Commercialization Strategies for Emerging Technologies: Wireless Power in the Market for External Power Adapters

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Abstract

The purpose of this thesis is to explore the different challenges facing start-ups that are engaged in intense competition to lead the commercialization of a complex technology that is initially unable to meet the demands of a market. Technology, intellectual property, and go-to market strategies are proposed with a particular focus on wireless power technology in the market for external power adapters.

Wireless power technology is a revolutionary technology that promises to replace the two billion external power adapters that are sold every year. It is a seemingly attractive opportunity for a start-up company, but the technology is complicated, the intellectual property landscape is dense, and the competition is intense. The technology will be sold into the pre-existing market for external supplies, which is reeling from declining prices and margins. The market is in need of change, and is looking for innovations that will improve the situation.

The commercialization of wireless power technology is a case example of how start-up technology companies can accelerate development times, reduce risk, and build sustainable competitive advantage by carefully planning their technology approach, fully understanding the intellectual property landscape, and leveraging the principles of open innovation. A technology strategy requires the selection of a technology vector which should be determined by weighing the importance of individual product features against the expected levels of technical risk. Within its technology vector, a company must evaluate the strategic importance the various engineering activities based on whether they enable freedom to operate, contribute to the creation of blocking patents, and/or are outside the expertise of potential partner organizations. The start-up should intensely focus its engineering resources on the strategically important activities while farming the remainder of the development work to partner organizations within the greater value chain.

A start-up entrenched in a competitive battle to serve a hungry market; with a green technology solution, faces a difficult choice: go to market niche by niche and face irrelevance in the greater market, or swing for the fences and risk bankruptcy. There are options beyond the traditional approaches, and in this case, a three track commercialization strategy is appropriate.

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Chapter 1: Introduction: Wireless power overview

Brief history of wireless power

Individuals have dreamed of wireless energy since ancient times when Zeus was thought to have harnessed the power of lightning. Almost two millennia later, a man named Nikola Tesla would wield the same power when he fired up the Wardenclyffe Tower: a 200 foot, 300kW, wireless power transmission station. He showed the world that he was capable of transferring power wirelessly, but the spectacular blue arcs radiating from the spire were an indication that the invention was too much, too soon and the concept faded into obscurity.

Sixty years would pass before two important developments reinvigorated the drive to build wireless power transmission systems. The first occurred in 1964 when William C. Brown invented the "Amplitron," or cross-field amplifier, which had the capability to output 400kW, at high frequency, at 70% efficiency (Low, 2009). The second innovation was the development of the Schottky-barrier diode by Hewlett-Packard associates. In 1975, scientists and engineers would combine the Amplitron and Schottky-barrier diodes in an awe-inspiring demonstration of wireless power transfer. A massive 26m parabolic dish antenna transferred 450kW, a distance of one mile and set a record that stands until this day (Low, 2009). But again, size, complexity, and lack of a compelling application doomed the concept for another 30 years.

Technology innovations and changes in consumer behavior have once again reignited the drive to develop and commercialize wireless power technology. The single most important change has been the proliferation of portable, low power, battery-life-constrained electronic devices. Today, many expect that we are on the precipice of a multi-billion dollar shift to a wireless power distribution system for low power devices. In anticipation of this shift, a variety of companies and technologies have emerged ready to meet the new market demands.

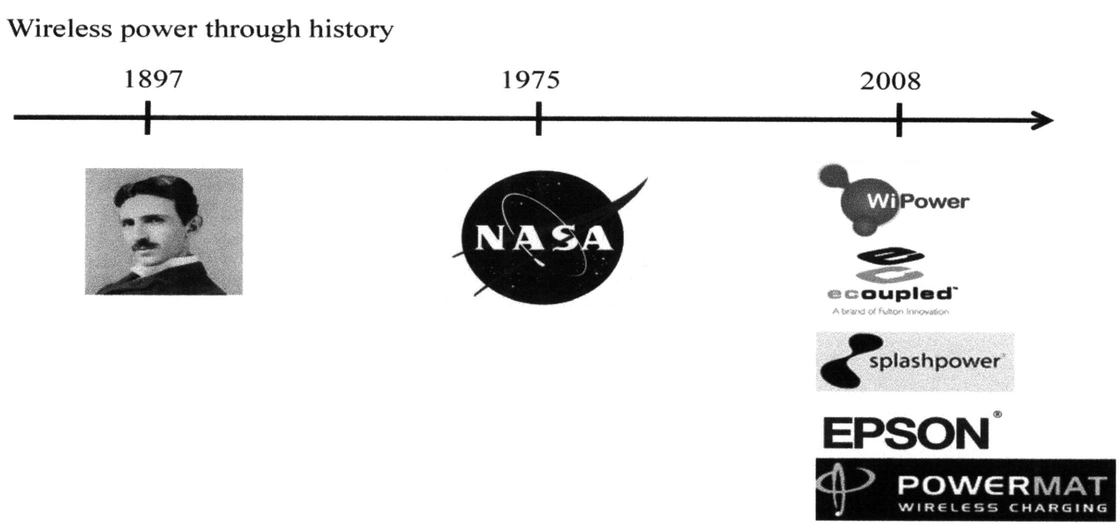

Figure 1: Chronology of wireless power developers.

Problem with today's power adapters

According to CEA, a typical household owns an average of 20 different consumer electronic devices and external power supplies (Consumer Electronics Association, 2008). As a result, end users are left to manage disorganized tumbleweeds of power adapters on their countertops and beneath their desks. There are other problems: power adapters are left behind during travel;

power cords fall behind desks and are difficult to retrieve; and batteries die at critical times if they aren't plugged in on a daily basis. But perhaps most frustrating for consumers, is that the same power adapter almost never works with more than one device. In fact, there are over 30,000 different models available in the United States (Premier Farnell Group, 2009).

For the environmentally conscious; today's power adapters represent a massive volume of unnecessary electronics waste. The world manufactured 3.2 billion new power supplies in 2008 (Socolow, 2008) and approximately 1.6 billion existing power supplies were discarded into our landfills. Device companies that create proprietary connectors and device specific chargers have inadvertently created a huge pipeline of electronics waste.

Figure 2: Left: Photograph of cords on the floor near a computer work station. Right: Photograph of power supply waste (Jordan, 2008).

The wireless power solution and ultimate vision

Wireless power offers consumers hope for salvation from the bondage of their power cords. Imagine a world where power is ubiquitously available; whether you are at home, in the office, in the car, or on vacation, wireless power hotspots stand ready to keep your electronics buzzing, and you connected. It doesn't matter how many, or what type of devices you carry, they are universally compatible with wireless power transmitters. The original equipment manufacturers have made this possible by integrating a standards based wireless power receiver into their portfolio of electronic products.

Today, 1.2 billion Bluetooth enabled products are sold each year (Solid State Technology, 2002), and in the future we can expect similar sales volumes of wireless power enabled products. It is an exciting technology and an exciting market, but there are many complexities to achieving this vision and building a successful company along the way.

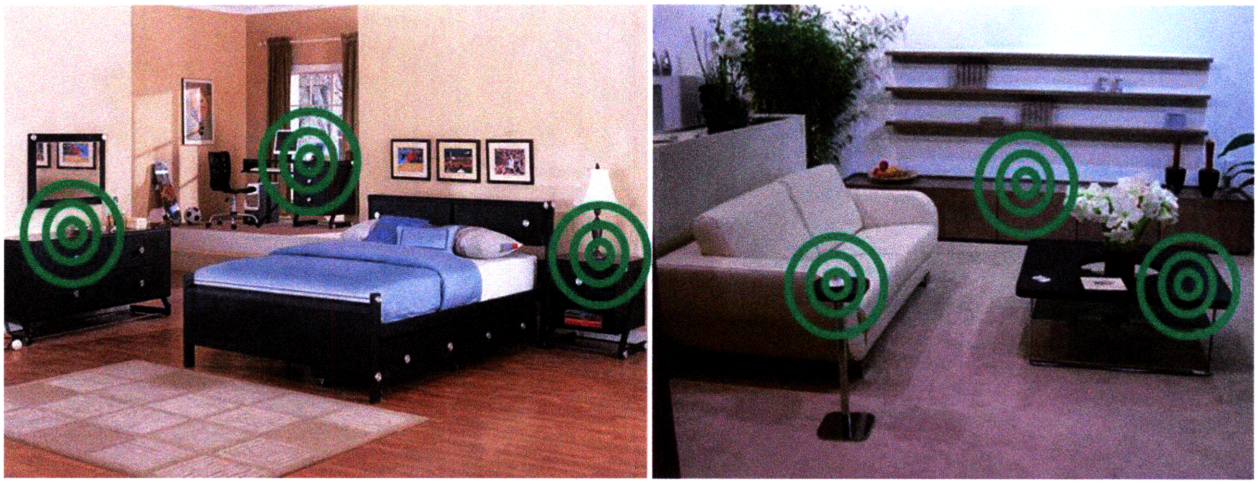

Figure 3: Wireless power hotspot concept.

How wireless power works

A wireless power transmitter is capable of sending power to one or more electronic devices. It can be a standalone platform, or it can be integrated into surfaces such as desktops, bedside tables, and countertops. The wireless power transmitter works by converting electrical energy into magnetic energy, which propagates easily through air and other non-metallic mediums.

A device that has an integrated or retrofitted wireless power receiver is capable of capturing that magnetic energy and converting back to electrical energy. The receivers use circuits known as voltage regulators in order to adopt to the requirements of virtually any device.

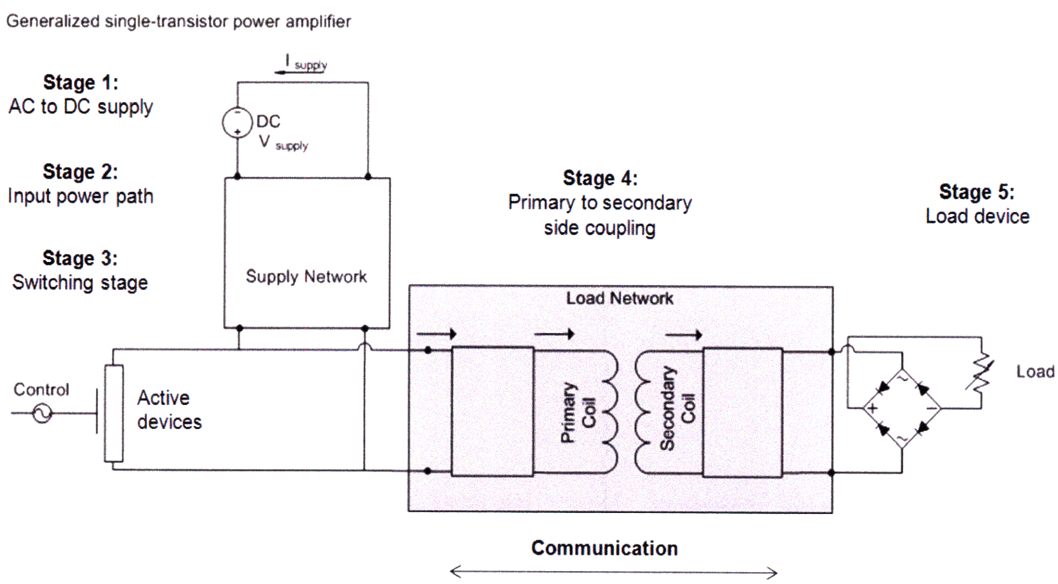

Figure 4: A functional block diagram of a basic wireless power transmission system. Source: **(WiPower Inc., 2009)**

A typical system is explained in more detail below:

- **DC supply:** The first stage of a wireless power system is an AC to DC power adapter. The power adapter can be a standard unit with no special adaptations being required. It provides a stable DC voltage that can converted to a higher frequency signal at a later stage.

- **Supply network:** The second stage of the wireless power system is the supply network which filters the power following into subsequent stages and prevents the backflow of differential noise into power lines.
- **Switching stage:** The switching stage converts the input from the supply network into a high frequency signal, by flipping a set of solid-state switches on and off at the desired frequency and duty cycle.
- **The load network:** The load network is used to overcome a transmission line phenomenon known as reflected power. The load network matches the impedances of the various stages such that power can flow without reflection from stage to stage. The load network enables high efficiency transmission of power from transmitter to receiver.
- **Load device:** The load device is adapted to receive power by incorporating additional voltage and current regulation mechanisms. Commonly, the load device is provided a communication channel in order to ensure that the transmitter sends appropriate amounts of power.

Relevant technical disciplines

In the case of a wireless power system, the technical disciplines of interest include electromagnetics, power electronics, controls, materials, system integration, and EMI/EMC control[1]. A practical wireless power product requires non-trivial innovations to take place within each category. Thus, deep technical expertise and specialization must be applied in each functional discipline.

- **Electromagnetics:** A wireless power system depends on the creation of highly optimized transmission and receiving coil structures. The design of these coils requires advanced knowledge of the creation and propagation of magnetic fields, electric fields, and their interactions with each other and the surrounding environment. It is a mathematics intensive field and a small percentage of organizations or individuals have strong competence in this field.
- **Power electronics**: Power electronics pertains to the design of the power system. It could be the design of an AC to DC adapter, or the power management system. The design of the power electronics for a wireless power system requires expert knowledge of analog circuit behavior, discrete component characteristics, magnetic materials, battery technology, and thermal management. Like electromagnetic, there are relatively few organizations or individuals that have strong competence in power electronics as they relate to the design of a wireless power system.
- **Controls:** Controls is a field of electrical and mechanical engineering that focuses on the characterization and control of a system. The actual control is straight-forward, but minimizing the cost of the control system is difficult without access to the appropriate people and tools. There are a large number of companies with the capability to produce low-cost, integrated control systems.

