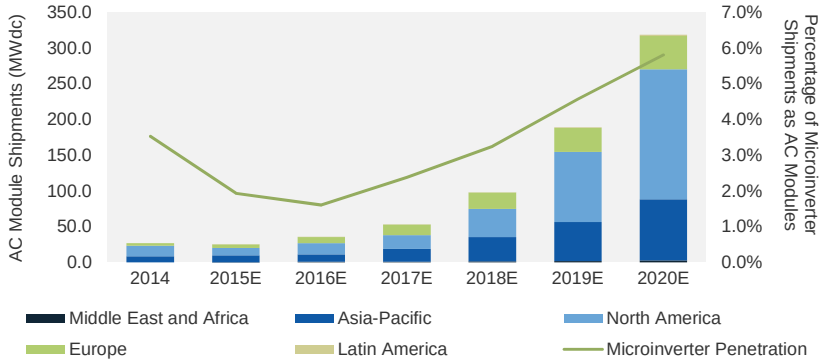
Smart Module Base Case	2014	2015E	2016E	2017E	2018E	2019E	2020E
Asia-Pacific	8.5	7.4	13.6	28.3	59.2	104.7	184.9
North America	15.7	16.4	22.0	27.7	54.1	111.9	197.3
Europe	22.2	35.4	49.4	86.8	137.1	192.1	275.7
Latin America	0.0	0.0	0.3	0.8	0.8	1.4	2.7
Middle East and Africa	0.0	1.2	3.8	9.3	15.4	22.3	29.9
Total	**46.4**	**60.5**	**89.2**	**152.8**	**266.5**	**432.4**	**690.5**
DC Optimizer Penetration	6.2%	4.2%	3.5%	5.0%	6.1%	7.1%	8.0%
Annual Growth	9%	31%	47%	71%	74%	62%	60%

Source: GTM Research

- We believe there is a stronger near term case for smart modules than for AC modules due to the widespread availability of fully embedded products.
- Additionally, smart modules, and DC optimization in general, are better suited for commercial and small utility markets due their comparatively lower up front cost and ability to better lower cost through scale relative to AC modules and microinverters. Our forecast calls for an overall average annual growth rate of 63% for smart modules from 2015-2020.
- However, our near term forecast is tempered by the existence of only three DC optimization companies, SolarEdge, Tigo, and Maxim Integrated, that are currently operating at a global scale. SolarEdge is only marginally committed to near term smart module growth, and though Tigo and Maxim are both taking an exclusively OEM path to market, their latest smart module technologies are still very new and yet to earn significant market share.
- Downside market risk is best portrayed by the individual outlooks for each of these suppliers: notably, a continued standalone strategy for SolarEdge, limited growth from Maxim, and declining sales or market exit by Tigo (though an acquisition is more likely).

AC Module Forecasts, 2015-2020E: Base-Case Scenario

AC Module Base-Case Forecast, 2015-2020E (MWdc)



AC Modules Base Case	2014	2015E	2016E	2017E	2018E	2019E	2020E
Asia-Pacific	8.5	9.7	10.7	18.3	34.1	54.7	84.9
North America	15.0	10.2	15.5	18.9	39.6	97.8	181.5
Europe	3.3	5.1	8.4	15.1	22.6	33.6	46.2
Latin America	0.0	0.1	0.5	0.3	0.5	1.0	2.2
Middle East and Africa	0.0	0.1	0.8	0.8	1.2	1.9	2.7
Total	**26.9**	**25.2**	**35.9**	**53.4**	**98.0**	**189.0**	**317.4**
Microinverter Penetration	3.4%	1.9%	1.6%	2.4%	3.3%	4.6%	5.8%
Annual Growth	1%	-6%	42%	49%	84%	93%	68%

Source: GTM Research

- The trends of 2014 have continued into 2015, as frame-attached microinverters have not been able to prove their value on labor savings alone. Multiple AC module products remain to serve the market, but 2015 will be the weakest year of AC module integration before the market builds an appetite for embedded products.
- Our base-case forecast assumes a gradual rise in the percentage of microinverters shipped as AC modules beginning in 2016 and 2017 as SolarBridge's next-generation product hits the market and Enphase/SolarWorld modules ramp up, and competing, fully embedded products hit the market from other MLPE suppliers.
- There is considerable upside to our forecast. We believe AC modules have a higher ceiling due to their ability to be used as a complete turnkey system. However, there is risk to the near term forecast in the case that the vendors are delayed in introducing embedded AC modules and the market is slow to adopt those products.