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[1] There are other areas that require attention, such as communication systems, mechanical design, thermal management, and integrated circuits, but they been excluded for the sake of simplicity.

- **Materials:** New component materials are required for the practical implementation of wireless power systems. Materials engineers have the capability to understand materials at the atomic and molecular level in order to create compounds with the appropriate chemical, electrical and mechanical characteristics. They must be capable of designing the processes needed to convert lab-scale samples into production materials.
- **System integration**: System integration is the combination of many discrete parts, subsystems, and/or functions into a completed product. Integrating a wireless power receiver onto the main board of a mobile phone is complex, and few people outside the engineers working at a major OEM, will have sufficient background knowledge to be successful. System integration requires broad knowledge of electrical and mechanical engineering.
- **EMI/EMC control:** Electronic products, including wireless power systems, are subject to a diverse set of regulatory constraints. Wireless power systems are particularly susceptible to compliance issues due to the large amounts of power they are attempting to send through space. EMI/EMC control engineers are familiar with noise and noise countermeasures, analog circuit behavior, and electronic materials for EMI/EMC suppression.

Technology approaches

A variety of technologies has emerged ready to meet the new market demands and each has unique characteristics. The solution that has attracted the most interest from consumer electronics industry is the coreless inductive solution.

- **Coreless induction (WiPower, eCoupled, Powermat, Convenient Power, Seiko Epson):** Coreless inductive solutions are a subset of inductive solutions and is believed by most players to be the best solutions for most applications. Like traditional inductive systems, a coreless inductive solution uses magnetic fields to replace a charging cord. It is distinguishable from an inductive system because it has not magnetic core material. Removing the core allows for a flatter, more compact design.

  These systems operate at a higher frequency than core based solutions, but they are typically less stable. They are also sensitive to alignment between the transmitter and receiver, and are typically not suitable for multiple loads.
- **Induction (Various):** Inductive systems use one or more transmitter coils that are magnetically coupled to one or more receiver coils. As with the coreless inductive solution, the technology uses magnetic fields to replace a charging cord.

  Large amounts of power can be transferred at very high efficiency over a short distance. This configuration is common in transformer applications. These systems operate at low frequencies and are large due to the magnetic core. In the consumer products domain, inductive solutions can be found in electric toothbrushes and razors.
- **RF harvesting (Powercast):** RF power transfer systems, commonly known as RF harvesting systems, can gather energy from an intentional radiator or from the ambient environment. The systems provide low power, at low efficiency, but the range can extend over a few meters.

  RF solutions can be useful for providing milliwatts of power which is several orders of magnitude beneath the requirements of most consumer devices. These systems operate at high frequencies that are closely monitored by the FCC and limited by the IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields.

- **Directed RF (Powerbeam):** These solutions direct high frequency electromagnetic energy to the intended destination. They typically require a dish antenna, which is rather large (several meters, plus), in order to focus the beam. The beam is directed to a rectenna array that can convert the electromagnetic energy to electricity. The NASA JPL Goldstone Demonstration transmitted 34kW of power, 1.5km at an efficiency of 82% (Low, 2009).
- **Resonant wave coupling (Witricity):** Intel and MIT have both demonstrated resonant inductive power systems that use evanescent coupling to transfer power between two similar coils over a few meters. Notably, the coils are large relative to the size of contemporary electronic devices, and the electronics needed to support the coils are large and expensive. These systems have yet to address challenges related to the transmitter-receiver alignment, and being able to charge multiple devices simultaneously. Additionally, they operate at relatively high frequencies that are limited by the IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields.

Competitive environment

There are a wide variety of solutions being pushed by at least eight organizations who each intend to become the dominant wireless power solution provider. A single design win with a major OEM can lead to volumes in the hundreds of millions of units and the resulting installed base would effectively crown the market winner. In recognition of this, each of the eight players has overlooked a wide variety of potential applications, ranging from medical devices to ruggedized electronics, in order to focus on the consumer electronics market place. It is the market with that presents the largest opportunity, but it also involves the highest levels of technical risk. Each competitor has selected this high risk path despite their persistent inability to design a consumer-market-ready product.

Market participants				
Coreless inductive	**Inductive**	**RF Harvesting**	**Directed RF**	**Resonant solutions**
WiPower	Various	Powercast	Powerbeam	Witricity
eCoupled				
Powermat				
Convenient Power				
Seiko Epson				

Table 1: The technical approaches to wireless power and the companies that have adapted them as the core platform.

State of the technology

For the last eight years, engineers have struggled to produce wireless power products that are both technically practical and commercially viable (Anonymous, 2009). It is not for lack of trying, the world's leading OEM's have tried and failed to develop solutions: patent records point to previous research projects conducted by Nokia, Motorola, Samsung, and many others (Naskali, 2/20/2007), (Park, 1/27/2004), (Fernandez, 2/6/2001). In nearly all cases the technology encounters problems related to efficiency, charge time, cost, interoperability, regulatory compliance, and/or compatibility with high volume production processes[2]. Solutions to these problems are complex and require high levels of technical sophistication across a wide range of engineering disciplines. The requisite talent, tools, and time required to design a complete solutions requires considerable levels of investment.

State of the market

The players throughout the value chain for external power supplies are actively seeking opportunities to participate in the expected transition to wireless power technologies (Wireless Power Consortium , 2009). This activity and interest persists despite repeated failures of wireless power technology providers to meet expectations. A downturn in interest or wholesale rejection of the concept would be expected after eight years of repeat failures, but it has not happened for two reasons:

- In the parlance of health care, the market for external power supplies is in critical condition. In today's market some value chain segments lose billions of dollars, while the fortunate earn razor thin margins. The outlook is negative based on the ongoing commoditization of power supply components, the declining value placed on brand name adapters, and the increasing cost of regulatory compliance. It is illustrative to point out that, just five years ago, retailers routinely sold brand-name power adapters for $30 per unit, but today shelves are loaded with generic versions that cost under $5.
- Second, the largest buyers of power supply products, device OEMs (e.g. Nokia) are pressed by an increasingly competitive market. Intense rivalry combined with the growing threat of forward integration by their Asian suppliers, has led incumbent OEMs to seek out new vector of differentiation: one of those is the power system.

In short, the industry needs a major breakthrough in order to improve the unhealthy market dynamics.

[2] This assessment is based on conversations with dozens of conversations with marketing and engineering managers at the world's leading consumer electronics companies. Many discussions took place under NDA and therefore specific citations are not possible.

Chapter 2: External power supply products

Product background

Every year, external power supplies ship alongside two billion different products including mobile phones, computers, television sets, digital cameras, media players, printers, and game consoles (US Department of Energy, 2006) (WiPower Inc., 2009). Without these power supplies, electronics do not operate.

Power supplies are connected to billions of devices for thousands of different applications, but in all cases, they perform the basic function of conditioning a voltage available at a source, to a voltage that is usable by an electronic device.

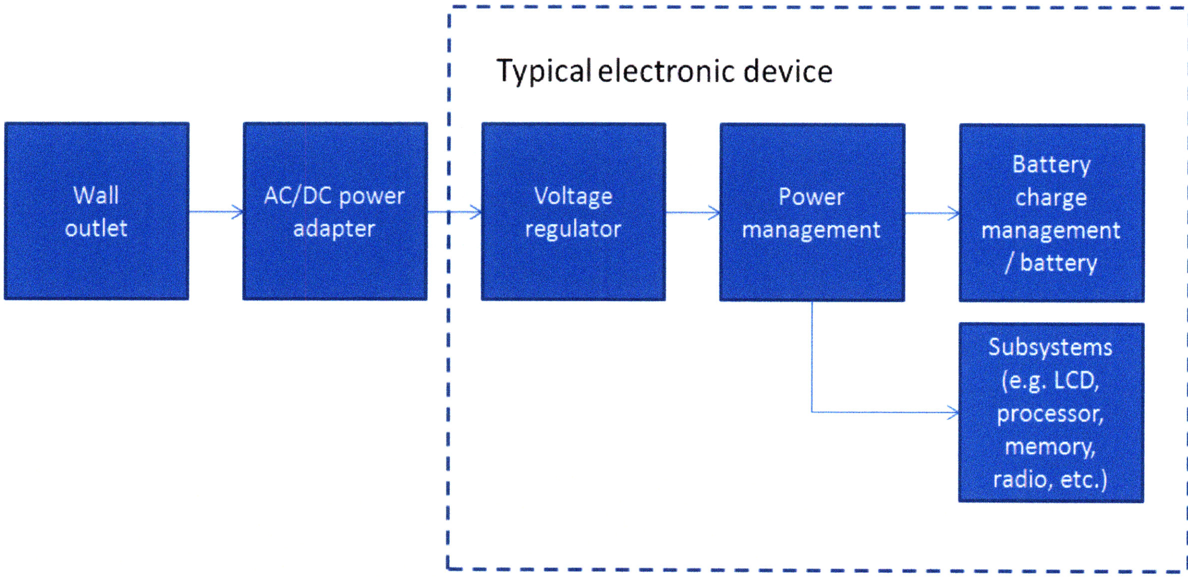

Figure 5: Block diagram of a typical charging system

In the typical use-case, a power adapter provides an interconnection between a wall outlet and an electronic device that has a unique power requirement. The power adapter has internal systems that rectify, step-down, and regulate voltage before passing it to the input jack of an electronic device. At this point a gate-keeper, semiconductor device called a voltage regulator filters the power and relays it to a power management system. A power management system, which resides on an integrated circuit, is the central distribution station of a miniature power grid that interconnects with all of an electronic device's various subsystems. One of the main subsystems is the battery charge management system that regulates power into and out of the main battery. Through the combination of power adapters, voltage regulators, power management systems, battery charge management systems, and batteries, a world of portable electronics is made possible.

Key power supply ratings		
Voltage – Volts (V)	**Current – Amps (A)**	**Power – Watts (W)**
A power supply voltage must match the requirements of the intended device. Low voltages allow for faster processor speeds by decreasing the power consumption of integrated circuits. Low voltages however can make the analog portion (e.g. power electronics, RF electronics) of circuits less efficient by increasing I^2*R losses. Low voltage results in higher current at any given power level.	Current is related to the amount of power consumed by a device at a given voltage. High current is undesirable because it creates heat; however it is required by high performance electronics. Heat is often the main, performance-limiting constraint of an electronic device. Unless the adequate thermal dissipation mechanisms can be implemented, high currents are avoided. Reducing current consumption is desirable.	The power consumed by an electronic device is equal to the product of device voltage and current. A 60V, 1A device consumes 60Watts (e.g. an AM radio transmitter). A 60A, 1V device also consumes 60W (e.g. Intel Microprocessor). Though the total power required by the example devices is the same, they do not have interchangeable power supplies because of the voltage-current mismatch.

Table 2: Key characteristics of an external power supply

Today's power solutions

There are tens of thousands, perhaps hundreds of thousands of different power supply designs circulating in the consumer market place. A quick search on Newark, a US based electronics parts distributors brings up 33,105 different external power supplies that are available for immediate purchase (Premier Farnell Group, 2009). The power supplies can be grouped into several categories including proprietary, universal, standard, and application specific.

- **Proprietary:** Proprietary charging systems fit a single device or a group of devices. Devices that use proprietary power supplies have mechanical features, such as an oddly sized openings or custom pin configurations, which lockout other power connectors. The mechanics are advantageous in that they prevent a user from inadvertently connecting the wrong type of power supply.

- **Universal:** The iGo charger is an example of a universal power supply. It is capable of charging a variety of devices through the use of interchangeable connector tips that allow matching of the power supply to a large number of different devices. These universal solutions alleviate the headache of managing many power adapters. But, the universal tips are small, easy to lose, and difficult to sell at retail. In fact, executives at retail locations have complained about the high return rates of iGo chargers because customers select the wrong connector tips or don't understand how to use the system.

- **Standard:** Of the solutions available, the most widespread is the Universal Serial Bus, or USB charger. The USB charging interface supports devices that require up to 5Watts of power, which covers over one third of the 2 billion portable electronics devices that ship each year (US Department of Energy, 2006). According to In-Stat, over 1.4 billion USB enabled units have shipped each year since 2005 and the number is expected to hit 2.8 billion units per year by 2010 (In-Stat , 2006). It is an interface that is closest to being considered a standard charging system.

Figure 6: USB connector configurations

- **Application specific:** Recently, renewable power sources have emerged that allow users to charge small portable electronics via solar cells and mini wind turbines. Similar to the iGo solution, they make use of swappable tips but do not require a connection to an electrical grid. These solutions tend to be expensive and are best suited to niches, such as the outdoors electronics market (e.g. hunting, fishing, hiking, and camping).

All of the power adapter types are available in both branded and generic versions. Branded versions carry the name of a major device manufacturer, such as Nokia or Motorola, or a large accessories provider such as Targus or Logitech. The generic versions promise the same functionality but at lower prices.

Generally, if the generic power supply is purchased at a reputable retail outlet, its quality and functionality is similar or identical to that of a branded product. However, this is typically not the case with generic products which are purchased through online channels. In many cases, the generic versions do not meet the same quality standards as their name-brand counterparts (Micro Power Electronics Inc., 2008).

Chapter 3: External power supply market

Market size and basic characteristics

The global market for external power adapters was roughly 2 billion units in 2008 and is forecasted to grow at a 7% CAGR (WiPower Inc., 2009) (US Department of Energy, 2006). According to Andrew Fanara of the EPA, there are roughly two external power supplies for "every man, woman, and child" on the planet, or 12 to 15 billion units (Hochman, 2009). The majority of this volume is driven by the sale of mobile phones, which accounted for roughly 1 billion units in 2008 (Medford, 2008). Cordless phones, laptops, personal care products, digital cameras, printers, and wireless headsets were responsible for another 500 million units. The remaining 500 million units are attributable to a wide variety of electronic products ranging from rugged electronic devices such as weapons scopes, to medical devices.

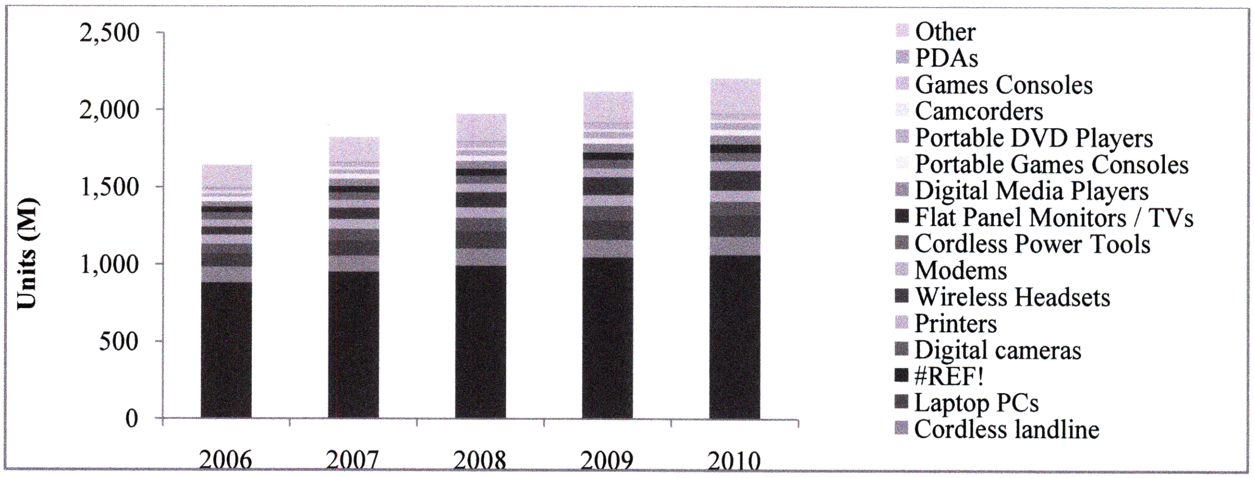

Figure 7: (US Department of Energy, 2006): The sales of annual power adapters per year based on product segment.

The production of the power supplies is dominated by East-Asian manufacturers who take advantage of a low-cost, well-developed electronics manufacturing infrastructure and have developed the requisite engineering sophistication.

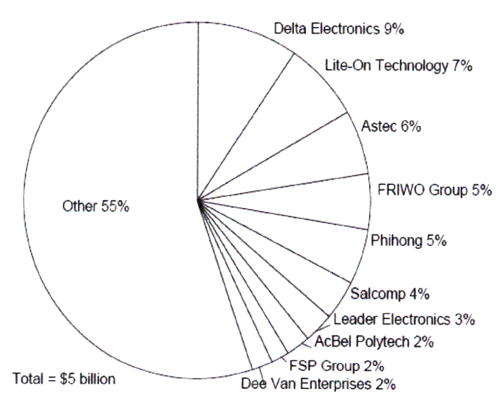

Figure 8: The market share of various external power supply manufacturers. Source: (US Department of Energy, 2006)

The size of the market and its high level of growth have attracted the interest of a wide variety of competitors. This has led to the following major trends:

- **Price erosion:** The average price of an external power adapter for a mobile phone was $1.12 in 2008 and that price is expected to decrease to $1.03 by 2011 (US Department of Energy, 2006). In today's power supply market, the technology barriers to entry are low and this enables a large number of small Asian suppliers to participate. There are limited opportunities for differentiation because power supplies are built to customer specifications. Deviation from these tight specifications does not generate incremental value and, in fact it is not desirable from their customers' perspective.

  The price erosion is also driven by consumers' unwillingness to pay for power adapters. They expect power adapters to be included for free, along with their electronics products. Some manufacturers have tried to separate the power supply from the device bundle, but doing so typically generates consumer ill-will.

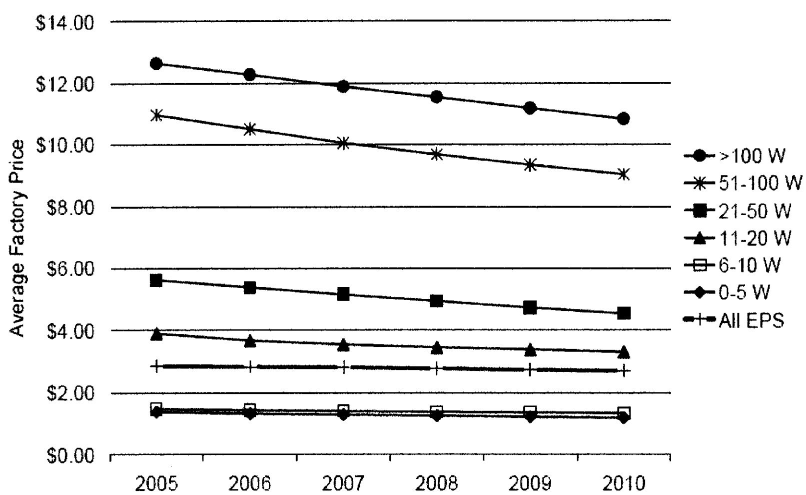

Figure 9: The average selling price of power adapters based on the power output, 2005-2010. Source: **(US Department of Energy, 2006)**

- **Focus on cost, not innovation**: Low margins provide little cash to invest in advanced research. The players focus their research on improving operations in order to improve margins, and therefore there have been few, if any disruptive innovations in external power supplies that have originated from the major designers and suppliers. According to the a division executive at Lite-On Corporation, "As soon as we come out with a new product, the first thing the OEM requests is a 'cost-down proposal', that is why we want to brand our own products. OEMs only care about cost." (Ho, 2009)

The value chain

The value chain for power supplies is relatively complex. There are a large number of channels through which each participant makes their products available. The major players are described in this section.

The value chain for power supplies

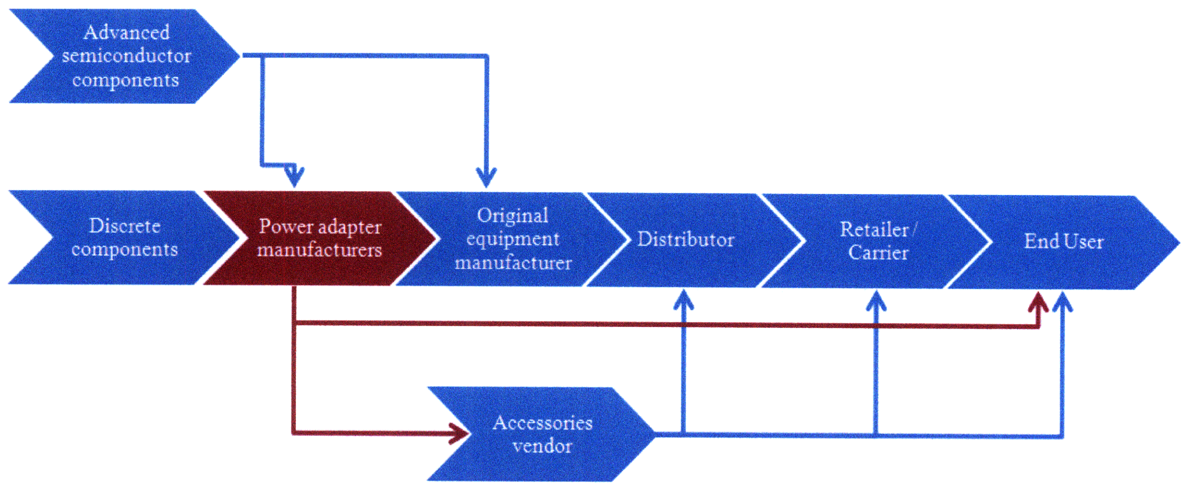

Figure 10: Value chain for external power supply products

- **Discrete component suppliers:** Discrete component suppliers design and manufacture a wide range of passive and semiconductor-based components that are used to create electronics. Example products include resistors, capacitors, inductors, MOSFET transistors, programmable integrated circuits, processors, memory, and communication chips. A typical electronic product incorporates hundreds of different components from a wide range of suppliers.

  If the end product is low volume the components will flow through a parts distributor. These distributors are a primary distribution channel during the design phase and are often the dominant suppliers if the number of products being assembled is less than 10,000 units.

  Examples component suppliers include: 3M, Vishay, Kemet, Magnetics, and Murata.

- **Advanced semiconductor components:** The advanced semiconductor component suppliers typically design and produce application specific semiconductor products. Application specific integrated circuits (ASIC) are used in a wide variety of high volume electronic products in order to shrink form factors, enable new functionality, reduce power consumption, and/or improve performance. They are found in virtually all consumer electronic devices. An ASIC might be a specialized digital processor, an analog voltage regulator, or a mixed signal radio frequency chipset.

  The design and production of the advanced semiconductor products requires a significant R&D investment along with a high level of engineering and manufacturing expertise. Modern designs cost in excess of $30M and thus investments are treated cautiously: companies look for strong market validation in advance of committing to a new product development cycle (Takahashi, 2008). These companies often work closely or collaboratively with OEM system integrators to design new products. Companies include Texas Instruments, National Semiconductor, Maxim Semiconductor, Linear Technologies, and Qualcomm.

- **Power supply manufacturers:** Power supply companies design power supplies for general purpose use or to the specifications of customers. They are vertically integrated from the design phase through manufacturing. Some of the larger players, such as Delta Electronics, have vertically integrated into the component design and manufacturing level. The major suppliers compete based on economies of scale and operating efficiency. There are several categories of power supply manufacturers (Cambridge Startegic Management Group, 2007):

- **Integrated**: These companies produce power supplies which represent a small portion of their overall business. They are typically companies that believe power supply production is a good strategic fit with their main lines of business. Examples: Lite-On and Flextronics.
- **High volume specialist:** These companies produce a limited variety of power supplies, but each one is intended to be suitable for numerous applications. A USB charger is a prototypical product for this type of company. Examples: Friwo and Phihong.
- **Custom product specialist:** These companies create custom power supplies for specialized applications or products. The requirements for these applications are atypical and require advanced engineering capability. The 200W power adapter for the Xbox360 gaming console is a good example of a product produce by a power supply specialist. Example: Delta Electronics.

- **Original equipment manufacturers:** Original equipment manufacturers and their suppliers are the largest buyers of power supplies in the world. Virtually every electronic product comes bundled with a power adapter, complements of the OEM (US Department of Energy, 2006).

  OEM's are known for strong product development expertise along with robust marketing and branding capability. Forward integration is the theme. Most have moved away from manufacturing in the last 10 years (Coker, 2004) and some have established a retail presence. Examples include Sony, Nokia, and Apple.

  It is important to take note of their suppliers because they are responsible for several important industry changes.

  - **Original design manufacturers:** Original design manufacturers design and manufacture original products for OEMs. Therefore, they do not brand or market to consumers. They are typically reverse-integrated into the supply chain meaning they handle their own component logistics while also manufacturing subassemblies, subsystems, and occasionally components.

    They are capable of new product design but typically shy away from making radical platform changes, leaving such work to the OEMs. While an OEM is unlikely to devise and develop new platform technologies, they are capable of iterating on technology platforms once they have been established.

    Example ODMs include Quanta, Asustek, and Lite-On. Lite-On, mentioned as a top supplier of power supplies, has vertically integrated itself into the design and production of power supplies.

  - **Engineering manufacturing services:** EMS' are similar to ODMs in that they manufacture products for OEMs. But, the designs are not original; they build them to the specifications of their OEM customers. They perform design for manufacturing work such as setting up injection molding machines, part picking and placing machines, reflow soldering ovens and human assembly lines.

EMS' integrate backward in the supply chain in order to reduce cost. An EMS competes by establishing itself as a dependable, high quality, low cost supplier. They make massive capital investments in factories and aggregate volume from OEMs in order to drive down cost. Companies include Foxconn, Flextronics and Jabil.