Geographic Drivers and Expectations for Smart and AC Modules

North America

- The United States and Canada serve as the base of MLPE shipments worldwide, with strong long-term prospects for residential PV demand.
- National Electric Code 2014 version encourages use of MLPE. The forthcoming 2017 version of the code will likely include module-level shutdown, which would essentially mandate MLPE and would create additional incentive for AC and smart module development.
- In the U.S., import tariffs are charged for integrated modules that range between $0.02 and $0.05 cents/watt, depending on the added cost of the DC optimizer/microinverter.

Europe

- Strong market for DC optimizers and growing market for microinverters.
- Unlike the U.S., there are no added tariffs for integrated modules. The minimum price floor often enables suppliers to sell integrated modules with the artificial module price increase covering a portion or all of the DC optimizer or microinverter. This creates a strong incentive to integrate the product in the factory rather than in the field.

Geographic Drivers and Expectations for Smart and AC Modules (Cont.)

Asia-Pacific

- The majority of integrated module shipments to date have been to the residential market in Australia. However, the low cost environment makes this a fairly difficult near-term market.
- Japan historically has not been a friendly environment for MLPE due to commitment to domestic inverter vendors. However, the country's feed-in tariff encourages system performance maximization, and MLPE vendors, notably Enphase, have spent several years preparing for market expansion in the country. Widespread use of kitted systems could encourage the use of AC modules due to packaging, shipping, and installation simplicity.

Latin America

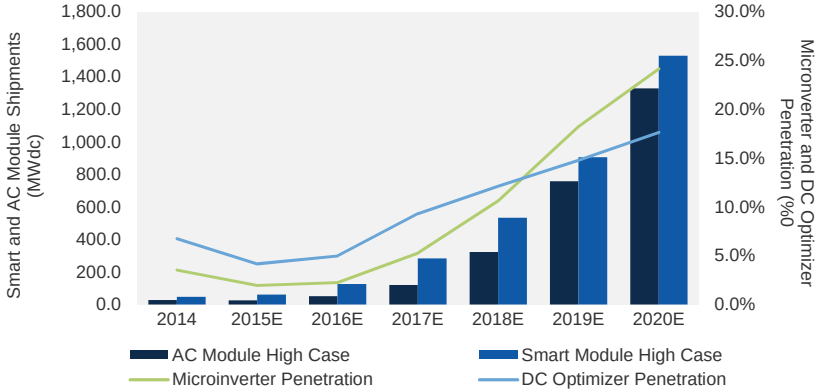
- Strong influence of U.S. solar market and North American distributors means that trends will more or less follow those of the U.S. Our base-case forecast assumes a two-year delay in adoption relative to the North American market, while our high case assumes penetration for integrated modules match across those regions.

Middle East and Africa

- Similar to Latin America, the Middle East and Africa often follow the trends of Europe. Our forecasts assume the same relationship between the MENA and European regions as the North American and Latin American regions.

Smart and AC Module Upside Forecasts, 2015-2020E: High-Case Scenario

Smart and AC Module High-Case Forecast, 2015-2020E (MWdc)



Smart and AC Module High Case	2014	2015E	2016E	2017E	2018E	2019E	2020E
AC Module Shipments (MWdc)	26.9	25.2	50.1	118.3	321.3	758.2	1,329.4
Smart Module Shipments (MWdc)	46.4	60.5	125.7	281.8	533.4	904.5	1,529.6
Total	**73.3**	**85.7**	**175.8**	**400.0**	**854.8**	**1,662.7**	**2,859.0**
Microinverter Penetration	3.5%	1.9%	2.2%	5.3%	10.6%	18.2%	24.2%
DC Optimizer Penetration	6.8%	4.2%	5.0%	9.3%	12.1%	14.8%	17.6%