- **Accessories companies**: Accessory companies sell power supply products that complement the electronic devices sold by the OEMs. These companies have strong competence in sourcing, marketing and distribution but have little internal engineering capability. Thus, they are dependent on their suppliers to provide them electronic products. They sell products through retailers, distributors, and directly to consumers.
- **Distributors**: Distributors manage shuttle product from the end of the manufacturing lines to the point of sale. Distributors differentiate by offering services such as inventory management, product packaging, accessories bundling, return logistics, and end customer support. Their participation in the accessories market, which includes power products, has led some of these companies to develop power supply design capabilities. An example company is Superior Communications.
- **Retailers / Carriers:** Electronic devices and their associated power products are available to consumers through online retailers, brick-and-mortar retailers, and cellular carriers. Both online and box retailers offer a wide range of products and accessories ranging from media players to flat panel TV's and everything outside and in-between those products . Carriers have a small presence in most electronics categories, but are the dominant volume channel for cellular phones. Carriers typically sell their handsets at subsidized rates in order to generate subscription revenue that is based on their customer's usage of cellular minutes.
- **End Users**: End users are provided the majority of power products for no cost, as part of an electronic device bundle. In the instance that a customer is interested in purchasing an adapter, they have a wide range of branded and unbranded options that are available through a wide range of channels. Customers typically make purchasing decisions based on convenience and flexibility (e.g. customer loses or forgets power adapter while traveling).

Launching a product: How the value chain cooperates

In order to understand the interactions between various players in the value chain, it is useful to consider the product development cycle from design through launch.

The design of a power supply product is commonly linked to the development of a new product or the prior existence of another product. It is atypical for users to purchase a power supply for the sake of owning one, unless it is being used for laboratory purposes. Thus the design of a power supply must be considered within the context of a complete product development process. For simplicity, considered first is the product development cycle for a mobile phone:

New product development cycle: cellular phone		
Task	Lead	Secondary
Product definition	OEM	ODM, EMS, Discrete and semiconductor component suppliers
Product design	OEM or ODM	Discrete and semiconductor component suppliers
➢ Power system specification	OEM or ODM	Semiconductor component supplier, power supply manufacturer
➢ Power management system	Semiconductor component supplier	
Product testing and verification	OEM or ODM	
Manufacturer qualification	OEM or ODM	ODM or EMS
Final component sourcing	ODM or EMS	Discrete and semiconductor component suppliers
➢ Supplier selection	ODM or EMS	Power supply manufacturer
➢ Power supply design	Power supply manufacturer	Discrete and semiconductor component suppliers
➢ Verification and testing	Power supply manufacturer	
➢ Production and quality assurance	Power supply manufacturer	Discrete and semiconductor component suppliers
Tooling and production	ODM or EMS	
Product auxiliaries	OEM	Retailer
Marketing / Sales	OEM / Distributor	Retailer
Fulfillment	Distributor	

Table 3: The table is an abbreviated list of activities that take place during the product development process. The tasks / activities that are relevant to the power system are highlighted in green.

The tasks and activities relevant to the power system are highlighted in the above table and described below. The others are beyond the scope of this thesis but are described in detail in various books and publications.

- **Power system specification:** The OEMs marketing organization produces a marketing requirements document for the overall mobile phone which is then passed along to the engineering team. The OEM's engineering organization, along with various suppliers, iterates with the marketing team until an achievable specification is created.

The completed phone's various features and subsystems, each have individual power requirements from which a power system specification can be produced[3]. If the OEM intends to use a standard power solution, the design and features of the phone might have to be adjusted to meet the capabilities of the standard power adapter.

The specification is passed to a semiconductor component supplier, who will be responsible for the creation of the phone's internal power management system, and also passed to the power supply manufacturer who will provide the external power adapter.

- **Power management system:** The power management system is important from the perspective of the external power supply manufacturer because it is the interface between the supply and the rest of the phone. A company, such as Texas Instruments or Qualcomm, designs power management integrated circuits (PMIC) that are capable of routing the appropriate voltage, current, and power to the various subsystems of the phone. The front end of the power management system ultimately determines the specification of the power adapter.
- **Power supply sourcing:** After the completed mobile phone design has been passed to either an ODM or EMS for manufacturing, the process of component sourcing begins. The external power supply is among the components to be sourced and various manufacturers are approached for quotations.
- **Power supply design:** The power supply manufacturer will complete the electro-mechanical design of the power supply. The electrical design involves the production of electrical schematics, printed circuit board designs, and a bill of materials. The electrical engineering team will interface with discrete and advanced semiconductor suppliers in order produce a completed design. The component suppliers may be asked to produce custom passive or integrated components in order to meet the electrical or mechanical requirements of the specification. The mechanical engineers are responsible for enclosure design along with thermal management, which is completed in cooperation with the electrical design team as well as the component suppliers.
- **Testing and verification:** The power supply manufacturer designs and conducts analyses in order to validate that the specifications are achieved, regulatory requirements are met, and that the results are repeatable in a high volume manufacturing environment.
- **Production and quality assurance**: The power supply manufacturer sources the components for production, establishes the appropriate assembly line which generally involves automated and human inputs, and begins production. Testing procedures are implemented to ensure that only functional products leave the line.

Ultimately, the power supplies are delivered, bundled with the mobile phone, boxed, and sent on their journey toward a customer.

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[3] It is important to note, that historically power supplies are adapted to product designs: product designs are not adapted to power supplies. The reasons for this are two-fold: first, the engineers and marketing teams of OEMs were unwilling to discard features based on the limitations of a power supply. And second, from an engineering perspective, it is straightforward to create a power supply to meet products requirements, but it is very difficult to modify a product to meet a power supply's requirements. Thus, it should come as no surprise that we have tens of thousands of different power supplies.

The complete product development and launch process is simplified if the power adapter is being produced for an existing product. In an example case, an accessories vendor requests a specification from an OEM, begins the power supply sourcing process, places a purchase order, and the manufacturer delivers the power supplies.

Allocation of value in the supply chain

Depending on a power adapter's path to the end customer, the distribution of value to the players within the value chain falls very differently. The two primary paths for a power adapter reaching a consumer are bundling and aftermarket sales.

- **Bundled products:** The bundling of a power supply refers to its inclusion alongside an electronic device and is standard practice in the electronics industry. From a consumer's perspective, a bundled power adapter is expected and thus, neither retailers nor OEM's are able to charge a premium for its inclusion.

  Because consumers do not pay for the inclusion, the retailer and OEM must subsidize the cost. The cost of subsidizing the bundled power supplies is conservatively estimated to be $2B per year. As a result, the OEMs put intense pressure on suppliers to bring down the cost.

Product Category	Assumed Proportion that Shipped with EPS
Mobile Phones	100%
Cordless Phones	100%
Modems	100%
Handheld Computers	100%
LAN Equipment	100%
Notebook Computers	100%
Wi-Fi Access Points	100%
Portable Gaming Devices	100%
Small Flat Panel TVs	100%
Portable Video Players	100%
Flat Panel Monitors	80-100%
Flatbed Scanners	65-75%
Inkjet Printers	100%
Camcorders	100%
Digital Cameras	65%
Portable Audio Players	40%

Source: Darnell Group, Inc., 2005.
Note: This table represents classification of EPS as per the ENERGY STAR definition of a BC and EPS. This initial classification of products may be revised for the determination analysis, based on stakeholder comment.

Table 4: Listing of products and the percentage of those products that are shipped with a bundled power supply. Source: (US Department of Energy, 2006)

- **Aftermarket sales:** The aftermarket for power supplies includes the sales of name-brand and generic power supplies. The value is split differently for each product type.
    - In the case of name brand power supplies, the majority of absolute value is captured at two levels. On the sale of a $30 mobile phone adapter, 50% of the retail price is profit captured by the retailer and 42% is profit captured by the OEM brand. The remainder is spread throughout the value chain. Advanced semiconductor component suppliers capture a very small portion of the absolute retail price, but it is important to note the high gross margins.[4]
    - The distribution of value from the sale of $5 generic adapter is considerably different. Once again, the retailer captures the majority of value, but in this case it comes at the expense of the OEM brand. The margins for the power supply manufacturers and components suppliers tend to stay consistent.

	Per unit (dollars)			Per Year (Millions of dollars)			
Bundled	**Rev.**	**Cost**	**Net**	**Rev.**	**Cost**	**Net**	**Margin**
Retailer /Carrier	$ -	$ 1.2	$ -	$0	$2,429	($2,429)	N/A
Distributor	$ -	$ -	$ -	$0	$0	$0	10%
OEM Brand	$ -	$ 1.2	$ -	$0	$2,429	($2,429)	N/A
Power Supply Mfg.	$ 2.4	$ 2.1	$ 0.3	$4,859	$4,227	$632	13%
Basic Components	$ 2.1	$ 1.8	$ 0.3	$4,227	$3,720	$507	12%
Adv. Components	$ 1.8	$ 0.6	$ 1.3	$3,720	$1,116	$2,604	70%

	Per unit (dollars)			Per Year (Millions of dollars)			
Aftermarket branded	**Rev.**	**Cost**	**Net**	**Rev.**	**Cost**	**Net**	**Margin**
Retailer /Carrier	$ 29.9	$ 12.0	$ 17.9	$1,255	$502	$753	60%
Distributor	$ 12.0	$ 10.8	$ 1.2	$502	$452	$50	10%
OEM / Accessory brand	$ 10.8	$ 2.4	$ 8.3	$452	$101	$351	78%
Power Supply Mfg.	$ 2.4	$ 2.1	$ 0.3	$101	$88	$13	13%
Basic Components	$ 2.1	$ 1.8	$ 0.3	$88	$77	$11	12%
Adv. Components	$ 1.8	$ 0.6	$ 1.3	$77	$23	$54	70%

[4] Allocation of value is based on interviews with OEM accessory product managers and major retailers.

	Per unit (dollars)			Per year (Millions of dollars)			
Aftermarket generic	**Rev.**	**Cost**	**Net**	**Rev.**	**Cost**	**Net**	**Margin**
Retailer /Carrier	$ 6.7	$ 2.7	$ 4.0	$281	$112	$169	60%
Distributor	$ 2.7	$ 2.4	$ 0.3	$112	$101	$11	10%
OEM Brand			$ -	$0	$0	$0	0%
Power Supply Mfg.	$ 2.4	$ 2.1	$ 0.3	$101	$88	$13	13%
Basic Components	$ 2.1	$ 1.8	$ 0.3	$88	$77	$11	12%
Adv. Components	$ 1.8	$ 0.6	$ 1.3	$77	$23	$54	70%

Table 5: The distribution of value from the sale of power adapters. The table breaks down the distribution of value based on whether the supply is bundled, aftermarket branded, or aftermarket generic. Figures are based on a per unit and per annum basis. [5]

	Annual Cost (Millions of dollars)					
Net	**Rev.**	**Cost**	**Net**	**Margin**	**Performance**	**Outlook**
Retailer /Carrier	$1,536	$3,044	($1,507)	N/A	Poor	Negative
Distributor	$615	$553	$61	10%	Marginal	Negative
OEM Brand	$452	$2,531	($2,079)	N/A	Poor	Negative
Power Supply Mfg.	$5,061	$4,403	$658	13%	Marginal	Negative
Basic Components	$4,403	$3,875	$528	12%	Marginal	Negative
Adv. Components	$3,875	$1,162	$2,712	70%	Good	Negative

Table 6: The annual, aggregate distribution of value based on the sale external power supplies through all channels.[6]

The net distribution of value can be calculated by combining the sales of bundled, aftermarket branded, and aftermarket generic power supplies. From this analysis, it is estimated that the entire industry earns several hundred million dollars for building and selling roughly two billion, relatively sophisticated electronic devices each year. Two segments of the value chain lose in excess of one billion dollars per year. The industry is unhealthy.

The losses by various players are surprising to many whom believe that power adapters are a high margin source of revenue for OEM brands and retailers. Purchasing a $30 power supply and knowing that they cost $1.10 to manufacture might lead one to draw that conclusion. And yes, considered from a narrow perspective, power supplies are high margin. But when one considers the cost impact of bundled adapters the picture is much different.

There are some exceptions, notably the Apple 30 pin connector which has created an aftermarket worth greater than $2B per year (Johnson, 2008). But, that aftermarket is not driven by power adapter sales; rather, it is driven by the sale of a very wide range of accessory products like radios and FM transmitters that incorporate the connector into their product design. It is atypical for a small set of devices, like the Apple iPod and iPhone, to have such a large surrounding market.

[5] The distribution of sales was assumed to be 96% bundled and 4% aftermarket. The aftermarket volume was split 50 /50 between branded and generic versions. (Cambridge Startegic Management Group, 2007)

Today's deteriorating market conditions

The market as described is expected to experience further deterioration based on a number of market trends that will increase competition and reduce opportunities for differentiation. The trends and their impact on the value chain are summarized below:

Market trend	Impact	Explanation
Vertical integration	Negative	Increased competition
Decline of brand name power solutions	Negative	Decreased opportunity for differentiation
Commoditization of semiconductor products	Negative	Declining prices
Regulations	Negative	Decreased opportunity for differentiation
Standardization	Negative	Decreased opportunity for differentiation

Table 7: The impact of individual market trends on the health of the overall market.

- **Vertical integration:** The supply chain for consumer electronics is becoming increasingly competitive and convoluted as formerly specialized market players are taking steps towards vertical integration (Ojo, 2005). The most impactful integration strategies, as it relates to the market for power supplies, are those being executed by the engineering manufacturing services providers and original design manufacturers.

		Value chain segment			
		Advanced component supplier	Component supplier	Power supply manufacturer	Engineering manufacturing services
Functions traditionally performed by the:	Advanced component supplier			↑↑↑↑↑	↑↑↑↑↑
	Component supplier			↑↑↑↑↑	↑↑↑↑↑
	Power supply manufacturer				↑↑↑↑↑
	EMS provider		↓↓↓↓↓		
	ODM				↓↓↓↓↓
	OEM	↓↓↓↓↓			↓↓↓↓↓
	Accessories Vendor				
	Distributor				
	Retailers				

Table 8: Shows the direction of integration for the back end of the value chain relative to the previously defined boundaries. The value chain segment is listed along the horizontal axis and the traditional functions are listed on the vertical axis. Blue boxes correlate baseline functions with the value chain segment. Green boxes functions that are being integrated into a particular value chain segment.

Functions traditionally performed by the:	Value chain segment: ODM	OEM	Accessories Vendor	Distributor	Retailers
Advanced component supplier	↑↑↑↑↑				
Component supplier	↑↑↑↑↑				
Power supply manufacturer	↑↑↑↑↑				
EMS provider	↑↑↑↑↑				
ODM					
OEM	↓↓↓↓↓			↑↑↑↑↑	
Accessories Vendor		↓↓↓↓↓			↑↑↑↑↑
Distributor		↓↓↓↓↓			
Retailers		↓↓↓↓↓			

Table 9: Shows the direction of integration for the front end of the value chain relative to the previously defined boundaries. The value chain segment is listed along the horizontal axis and the traditional functions are listed on the vertical axis. Blue boxes correlate baseline functions with the value chain segment. Green boxes functions that are being integrated into a particular value chain segment.

ODMs and EMS' are pursuing vertical integration strategies that take them forward and backward in the supply chain. ODMs and EMS' have been very successful in their execution of vertical integration strategies and have grown rapidly as a result. Their movement into design engineering squeezes the OEMs on the front end while their movement into sub-assemblies and components pressures power supply manufacturers and component suppliers on the back end of the supply chain.

Top Ten ODMs: Company Name	2007 Annual Revenue(000)	2006 Annual Revenue (000)	Change	Top Ten EMS: Company Name	2007 Annual Revenue (000)	2006 Annual Revenue (000)	Change
Quanta	$23,259	$14,170	64%	Foxconn	$54,706	$39,253	39%
Asustek	$23,033	$17,348	33%	Flextronics	$33,346	$28,876	15%
Compal	$13,634	$9,410	45%	Jabil	$12,432	$11,087	12%
Wistron	$8,658	$6,603	31%	Sanmina-SCI	$10,138	$10,872	-7%
TPV	$8,419	$7,238	16%	Celestica	$8,069	$8,811	-8%
Inventec	$7,191	$7,167	0%	Elcoteq	$5,740	$5,139	11%
Lite-On	$5,760	$5,048	14%	Benchmark	$2,915	$2,907	0%
Innolux	$4,806	$3,207	50%	Venture	$2,617	$1,971	33%
Mitac Intl	$2,558	$2,540	1%	USI	$2,046	$1,676	22%
Inventec App	$2,378	$3,389	-30%	Plexus	$1,624	$1,513	7%
Total Top 10	**$99,696**	**$76,120**	31%	**Total Top 10**	**$133,633**	**$112,105**	19%

Table 10: Growth of top 10 ODM and EMS organizations from 2006 to 2007 **(EMS Now - iSuppli, 2007)**

- **Backward pressure:** The backward integration of ODMs and EMS' is bringing new multi-billion dollar companies, like Flextronics, into the power supply manufacturing business (Mankika, 2007). The moves are increasing competition, but the impact is moderated by the fact that the moves are acquisition based. This reassigns capacity from one entity to the next, without increasing industry wide capacity.

   - **Forward pressure:** The forward integrations impacts are more powerful, though they are indirect. The moves are significantly increasing competition in the broadly defined, and already competitive, consumer electronic market. The competitive pressure by OEMs on one another, combined with the pressure from increasingly capable ODMs and EMS' is leading them to take more aggressive views on new technologies. Power supplies, once considered the engineering backwater of consumer product design, have been flagged as opportunities for innovation and differentiation.

- **Decline of OEM brand name adapters:** Retailers carry an increasing number of generic power supplies rather than the brand-name versions. This has occurred for primary two reasons: first, the engineering knowledge required to produce power supplies has become more widespread. The growing number of capable suppliers and distributors, who represent newly capable suppliers, has made it easier for retailers to directly access generic power solutions. Second, many of today's consumers now understand that generic power adapters can be used interchangeably with brand name adapters. Because there is little or no perceptible difference between the branded and generic versions, most consumers prefer the low cost generics. According to an executive at one OEM, the business for OEM branded aftermarket power products has been "destroyed."

  When selling generics, the retailers earn approximately the same margins on a percentage basis, but the absolute profits are lower. The shift to generic power products is motivated in part by retailers' need to stay price competitive with online channels that primarily offer low cost generic solutions.

- **Advanced semiconductor components commoditized:** The most advanced component of a power supply is the DC to DC converter or switching regulator. Inside a power adapter, a small integrated circuit orchestrates the conversion of one voltage to another. Additionally, it provides protection against unsafe operating modes such as over current, over voltage, or high temperatures. These product lines are high margin, but have become less profitable in recent years. Linear Technologies, one of the leaders in integrated power products and whose profit margins exceed 80%, made a strategic decision to exit large portions of the consumer electronics market in order to avoid participation what they believe is now a commodity segment.[7]

  In another example of vertical integration, Delta Electronics, the leading power adapter manufacturer, has made a strategic decision to enter the power semiconductor business. They have begun designing and producing voltage regulators and various other DC to DC conversion products.

- **Regulations:** The amount of power consumed and waste generated by external power supplies has captured the attention of regulators and lawmakers in the United States and abroad. China has taken a significant step in reducing electronics waste by requiring that small electronic devices standardize around the USB power interface (Conner, 2008). And currently, the United States Department of Energy is evaluating whether to propose

[7] Based on interview with product line manager.

legislation aimed at improving the energy efficiency of power supplies. Any regulation is expected to require that manufacturers create higher energy efficiency products.

State	Date Standard Takes Effect	Share of U.S. Population in 2005
California	Jan. 1, 2007 and July 1, 2007*	12.2%
Oregon	Jan. 1, 2007	1.2%
Arizona	Jan. 1, 2008	2.0%
Massachusetts	Jan. 1, 2008	2.2%
New York	Jan. 1, 2008	6.5%
Rhode Island	Jan. 1, 2008	0.4%
Vermont	Jan. 1, 2008	0.2%
Washington	Jan. 1, 2008	2.1%
Total		26.8%

** The California standard for EPS used with notebook computers, mobile phones, printers, printer servers, scanners, PDAs, and digital cameras will become effective on January 1, 2007. The standard for EPS used with all other products will become effective on July 1, 2007.*
Sources: StateScape and State legislatures, 2005-2006; U.S. Census Bureau, 2005.

Table 11: Enforcement date of energy star standards for external power supplies. Source: **(US Department of Energy, 2006)**

- **Standardization -** Today's assortment of non-standard power products is attributable to the wide ranging voltage, current and power requirements of electronic devices. With today's technology, it is impossible to build a laptop that consumes the same amount of power as a Bluetooth headset (>1 watt). And, it is not practical to build a Bluetooth headset that uses the same amount of power as a laptop (>65W).

  That said, companies are making headway towards a piecewise standardization of the market. The most active efforts are taking place at lower power levels (e.g. small mobile devices). RIM, Motorola, and Palm are companies that presently ship all of their products with a USB standard charging interface. Recently, a number of major handset OEMs, including Nokia, Samsung, Motorola, Sony Ericsson and LG made a decision to standardize their power adapters around the USB standard interface (Meyer, 2007).

Product and technology trends

As with the market trends, the product and technology trends are neutral to negative. Power supplies have become progressively smaller, faster, more efficient, and smarter due largely to government regulation. Energy Star is responsible for a widely used set of voluntary guidelines that establish benchmark efficiencies for power products today. In the United States, California law requires compliance with Energy Star guidelines (US Department of Energy, 2006).

These improvements has made power supplies more expensive to produce, but has not substantially increased their value to end users. This hurts the entire value chain, besides the end users. As long as the function and use-model of a power supply is unchanged, consumers will be reluctant to pay for incremental improvements.

- **Energy efficiency:** In the last ten years, a shift from linear to switch-mode power architectures resulted in a significant, 20 to 30%, improvement in the average efficiency of power supply products. Switching technology has the further benefit of reducing the "no-load" power consumption of a supply that is plugged into a wall socket, but is not terminated at an end device. Today, the switch-mode designs are dominant and represent 90% of the unit volume (Cambridge Startegic Management Group, 2007).

  Most consumers are oblivious to the efficiency of power supplies and rarely, if ever, make electronics purchasing decisions based on the efficiency of the bundled power adapter.

- **Reduced charge time:** As everyday life becomes more mobile and connected, consumers have started to expect uninterrupted access to the functions, features, and content provided by their portable electronic devices. System level, semiconductor, component, and power companies responded with innovative technologies that enabled faster charging.

- **Form factor reductions:** Smaller form factors of power supplies improve the portability of electronic devices, which is important to end-users. The previously introduced switch-mode power supply technology enables the smaller form factors.

- **"Smart charging":** Newer battery charge systems may utilize a reconfigurable power architecture and communication link in order to achieve better performance in several dimensions.

  - **Improved average efficiency:** The majority of power supplies have a maximum efficiency operating point that correlates with the maximum rated output power; this is an intentional design characteristic that minimizes absolute power loss. To achieve a co-location of maximum power and maximum efficiency points, designers allow the efficiency to suffer, typically by 10-15%, at lower output power (Low, 2009). The trade-off is inherent in the design of traditional supplies. The newer systems enabling dynamic optimization of the power supply architecture to achieve maximum efficiency across all operating points.

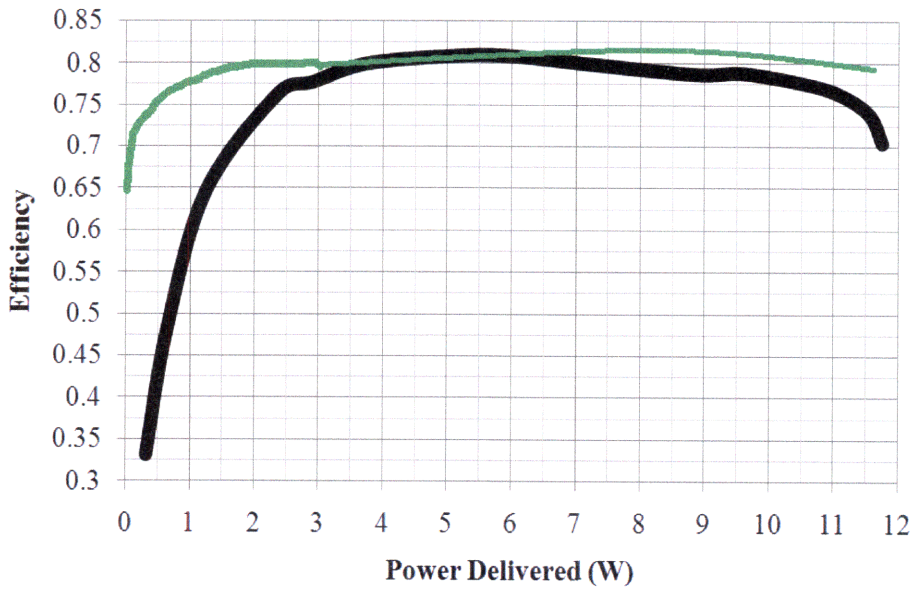


Figure 11: The black line is the energy efficiency curve of a switching power supply across a range of power outputs, in this case the supply is rated for roughly 10Watts. The power supply can be expected to operate across the full range of output power. Note the efficiency is lower at low power. The green line is the efficiency of the same supply with "smart" charging functionality. In this case, the supply has the ability to reconfigure itself depending on power requirements. Source: **(WiPower Inc., 2009)**

- **Battery life extension**: Typical battery products last through approximately 300 charge / discharge cycles at which point the battery should be replaced (Battery University, 2006). Depending on the management of the charge and discharge cycles, that number can be higher or lower. Thus, engineers use these communication channels to improve the longevity of a battery.
- **Safety**: Counterfeit battery and power supply products have resulted in the injury and death of consumers. Low cost battery and power supply products, typically produced in East Asia, are often of lower quality than their OEM counterparts. By adding communication, preferably encrypted, between batteries and power supply products, the level of technical complexity becomes difficult to replicate. Counterfeit batteries and power supplies will not work without the communication channel, which reduces the chance that end-users will be subject to harm (Vanzwol, 2009).