Source: GTM Research

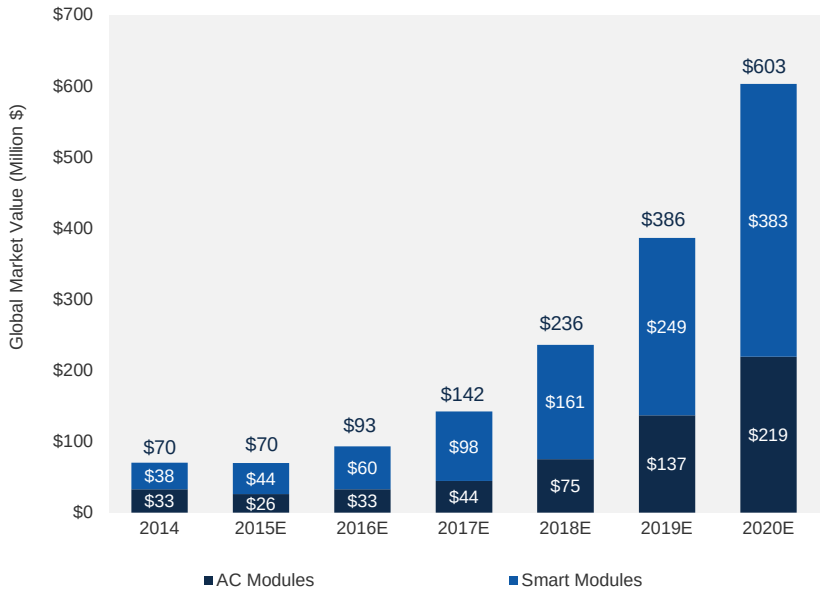
It is more likely the market will exceed our baseline expectations due to the limited historical penetration of smart and AC modules. Our base-case forecast is a business-as-usual scenario with limited downside. GTM Research's high-case scenario is an optimistic upper-bound view that assumes several or all of the following events occur:

- Embedded modules grow in scale and material savings begin to be passed on to the customer
- Major market players like SunPower/SolarBridge and potentially SolarCity/Silevo bring fully integrated modules to the market and leverage their dealer/installer bases in order to scale
- MLPE vendors, most importantly Enphase and SolarEdge, recommit to integrated modules as a primary sales channel and work with select module partners to commercialize offerings
- M&A occurs among module/MLPE vendors or additional single-supplier products such as LG's AC module are brought to market to alleviate warranty risk and simplify sales processes
- U.S. tariff issues are adapted to or resolved, product certification processes are streamlined, and patent suits remain minimal

While our base-case forecasts favor DC optimization, there is greater upside for AC modules due to their labor savings potential, ability to fully replace the inverter, and the existence of a greater number of microinverter vendors.

Global Market Value by Technology for Smart and AC Modules, 2014-2020E

Smart and AC Module Global Market Value Forecast, 2014-2020E (M$)

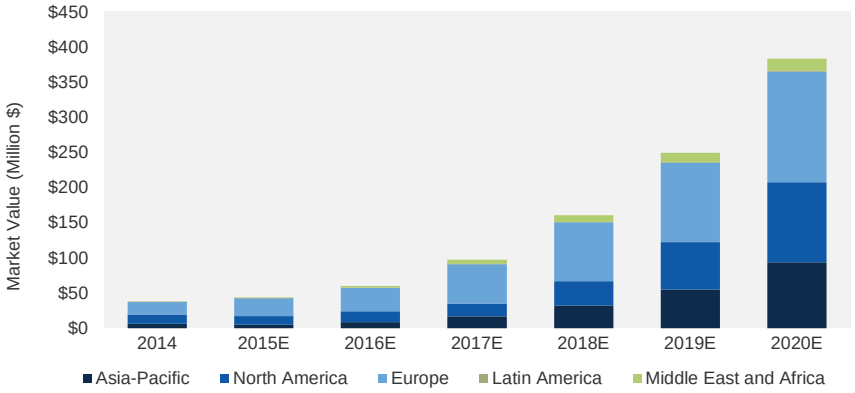


Source: GTM Research

- Under our base-case scenario, we forecast that the global market for smart and AC modules will grow from $70 million in 2015 to $603 million in 2020. This represents a CAGR of 54 percent.
- The smart-module market will grow more rapidly in the near term, however, from 2015 to 2020 smart and AC modules will grow similarly at CAGRs of 54 percent and 53 percent, respectively.
- Though AC modules will account for just 30 percent of integrated module shipments by MW over that same time period, they will account for 35 percent of the overall market value due to their higher price point.
- From a geographical perspective, North America will be about half of the global market from 2015 to 2020 for AC modules at 51% and Europe will be the leading smart module market with 47% of the market over that time. North America will follow with 26% of smart module sales.
- The pullback that occurs after the U.S. federal Investment Tax Credit drop in 2017 will lower North American market value shares to 36 percent and 19 percent in that year, respectively.

Global Smart and AC Market Value by Technology for Smart and AC Modules, 2014-2020E

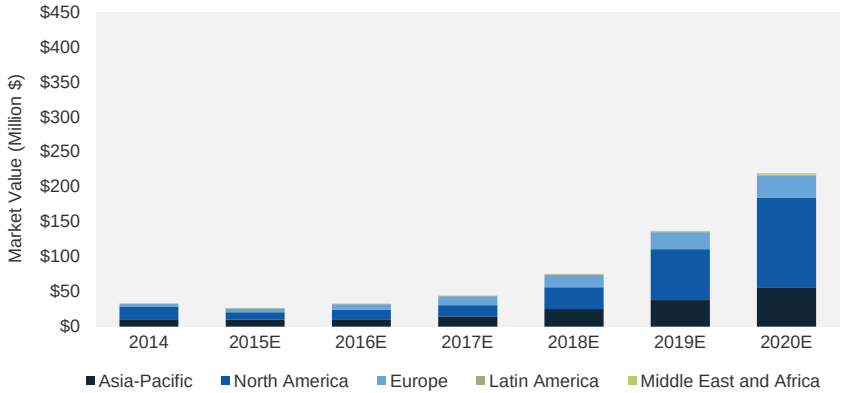
Smart Module Regional Market Value Forecast, 2014-2020E (M$)



Smart Module Market Values (M$)	2014	2015E	2016E	2017E	2018E	2019E	2020E
Asia-Pacific	$6	$5	$9	$17	$33	$55	$94
North America	$13	$12	$15	$19	$34	$67	$114
Europe	$18	$25	$34	$56	$84	$113	$157
Latin America	$0	$0	$0	$1	$1	$1	$2
Middle East and Africa	$0	$1	$3	$6	$9	$13	$17
Total	**$38**	**$44**	**$60**	**$98**	**$161**	**$249**	**$383**

Source: GTM Research

AC Module Regional Market Value Forecast, 2014-2020E (M$)

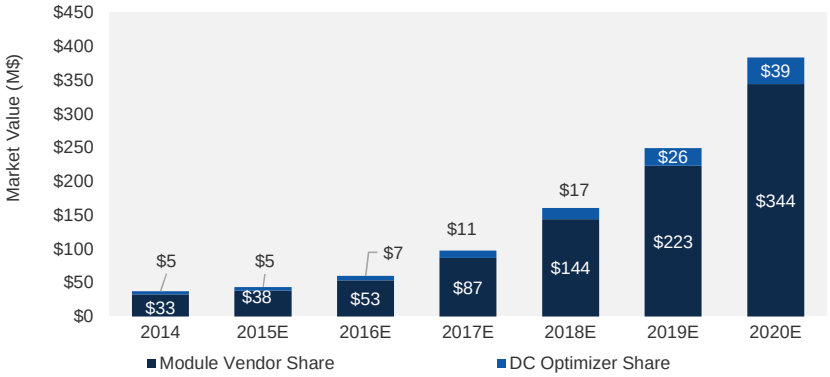


AC Module Market Values (M$)	2014	2015E	2016E	2017E	2018E	2019E	2020E
Asia-Pacific	$9	$10	$10	$15	$25	$38	$56
North America	$19	$11	$14	$16	$31	$73	$128
Europe	$4	$5	$8	$13	$18	$24	$32
Latin America	$0	$0	$0	$0	$0	$1	$2
Middle East and Africa	$0	$0	$1	$1	$1	$1	$2
Total	**$33**	**$26**	**$33**	**$44**	**$75**	**$137**	**$219**