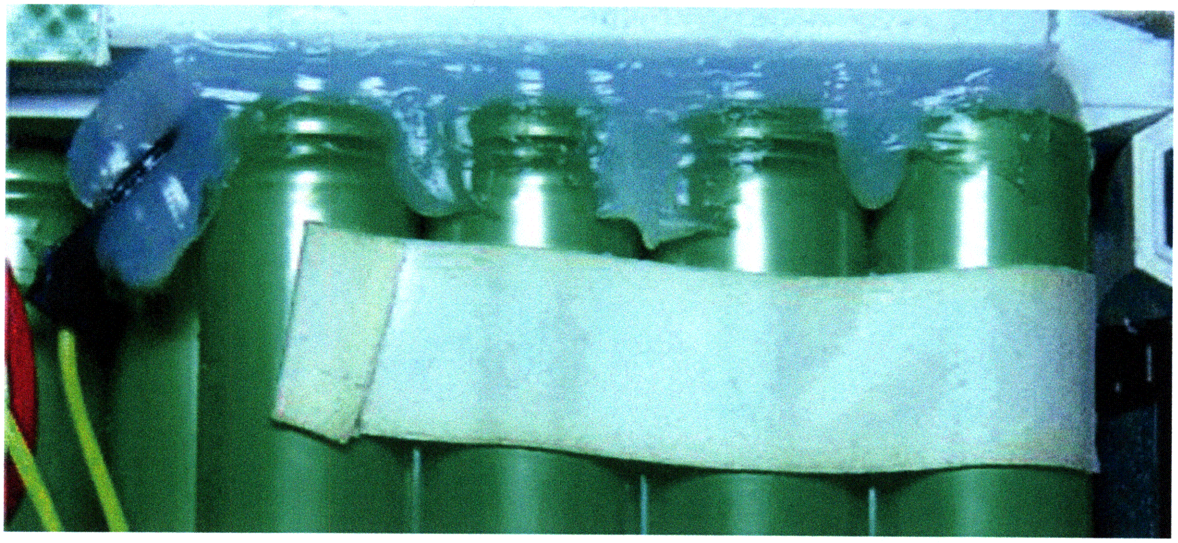


Figure 12: (Vanzwol, 2009): Counterfeit battery. A silicon compound is improperly blocking the vents of the battery cells. In the event of overheating these batteries are likely to explode. Smart charging that involves encrypted communication between the battery pack and the charger could prevent unsophisticated counterfeit batteries from a) charging and b) exposing consumers to danger.

- **Increasing complexity:** It is relatively straightforward to create an old-model power supply, but such products are falling out of favor. Demand for safer, smaller, faster, smarter and more efficient power supplies has increased the complexity of modern power products. Today's power supply designers must know how to implement the newer, more complicated switching designs and smart charging features in order to meet the demands of customers and government regulators. The trend toward more sophisticated designs is expected to continue pending government regulations that mandate minimum efficiency thresholds.

Pathways to recovery

The market trends are negative and the product trends are not ground breaking. Neither the market nor the product trajectories offer hope for a radical turn around. The industry has two basic options that can improve its fortunes 1) accept standardization or 2) find ways to increase differentiation.

- Standardization is difficult to achieve, but if it takes place, it would greatly benefit OEMs and Retailers by allowing them to remove the power supply from the product bundle. This will save billions of dollars a year for OEMs and Retailers, but it would also result in an equal amount of lost revenue for power supply manufacturers and their component suppliers.
- Increased differentiation is a viable and more likely option, because true standardization is near impossible for technology related reasons. The differentiation can be technology or marketing driven, but given the declining success of branded power products, technology based differentiation is likely required. The incremental innovations described in the previous section are insufficient which creates an opportunity for wireless power technology.

Chapter 4: Technology and intellectual property strategy

Successful commercialization of wireless power, or a similar technology, demands a carefully calculated and closely linked intellectual property and technology strategy. The reasons for this are twofold: first, there is a high level of technical risk related to creating wireless power systems, as evidenced by scores of failed attempts, befuddled engineers and bankrupt wireless power companies. And second, the intellectually property landscape is dense, by nature of the fact that numerous engineers and organizations have attempted to design and build commercially viable wireless power systems for the last 100 years.

The ideal strategy should mitigate technical risk, control cash burn, protect a company's freedom to operate, create barriers to entry, and ideally obstruct the current and/or planned activities of competitive organizations.

Choosing a technology direction – Technical approaches

The beginning of technology strategy depends on an understanding of the technology approaches and their respective advantages, disadvantages, capabilities, and limitations. Without carefully considering the options, a startup company risks committing significant time and financial resources to dead-end approaches.

To begin the process of selecting a technological approach, the marketing team defines the product and prioritizes the desired features. The various approaches can be ranked on their ability to meet marketing requirements. It is unlikely for any particular approach to be a perfect fit: they will all require some level of engineering investment in order to finesse the technology into a form that is acceptable. If that is not practical, the engineering team can work with the marketing team to arrive at compromises.

The various wireless power technical approaches are evaluated below:

	Characteristic	Rank	Coreless induction	Induction	RF Harvesting	Directed RF	Resonant
Marketing	Safe	1	Green	Green	Green	Red	Green
	Low cost	2	Orange	Green	Orange	Orange	Red
	Small form factor	3	Green	Red	Green	Orange	Orange
	Fast charging	4	Green	Green	Red	Green	Green
	Powers multiple devices	5	Orange	Orange	Orange	Red	Orange
	Position agnostic	6	Orange	Orange	Orange	Orange	Orange
Engineering	Mass production compatible	1	Orange	Green	Orange	Red	Red
	Passes regulatory testing	2	Orange	Green	Orange	Red	Red
	Low temperature rise	3	Orange	Green	Green	Orange	Orange
	High power transfer	4	Green	Green	Red	Green	Orange

Table 12: Commonly discussed marketing and engineering requirements for each technological approach. A green box indicates that a solution meets a requirement. An orange box indicates that the solution falls short of a requirement, but that the requirement is in reach with sufficient innovation. A red box indicates an extreme gap between present capabilities and the requirements.

Based on the failures of previous engineers and organizations, it is not surprising to see that none of the baseline technology approaches satisfy all of the requirements. A two step analysis allows the determination of the most suitable approach. First, an evaluation is made concerning whether the baseline approach is capable of meeting requirements. And second, if the baseline approach falls short, the team assesses the magnitude of technical risk involved with meeting the specifications.

The above table shows that coreless inductive charging systems show the most promise: there are no extreme gaps between the technology's present capabilities and the market's requirements. This happens to be consistent with the conclusion of most market players that have selected this approach over the alternatives. It does not meet all requirements, but achieving them is conceivable based on the engineering team's evaluation.

Framing the intellectual property landscape and formulating a strategy

After a technology path has been selected, a team must devise an intellectual property strategy. This requires identifying, organizing, and analyzing relevant patents and journals in order to assess:

- **Freedom to operate:** A company will often encounter patents that describe inventions similar to the intended product. To prevent possible lawsuits, it is important that these patents be identified early and analyzed by engineers in conjunction with legal counsel, in order to determine whether conflicts exist.

  Should a conflict arise, the engineering team is well positioned to determine whether work-around solutions are viable. And if not, the management team can engage the holder of the blocking patents in order to seek a technology license.

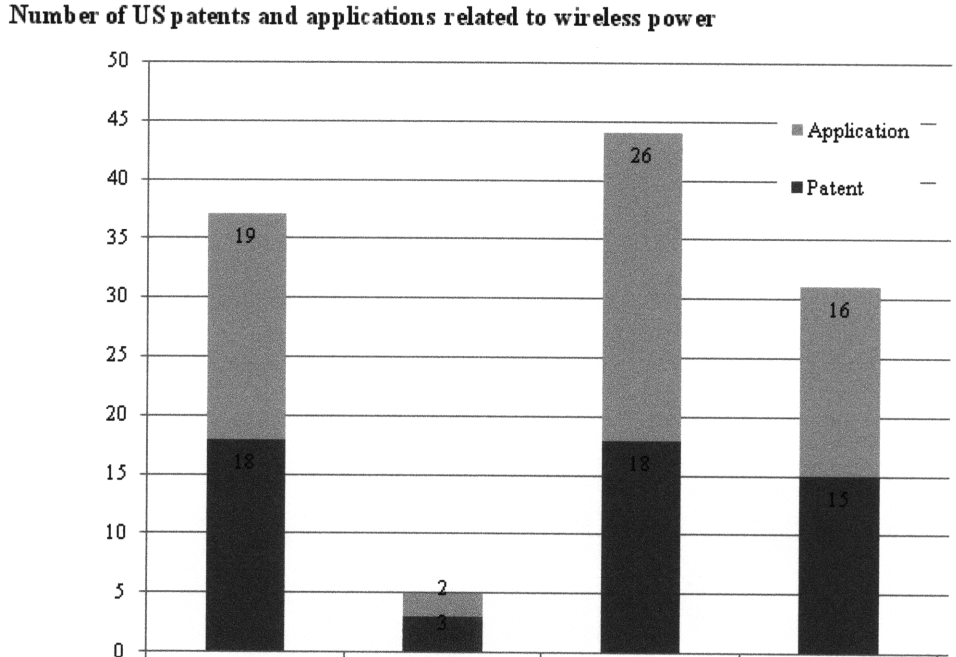
- **Defensive patent opportunities:** A key component of intellectual strategy is building a defendable position. Start-up technology companies should identify areas where little innovation has taken place because they provide a good foundation for building a defensible position. In the green-field technology area, a larger percentage of the innovations are eligible for patent protection.

- **Offensive patent opportunities:** Offensive patent strategy involves the identification of areas that have been overlooked by competitors, and the subsequent filing of patents in those areas in order to obstruct their ability to achieve intended objectives.

Case example: Formulating IP strategy for wireless power technology providers

In the wireless power landscape, the intellectual property can be grouped by the previously introduced technology categories which include coreless induction, traditional induction, RF harvesting, directed RF / laser, and resonant wave coupling. For the most part, the patents within each category do not overlap.

Coreless inductive charging systems were identified as the most promising technical solution and are thus the focus of this analysis. Specific to these inductive solutions, there are four technology centric classifications of the intellectual property: communication systems, control systems, power electronics, and magnetic coupling structures. A typical inductive charging system draws from intellectual property in ***all*** four categories (e.g. a magnetic coupling structure + power electronics + control system + communication system = wireless power system).



	Electromagnetic	Power Electronics	Controls	Communication
Application	19	2	26	16
Patent	18	3	18	15

Figure 13: Patent activity in the wireless power intellectual property landscape, subdivided by technical classifications **(WiPower Inc., Ryan Tseng, 2009).**[8]

- **Communication (15 patents, 16 applications)** (WiPower Inc., Ryan Tseng, 2009, p. 8): There is a high level of patent activity at this level and while there may be an opportunity for incremental innovation related to the communication system, it will be difficult to navigate the landscape.
  - Difficult to establish a strong defensive position or make offensive patent filings.
  - Freedom to operate should be closely evaluated
  - There are a large number of players at this level, so there are licensing options. Choosing the right license will be difficult because there are many overlapping patents and applications (e.g. WO 2007/013726 A1 & US 6,683,438 B2).
- **Control (18 patents, 26 applications)** (WiPower Inc., Ryan Tseng, 2009, p. 8): There is also a high level of activity at the control system level, but this space is more difficult to navigate than the communication space because there is less design flexibility at the control level.
  - Difficult to establish a strong defensive position or make offensive patent filings.
  - Freedom to operate should be closely evaluated

[8] The analysis is based on the review of over 100 IEEE journals, screening of 500+ patents and applications, analysis of 120 of the most relevant patents and applications, and a detailed review of the office actions and transaction history of 40 patents and applications.

    - The high level of IP fragmentation suggests several licensing opportunities, but as before, selecting the right license will be difficult because there are many overlapping patents and applications (e.g. US 2008/0200119 & US 6,683,438 B2).

- **Power electronics (3 patents, 2 applications)** (WiPower Inc., Ryan Tseng, 2009, p. 8)**:** Closely linked with the electromagnetic elements, the power electronic system is a fundamental element of the design. Interestingly there is almost no patent activity on this aspect of the design. The subject matters appear to have been overlooked or intentionally ignored by the companies that have attempted to build wireless power systems.

  This suggests there are attractive patenting opportunities, made strong by the fact that there are few viable power electronic architectures. Patents would seemingly provide significant differentiation and provide an opportunity for very strong, sustainable IP protection.

    - Strong defensive opportunity
    - Good opportunity to make offensive patent filings
    - Few concerns regarding freedom to operate

- **Electromagnetics (18 patents, 19 applications)** (WiPower Inc., Ryan Tseng, 2009, p. 8): There are a large number of patent applications and filings. There are very few ways to create the coils and materials, and the key solutions are part of the public domain. Therefore patents at this level are weak.

    - Difficult to establish a strong defensive position or make offensive patent filings.
    - Freedom to operate should be closely evaluated

	Freedom to operate	Defensive position	Offensive opportunity
Communications	Watch closely	Unlikely	Unlikely
Controls	Watch closely	Unlikely	Unlikely
Power electronics	Yes	Likely	Likely
Electromagnetics	Yes	Unlikely	Unlikely

Table 13: Assessment of freedom to operate, defensive opportunities, and offensive opportunities in the intellectual property landscape for wireless power technology.

Of the areas considered, power electronics provides the strongest opportunity for a company to begin fortifying an intellectual property position. There are offensive and defensive aspects to the focus on the relatively unaddressed area of power electronics. From an offensive perspective, power electronics must be incorporated into the final design, and today's power electronic solutions are inadequate for wireless power applications. Thus, a company with the foresight to effectively fortify a position in power electronics will have the capability to obstruct progress of existing competitors. From a defensive perspective, a strong patent position in power electronics creates both a psychological deterrence and an option for legal action to prevent new competition from entering the market.

The high level of patent activity along other dimensions of the wireless power systems suggests that a company must be diligent about ensuring its freedom to operate. To do so, a company should participate in each of the four technology segments to anticipate and avoid the impact of offensive patent filings by competitors. Within each segment, the company can choose to file patents, or make public disclosures in order to preclude offensive patent activity.

The patent activity of various competitors is mapped below. WiPower is an organization that has filed patents in each of the four technology centric classifications in order to preserve their freedom to operate. Additionally, they have invested in the design and development of new power electronic architectures. This is expected to build a strong defensive position and possibly obstruct the future activities of their competitors.

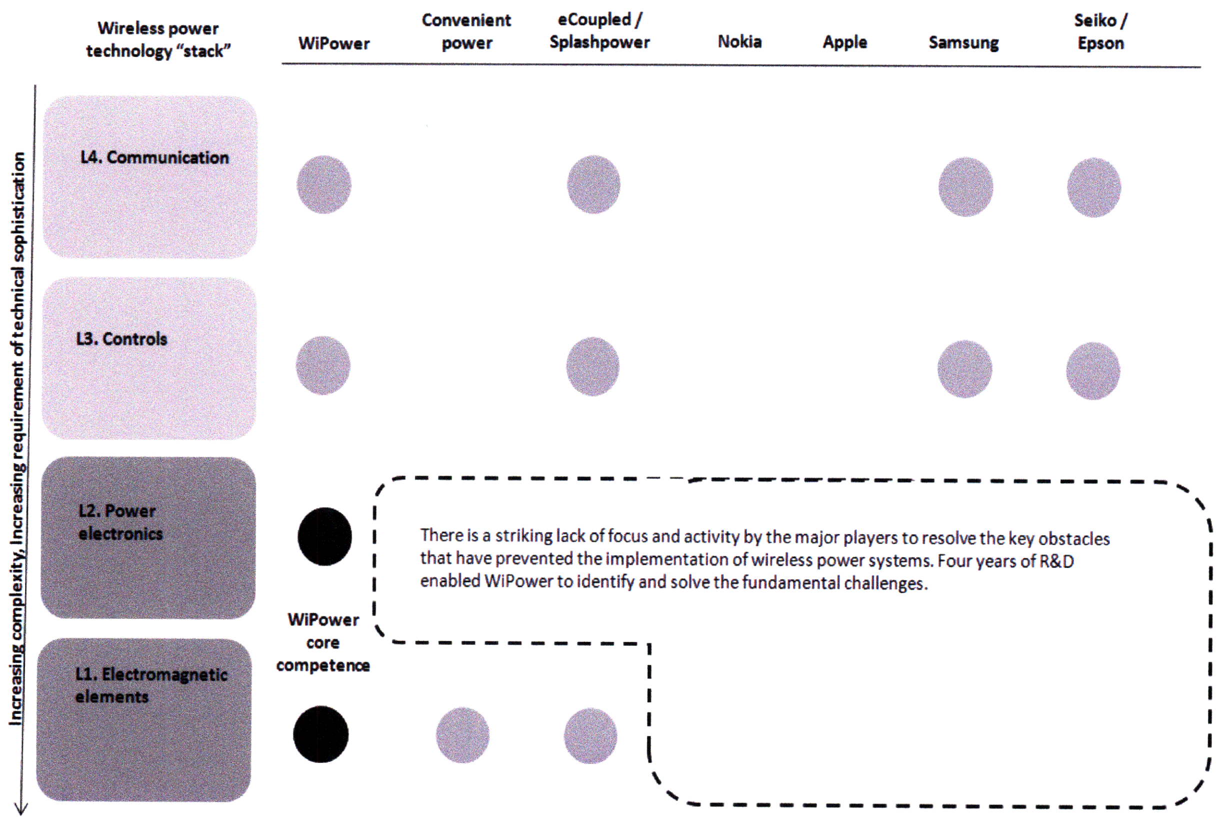


Figure 14: Map of patent activity by the major players in the wireless power industry. Dots indicated patent activity within the various subsets of wireless power technology. Source: **(WiPower Inc., Ryan Tseng, 2009)**

Other Forms of Intellectual Property

Beyond patents, there are other instantiations of intellectual property that have a high degree of value to a start-up organization and their eventual acquirers. The technology described in a patent, needs considerable work before becoming ready for commercialization. As a result, a start-up has an opportunity to build considerable institutional knowledge during the design and development of a product based on a new technology. The supporting technologies and processes developed during this time can take the form of trade secrets, a form of intellectual property that is not publically filed, but can be of considerable value. Acquiring companies need not only the core technology, but the institutional knowledge regarding its implementation.

In this vein, a wireless power company has several avenues to develop alternative forms of intellectual property:

- **Electronic design automation tools:** Electronic design tools streamline and accelerate the development of wireless power systems. They are complicated to design and difficult to replicate.
- **Functional testing and verification procedures:** Interoperability of wireless power transmission and receiving devices is dependent on the thoughtful design of verification and test procedures. The creation of these procedures requires intimate knowledge of customer requirements and technology constraints. As the number of wireless power products grows, only companies with a deep understanding of verification and test procedures will be capable of designing new, interoperable products.
- **Design for manufacturing:** Many design modifications are required to stay within the limitations of contemporary manufacturing technology. As a wireless power technology provider goes through the process of building its first products, it becomes intimately familiar with those limitations and can apply the knowledge to all future products.

Start-up centric open innovation

The combination of a technology direction and intellectual property strategy enables a start-up to begin planning and executing on a technology development plan. In many cases, a start-up will find that a large number of engineering activities must take place before a product can be sold.

In the case of the wireless power, it is highly atypical for an engineer, or small team of engineers, to have sufficient technical depth and breadth to adequately address the problems. This presents a conundrum to the start-up, which might be unable access to appreciable levels of financing due to high levels of technical risk across several dimensions. The company has a finite period of time, set by the cash burn-rate, in which it has an opportunity to solve the engineering problems. Thus, a start-up must find solutions quickly.

A start-up organization can accelerate technical progress, manage cash, and spread risk by embracing the same open-innovation principles being applied at large organizations such as PEG, IBM, Qualcomm, and Cisco (Teresko, 2004). The central principle is that a company cannot depend entirely on internal research and is better served by leveraging the capabilities of an entire ecosystem, through cooperative agreements (Vanharverbeke, 2009).

Define key IP territories and capabilities: Before engaging partner organizations in the technical development process, a start-up company must first determine strategically important IP territories and institutional capabilities. These territories and capabilities can be correlated with the expected tasks and activities which will be conducted during the technical development process. Capability permitting, any task or activity related to strategic real-estate should be kept in-house. The remainder can be passed to, and executed by the ecosystem.

The list of strategically important territories and capabilities should be narrow, which is consistent with the resources available to a start-up organization. The objective is to maximize the effect of a minimal investment by encouraging involvement of market participants with similarly aligned incentives.

In the case of wireless power, the technology provider should consider power electronics development a strategic activity because of the attractive, accompanying intellectual property opportunities, both offensive and defensive. Power electronics has the further attractive characteristic of being technically complex as it relates to wireless power and there are few individuals or organizations with the capability to produce the necessary innovations.

Electromagnetics should also be considered strategic due to the lack of individuals and organizations with the capability to produce the necessary innovations.

Identify partner organizations: A clear picture of which tasks to perform in-house and which to outsource enables the start-up to identity the best partner organizations for collaboration. For the strategy to be effective for the start-up, the prospective partners must have the appropriate technical specialization.

Partnerships can be formed with standards bodies, consortiums, universities, government labs, contractors, or other start-ups. The ideal partners should be members of the value chain that serves the start-up's intended end customers. Early development of reference-able partners will help improve the credibility, and smooth the sales process of a young start-up entering a new market[9].

Returning to the example of a wireless power system, there are six areas that require deep technical knowledge, of which two are considered strategically important. For the remaining technical areas, the segments of the value chain with the appropriate competence have been identified and can be approached for collaborative technical development.

		Value chain segment					
		Electro-magnetics	Power electronics	Controls	Materials	Systems integration	EMI/EMC control
Functions traditionally performed by the:	Semiconductor supplier						
	Component supplier						
	Power supply manufacturer						
	EMS provider						
	ODM	Strategic	Strategic				
	OEM						
	Accessories Vendor						
	Distributor						
	Retailers						

Table 14: Value chain segments and their capability to assist in the development of wireless power technology. Black boxes are strategic capabilities that will be kept in-house. Blue boxes indicate the value chain segments with one of the important technical capabilities.

Winning partners: The typical start-up organization has a number of collaborators at their fingertips; the challenge is to develop the story and the credibility which will lead to their participation in a co-development. Why should the prospective collaborator consider investing alongside an inherently high risk, start-up partner?

Credibility can be established in a variety of ways depending on the situation: ranging from the publication of technical journals, to mentions in the business press. Endorsements by respected

[9] See Crossing the Chasm, by Geoffrey Moore for detailed explanation of rational.

members of the business and technical community are also useful (e.g. a strong technical and business advisory board). But, most importantly, the start-up must clearly and convincingly articulate the value proposition of collaboration.

It is not in the start-up's interest to "trick" a company into collaboration, so the rational for the collaboration must be fundamentally sound. If it is not, the start-up company may lose partner support before the project is completed.

In the power supply market, a wireless power company finds strategic alignment with component suppliers, semiconductor suppliers, power supply manufacturers, and OEMs. This correlates with a collection of players with the appropriate technical skill-sets. Winning the commitment of this organization would dramatically reduce design time, improve results, and lower cost to the start-up organization.

Value chain segment	Capabilities	Basis for interest in wireless power	
		Problem	Opportunity
Component suppliers	o Raw materials creation and processing. o Assembly of basic materials into discrete components.	o Basic components are being commoditized as low cost suppliers enter the market o The selling price of basic components is low, fractions of a cent in many cases o Today's power supplies do not require radically different / innovative component technologies.	o Wireless power systems depend on advancement of component level technology. Today's component technology is responsible for the shortcomings of many systems. o A component supplier can develop new technology and products for the wireless power market and sell them with little or no competition.
Semiconductor suppliers	o Control system design o Creation of power and battery charge management systems with onboard communication and control system for wireless power applications. o System level design perspective and close working	o Power management and battery charge management products are becoming relatively homogenous. o Today's power supplies take advantage of low end power semiconductors o There is little need for their high end	o Creation of highly differentiated power and battery charge management systems that are compatible with wireless power technology. o Wireless power is a potentially high volume application that takes advantage of high-end power semiconductor

	relationships with OEMs.	products in high volume applications.	technology.
Power supply manufacturers	o Thermal management o Manufacturing of power products o EMI / EMC control expertise o Familiarity with modern discrete component technologies	o Power supplies have been commoditized o The product trends are steady and relatively mundane (i.e. no current or upcoming opportunities for differentiation) o Prices are expected to decline further	o Wireless power products are dramatically differentiated from their corded counter parts. o Opportunity to increase prices and establish leadership while the market is in its formative stages.
OEMs	o System level design expertise	o Consumer electronics has become increasingly competitive. o There are fewer opportunities to use hardware based features as differentiators because OEMs have similar technical capabilities and source their technologies from suppliers in the same value chain. o Power supplies have lost aftermarket value	o Differentiates product by making it simple for consumers to use. o Technically complex feature that will be difficult for less sophisticated competitors to replicate. o Potentially high volume, high margin aftermarket power system that could replace the margins that were formally produced by branded, aftermarket power products.

Table 15: Potential technology development partners and their incentives in the market for wireless power systems.

Chapter 5: Go to Market Strategy

Contemporary go to market strategies

New technologies are typically expected to follow the technology adoption curve, whereby a technology makes a gradual progression from the early market on the left, through the mainstream market, and finally skeptics, on the right (Moore, 1991). The selection of a market and the target customers within each market is subject to considerable debate by the management teams of start-up technology organizations.

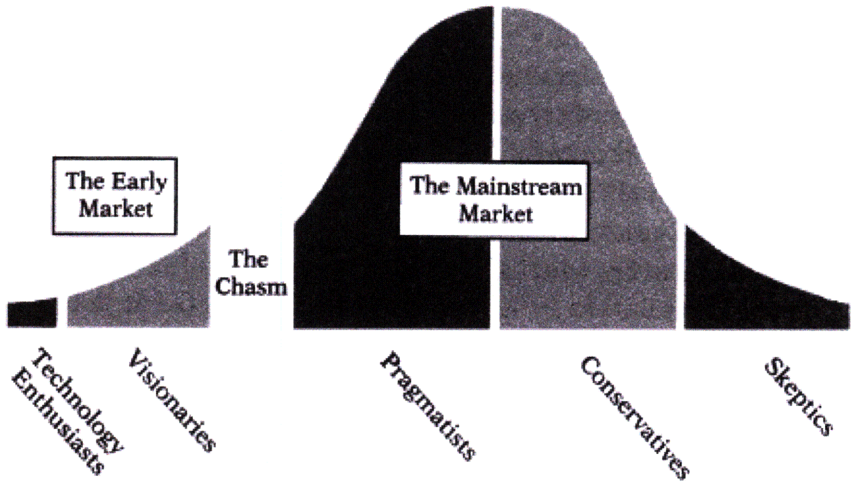


Figure 15: Technology adoption curve **(Moore, 1991)**

New technology commercialization requires an organization to make strategy decisions based on limited, typically speculative, information. The decision making process is especially difficult when tight balance sheets leave little margin for error. The basic strategies are summarized below:

Chasm model (Moore, 1991)		
Principles	**Advantages**	**Disadvantages**
○ Focus is critical ○ Attack smaller niche markets before mainstream markets ○ Conquer niches one at a time. Each subsequent niche market should overlap with previous the niche market. ○ The niche markets should eventually lead to the mainstream market of interest. ○ Leadership in a small market is better than a small piece of a big market.	○ Focused technology development plan maximizes efficacy of engineering team ○ Marketing activities are self referencing. The first "win" builds credibility within the start-up's narrowly defined market thereby reducing the time and financial investment required to collect incremental "wins." ○ Start-up becomes "big fish in a little pond." It is difficult for competitors to dislodge the start-up from	○ Risk of losing first-mover advantage, or even relevance, in mainstream markets if competitors skip the niche markets ○ Picking the wrong niche burns time and financial resources which can be fatal to the start-up ○ Start-up does not learn the needs of mainstream markets, until it enters the mainstream market. The start-up's capabilities which were developed in niche markets, might not translate to match the

o Mainstream customers look for fully developed products and market leadership, both of which are difficult for a start-up to prove.	this position and it creates a solid jumping-off point for the next markets. o Smaller markets can be more forgiving of technology and marketing mistakes. It provides a sheltered learning environment. o Activities within the smaller markets are not as attention grabbing as activities in mainstream markets, thus allowing the start-up to stay in "stealth-mode" and avoid attracting new competition.	needs of mainstream markets. o Forced to turn down opportunities, even if cash is tight.