Source: GTM Research

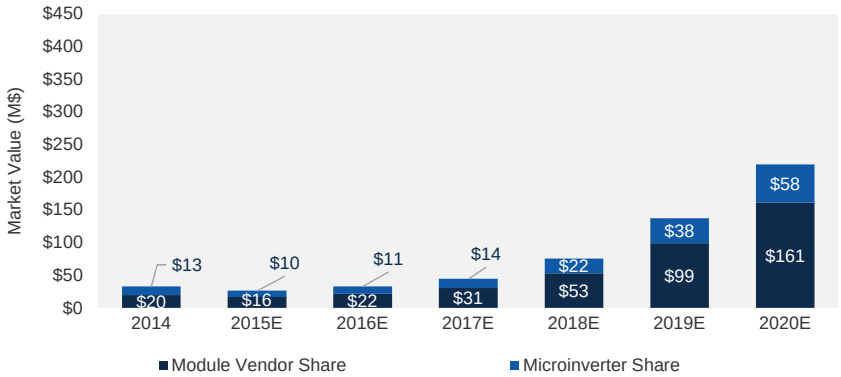
Global Smart and AC Market Value by Stakeholder, 2014-2020E

Smart Module Market Value Forecast by Stakeholder, 2014-2020E, (M$)



Source: GTM Research

AC Module Market Value Forecast by Stakeholder, 2014-2020E, (M$)



Source: GTM Research

- Due to the much lower price point of DC optimizers, the market value attainable from the integrated module market for DC optimizer vendors from 2015 to 2020 totals just $105 million compared to $153 million for microinverter vendors over that same period.
- The microinverter share of the annual AC module market value will fall from 37% in 2015 to 27% in 2020 due to microinverter prices falling more rapidly than PV module prices. The DC optimizer share of smart module market value will similarly fall from 12% to 10% over the same time period.
- Such a limited addressable market for DC optimizer vendors suggests that new market entrants must own a larger piece of the value chain, either the module or inverter, to reach significant scale. Due to the barriers of introducing multiple products or an entire system, we expect that the majority of market entrants to the DC optimizer space will be existing module and inverter manufacturers.

Conclusions

Conclusions: The Road to Module Integration

- **We believe growth in the smart and AC market is inevitable**. MLPE suppliers all point to integrated smart and AC modules as part of their long-term roadmap. The MLPE market is still nascent, and as it matures, we expect that increasingly reliably power electronics will find their way into embedded PV module offerings.
- **We do, however, believe the market will see gradual growth rather than a tipping point**. Current integrated technologies have only seen minimal volumes, and we believe even with significant cost reductions and improved bankability and reliability, the market will continue to be just a fraction of the total MLPE market. We do not see one single factor or determinant that would cause hockey stick-style growth for integrated offerings relative to standalone products.
- **The biggest challenge for smart and AC modules remains the business model** and not the technology. Module vendors will be helped considerably by the now-proven MLPE value proposition, but in order to scale the market, these manufacturers must learn to streamline the partnership sales model and offer compelling prices to customers. To grow, smart and AC modules must be seen as cost-effective solutions rather than premium products that simplify purchasing and installation for a price.
- **There is room for more MLPE vendors to enter the market, especially with DC optimizers.** The window for new entrants is narrow, especially for standalone suppliers, but the existence of only three true module-level DC optimization companies in North America means there is room for competitors. However, the limited addressable market for DC optimizers means that newcomers will look to own more than just the DC optimizer. The most likely entrants are major inverter vendors hoping to compete more directly with SolarEdge and module vendors enticed by the technical simplicity and limited customer service requirements of DC optimizers relative to microinverters.
- **M&A will continue to occur in the market, though at a declining rate.** Exits are much more likely than full acquisitions, especially in the crowded microinverter space. We do not anticipate many more SunPower/SolarBridge type acquisitions, and though the thought of SolarCity/Silevo taking this approach is enticing, we believe downstream vendors will stay away from the challenging power electronics market. However, with many early-stage companies faltering, as well as a growing graveyard of extinct suppliers, IP acquisitions are not out of the question.

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