Table 16: Basic principles, advantages and disadvantages of the Chasm Model of new technology commercialization

Direct-to mainstream model		
Principles	**Advantages**	**Disadvantages**
o Go directly after the end market o Niche markets are a distraction from the end market	o Potential to win first mover advantage o Provides direct knowledge of the needs of the mainstream marketplace o Cutting edge technology attracts the interest of potential customers (i.e. lower-cost marketing) o Early partnership opportunities with credible mainstream market participants	o Market might be slow to accept new technology after initial excitement. o Mainstream markets are less forgiving. A start-up's technology and supporting infrastructure will be held to high standards. Failure to deliver can destroy a reputation. o High cost of winning and supporting customers o Attracts interest of competitors o Start-up becomes a small fish in a big pond. It is difficult to establish a solid beach head. o Pursuit of the wrong market could be fatal to start-up. o Forced to turn down opportunities, even if cash is tight.

Table 17: Basic principles, advantages and disadvantages of the direct-to-mainstream model of new technology commercialization

Ad-hoc or services based model		
Principles	**Advantages**	**Disadvantages**
o Pursue opportunities as they arise	o Requires less up-front investment by providing the start-up flexibility to pursue many opportunities. o Mitigates risk by pursuing multiple opportunities o Potentially earlier access to cash	o Stretches a start-up's limited resources which can make growth difficult – similar to a services model. o Low marketing / business development efficiency o Low technology development efficiency because the requirements of each opportunity are likely to be different

Table 18: Basic principles, advantages and disadvantages of the direct-to-mainstream model of new technology commercialization

In the last 20 years, numerous case studies on innovation and new technology commercialization have reinforced the Chasm model as the best foundation for a young technology company's go-to-market strategy. In many cases this niche-by-niche approach is an appropriate strategy for the start-up as explained by Geoffrey Moore in his books *Crossing the Chasm* and *Inside the Tornado.*

First mover advantage is not always at risk when a start-up is defining its commercialization strategy. Thus leaving the start-up the manageable risks of a) choosing the wrong market b) misinterpreting the needs of mainstream customers and c) turning down non-strategic opportunities. Thorough market research, carefully selected board members, and deep-pocketed venture investors can help mitigate risks 'a', 'b' and 'c' respectively.

The direct to mainstream approach is widely viewed as a cash incinerating, strategic mistake while the ad-hoc strategy is seen as a growth-inhibiting strategy. That said, each model has its place depending on the needs and capabilities of an organization. A strategic direction can be determined by considering the start-up's product and business development needs in light of their ability to access financial resources and tolerate risk.

	Efficacy of product development	**Efficacy of sales / business development**	**Financial requirements**	**Acceptable level of risk**
Chasm Model	Moderate	High	Moderate	Moderate
Direct to mainstream	High	Moderate	High	High
Ad-hoc	Low	Low	Low	Low

Table 19: Benefits and drawbacks of primary go-to-market strategies considered along the functional aspects of start-up organization. Red boxes indicated unfavorable characteristics, green boxes indicated favorable characteristics.

- The Chasm model favors effective sales and marketing. However, it is less effective at product development because the needs of the mainstream market are not necessarily considered from the outset. Rather, the engineering team is tasked with optimizing the technology in order to win each niche along the way achieving mainstream adoption. This approach requires sufficient financial backing to turn down opportunities outside the niche markets of interest. The tight focus of the chasm model is riskier than the more diffused focus of an ad-hoc model.
- The direct-to-mainstream model favors effective product development because the product is being developed for a singular group of customers. The engineering team can more easily develop an understanding of for whom, and for what the technology is being developed. The business development team faces a challenge in building credibility because they cannot point to any track record. The deliberate pace of mainstream customers and the lack of track record are likely to extend the time to revenue which increases the financing requirement.
- The ad-hoc model favors low risk and low financial requirements at the expense of product and business development efficacy. It is difficult for an engineering team to optimize a technology, and equally difficult for a sales team to hone a pitch, if the customer and market are undefined. iRobot is known to have taken this approach before choosing to focus on robotic vacuum cleaners. According to Colin Angle on iRobot, "Focusing this company too early," says the CEO, "would have killed it." (Buchanan, 2003)

Three track commercialization strategy

The basic approaches described above do not meet the needs of all situations and there is a need for an alternative strategy. Consider the following three situations:

- An entrepreneur is interested in trading the efficacy of his sales force for a more efficient product development process, but does not have the financial resources to go to a direct model.
- An entrepreneur would like to minimize financial requirements, but cannot accept the product development inefficiencies that come with an ad-hoc model.
- An entrepreneur who is considering a direct approach may wish to reduce overall risk, but not at the expense of losing first mover advantage.

In these instances and others, a three track strategy whereby the start-up pursues carefully screened opportunities within three thoughtfully selected markets, is a viable strategic alternative.

The concurrent pursuit of three markets runs counter to the advice of academics and industry practitioners because it has the downside of diffusing the limited resources of a start-up (Stern, 2002) (Archambault, 1999) (Yoffie, 2005). Therefore its implementation should be considered only in the instance of appropriate start-up company needs and or market conditions. This strategy is designed to be relevant when product development and financial efficiency are of the highest priority, while sales activities are of the lowest priority.

	Efficacy of product development	Efficacy of sales / business development	Financial requirements	Acceptable level of risk
Three track strategy	High	Low	Low	Moderate

Table 20: Benefits and drawbacks of primary go-to-market strategies considered along the functional aspects of start-up organization

The objective of the three track commercialization strategy is to maximize the efficacy of product development by involving partner organizations from the mainstream market while minimizing financial requirements by taking advantage of revenue opportunities in an outside, likely, unrelated market. After development is complete, the technology is qualified for mainstream customers in the primary market in smaller, but related market.

Three track commercialization strategy		
Principles	**Advantages**	**Disadvantages**
o Pursue three markets simultaneously o Technology requirements are similar across markets o The mainstream market of interest, or primary market, is approached to understand requirements and build relationships o A validation market, which is similar to the primary market, is used for technology validation o A research market is approached to provide cash and/or a sheltered development environment. o Opportunities within in each market must be rigorously screened and prioritized.	o Early access to cash and sheltered development environment o Mainstream market provides product and capabilities feedback o Partnership / co-development opportunities with leading customers. o Potential preservation of first mover advantage in the mainstream market o Risk mitigation through participation in multiple markets	o Taxing on resources o Requires strict prioritization of leads within each market o Reduced marketing and business development synergies.

Table 21: Principles, advantages and disadvantages of three-track commercialization strategy

Market selection

Initially, the three markets must satisfy the need of rapid product development and minimal financial requirement. Later, the collective markets should provide a place for technology and market validation. The characteristics of the appropriate markets and their contribution to the strategy are described in the following table:

	Primary market	Validation market	Research market
Characteristics	○ Mainstream market	○ Similar technical requirements to the primary market ○ Subset of mainstream market – niche players	○ Similar technical requirements to the primary market ○ Risk tolerant
Function	○ Understanding of product requirements ○ Technology partners ○ Competitive intelligence ○ First mover option	○ Technology validation	○ Cash flow ○ Survival of company during high risk development phase

Table 22: Characteristics and functions of the target markets in three track commercialization strategy

- **Primary market:** This represents the mainstream market and is the cornerstone of the three because it is through this channel that the start-up can learn the product requirements and expected supplier capabilities. It is also the place where the start-up can find collaborators who can help accelerate the development cycle through the open-innovation processes introduced and discussed in chapter four.
- **Validation market:** The second market should be a subset of the primary market and a proving ground for the technology upon readiness. The technology requirements of this market must be similar to the technology requirements of the primary market.
- **Research market:** This market should provide early cash flow and be tolerant of technology risk. The technical requirements must similar to those of the primary market such that development activities are transferable. The work here can sustain the start-up as both internal and external development activity takes place.

Key activities and modulation of activity

It is important to note that the company is not engaged in full blown technology commercialization activities across all three markets. The activities are modulated depending on the state of the technology and progress that is made towards acceptance.

	Progress >>		
	Phase 1: Technology development	**Phase 2: Market / technology validation**	**Phase 3: Commercialization**
Primary market			
Validation market			
Research market			

Table 23: Intensity level of activities within each market depending on the progress towards commercialization. Green boxes indicate high levels of activity within a particular market, while red boxes indicate low levels of activity.

- **Phase one**: The focus of phase one is to complete the product development and meet the technology needs of mainstream customers at the lowest possible cost. The important activities are described below:
    - **Primary market**: The start-up must manage a high intensity engagement in order to assess the needs of customers and build strategic co-development partnerships. It is an opportunity to build technical credibility and shape the thinking and expectations of future customers. Managing the technical engagements and soliciting on-going feedback from the customers will consume the majority of the start-ups bandwidth.
    - **Validation market:** The start-up identifies potential validation markets and feels out initial interest, but avoids deep engagements. Identification of a validation market during this stage is important to a smooth phase two transition.
    - **Research market:** The start-up seeks a market for the technology with requirements similar to those of the primary market, but has the additional characteristics of being tolerant of technical risk and willing to invest in the development. Federal and state grant programs are good starting places. These activities consume considerable bandwidth, but less than that devoted to the primary market.
- **Phase two:** The focus of phase two is to validate the technology and the market in a credible (as judged by the mainstream customers) niche market. The activities in this phase are sales and business development focused.
    - **Primary market**: The start-up limits the level of engagement with mainstream customers. The technology is ready, but the mainstream customers require high levels of engineering support which might be difficult for a start-up to provide. Furthermore, the mainstream customers are likely to draw out the decision making process until they have evidence of market and technical validation. Co-development activities should be winding down.
    - **Validation market:** The start-up engages with one or more customers in order to set-up pilots. Assuming success, the start-up works with customers within this market to launch products. The technical and market data become part of the sales pitch to primary market customers in phase three.

- **Research market:** The activity in the research market is decreased as the technical risk decreases. There might be commercialization opportunities in this market, but they are not the highest priority.

- **Phase 3 / revisiting strategy:** By phase three, technical risk is considerably reduced and thus company priorities are likely to change. With a fully-baked product the number of financing opportunities increase and business development activity takes a higher priority. At this point it is logical for a start-up to re-evaluate its strategy and consider more traditional approaches such as the one outlined by the Chasm model.

Go-to-market – Wireless power example

Wireless power technology is a good candidate for a three track commercialization strategy for a number of reasons. First, the product development challenges are significant and addressing them tops the priority list of any technology provider. Without a working solution, none of the sales and business development activity matters. Second, the market is well aware of wireless power and is actively seeking the solutions. This market characteristic allows the start-up to invest less in sales and business development activity. Third, the poor track record of previous wireless power companies has made access to financing difficult. Fourth, activity by competitors requires wireless power start-ups to stay engaged with their ultimate mainstream customers, or risk irrelevance. And fifth, the final product is deeply intertwined with the system level design of OEM products.

One wireless power start-up, WiPower, is engaged with three different markets. OEMs are providing the relevant product and market feedback. Accessories providers are gearing up to provide technology and market validation, while the United States Navy is providing research funding in order to adapt the technology to military radios.

Conclusion

Wireless power technology is a revolutionary technology that promises to replace the two billion external power adapters that are sold every year. It is a seemingly attractive opportunity for a start-up company, but the technology is complicated, the intellectual property landscape is dense, and the competition is intense. The technology will be sold into the pre-existing market for external supplies, which is reeling from declining prices and margins. The market is in need of change, and is looking for innovations that will improve the situation.

The commercialization of wireless power technology is a case example of how start-up technology companies can accelerate development times, reduce risk, and build sustainable competitive advantage by carefully planning their technology approach, fully understanding the intellectual property landscape, and leveraging the principles of open innovation. A technology strategy requires the selection of a technology vector which should be determined by weighing the importance of individual product features against the expected levels of technical risk. Within its technology vector, a company must evaluate the strategic importance the various engineering activities based on whether they enable freedom to operate, contribute to the creation of blocking patents, and/or are outside the expertise of potential partner organizations. The start-up should intensely focus its engineering resources on the strategically important activities while farming the remainder of the development work to partner organizations within the greater value chain.

A start-up entrenched in a competitive battle to serve a hungry market; with a green technology solution, faces a difficult choice: go to market niche by niche and face irrelevance in the greater market, or swing for the fences and risk bankruptcy. There are options beyond the traditional approaches, and in this case, a three track commercialization strategy is appropriate.

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