UNIVERSITY OF CALIFORNIA
Santa Barbara

ENERFICIENCY

An Eco-E Project submitted in partial satisfaction of the requirements for the degree of
Master of Environmental Science and Management
for the
Bren School of Environmental Science & Management

by

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April 2018

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Acknowledgements

The Enerficiency Team acknowledges and would like to extend our thanks to the individuals that provided their time and insight to help us along the timeline of our venture. We thank our faculty advisors at the Bren School, Emily Cotter and Dr. Sangwon Suh, both of whom oversaw us through the evolution of our project. Their knowledge and intuition regarding start-up creation, customer discovery, and the energy efficiency industry proved to be invaluable in our learning how to best tackle the issues we were trying to solve. We would also like to extend our gratitude to our external advisors, Russ Kohler and Alex Kehaya, both provided us with the necessary guidance and motivation early on to pursue this venture.

Secondly, we thank the countless industrial engineers, sales representatives, and plant managers that took time out of their day to offer us their industry expertise in both the scopes of industrial air compressors and the energy service sector. The knowledge and experiences these individuals offered was vital to steer us within the highly dynamic environment our project was to navigate through.

Finally, we would like to thank the Bren School for giving us the opportunity and resources to pursue this project and allowing us to have this awesome experience. From the Enerficiency Team, we extend our sincerest gratitude to everyone that played a part in this experience.

Enerficiency

As authors of this Eco-Entrepreneurship Thesis Project report, we are proud to archive this report in the Bren School's library of Eco-Entrepreneurship Projects. Our signatures on the document signify our joint responsibility to fulfil the archiving standards set by the Bren School of Environmental Science & Management.

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Ankur Dass

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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems require quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Eco-Entrepreneurship Project fulfills a core requirement for the Masters of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small teams of students conduct customer discovery research to develop a business model for a new environmental venture, in addition to focused, interdisciplinary research on scientific, management, and policy dimensions of a specific environmental issue. This Eco-Entrepreneurship Thesis Project Final Report is authored by MESM students and has been reviewed and approved by:

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Emily Cotter

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Dr. Sangwon Suh

April 2018

Abstract

The industrial sector accounts 27% of electricity consumption in the US. Approximately 20% of electricity used by the industrial sector is wasted. Compressing air is a particularly energy intensive process in the industrial sector. It accounts for 10% of the energy consumed in the sector, of which 20-30% is wasted due to air leaks. This amounts to 24.4 billion kWh per year in wasted energy and costs the industry $2.9 billion. In addition, there is a significant environmental impact associated with this wasted energy; it contributes 14.9 billion tons of CO2 equivalents annually to greenhouse gas emissions (GHG). This is equivalent to the GHG emissions of 2.7 million cars. Typically, compressed air leak-repair projects have an ROI of less than 2 years. Therefore, they represent a significant cost-savings opportunity for industrial facilities. However, the industrial average leak rate continues to range from 20 to 30%, suggesting a low implementation rate in the sector.

Enerficiency's founding purpose was to determine the root cause of the low implementation rate of compressed air leak-repair projects in the industrial sector and to conceive of an innovative business solution to this problem. During our entrepreneurial process, we explored two solution spaces: 1) increase the number of industrial facilities interested in implementing projects 2) improve the rate of project completion by interested facilities. Our current hypothesized solution exists in the first solution space. Our distinct value proposition is to lower the barriers to industrial customers taking the first step – an audit of their compressed air system. The primary barriers are the cost and efficiency of the audit. We believe that we can lower the cost and improve the efficiency of the audit through technological innovation - by replacing hand-held leak detectors, the current default technology, with drone-mounted leak detectors.

Our Team

Ankur Dass – Project Manager

University of Texas: B.S. Chemical Engineering

Graduate Specialization: Energy and Climate

Ankur studied chemical engineering as an undergraduate at University of Texas at Austin. He worked for 5 years in roles of increasing responsibility in chemical manufacturing facilities. His time in manufacturing highlighted the need for sustainability practices in the industrial sector and an idea based on his experience was the starting point for Enerficiency.

Easton Williams – Data Manager

University of California, Santa Cruz: B.S. Biology and Political Science

Graduate Specialization: Pollution Prevention and Remediation

Easton studied political science and biology as an undergraduate at UC Santa Cruz. He developed a strong interest in environmentalism and conservation while studying and working in a marine ecology research lab in Santa Cruz. Easton came to the Bren School to study interdisciplinary solutions to sustainability and conservation.

Arun Bird – Financial Manager

University of California, Santa Barbara: B.S. Biology

Graduate Specialization: Energy and Climate

Arun studied biology and ecology as an undergraduate at UCSB. He became increasingly interested in the damage to local ecosystems from climate change impacts, as well as the role of economic growth in the creation of greenhouse gas emissions. Arun came to the Bren School to further learn and work on these impacts, and believed in the core mission of Enerficiency.

Executive Summary

The industrial sector accounts for 22% of primary energy consumption and 27% of electricity consumption in the US. Approximately 20% of electricity used by the industrial sector is wasted. [1]

Compressing air is a particularly energy intensive process in the industrial sector. It accounts for 10% of the energy consumed in the sector, of which 20-30% is wasted due to air leaks. This amounts to 24.4 billion KWH in wasted energy and costs the industry $2.9 billion annually. [2]

In addition, there is a significant environmental impact associated with this wasted energy. The wasted energy contributes 14.9 tons of CO_2 equivalent annually to greenhouse gas emissions. This is equivalent to the GHG emissions of 2.7 million cars annually.

Typically, compressed air leak-repair projects have an ROI of less than 2 years. Therefore, they represent a significant cost-savings opportunity for industrial facilities. However, the industrial average leak rate continues to range from 20-30%, suggesting a low implementation rate in the sector. [2]

Enerficiency's founding purpose was to determine the root cause of the low implementation rate of compressed air energy efficiency projects in the industrial sector and to conceive of an innovative business solution to this problem.

Our entrepreneurial process led us through three distinct iterations of our business model. The first and third (current) business models were specific to compressed air energy efficiency. The second business model tried to tackle the broader issue of energy efficiency in the industrial sector.

The following report elaborates on the natural evolution of our business models. It serves as a case study for the barriers-to and opportunities-in industrial energy efficiency- in general, and compressed air energy efficiency - in particular.

Approach

Methodology

The overarching problem we sought to address was industrial energy efficiency. Specifically, we wanted to improve the rate of adoption of energy efficiency projects in the industrial sector, particularly compressed air energy efficiency projects.

We explored two solution spaces to address this problem:

A) Increase the number of facilities interested in implementing projects.
B) Improve the rate of completion of projects by interested facilities.

Approach A necessitated that we lower the barriers to entry for industrial facilities. That is, make it easier for facilities to take the first step – an audit of their compressed air systems to determine the leak rate.

Approach B necessitated that we solve one or several of the process issues associated with the life-cycle of compressed air energy efficiency projects that prevent facilities that have taken the first step (audit) from completing projects.

Iteration	Approach	Life-Cycle Step Targeted by Solution
3 - Drone Leak Auditing	A	Audit
2 - EPC Financing	B	Financing
1 - Integrated Service	B	Entire Life-Cycle

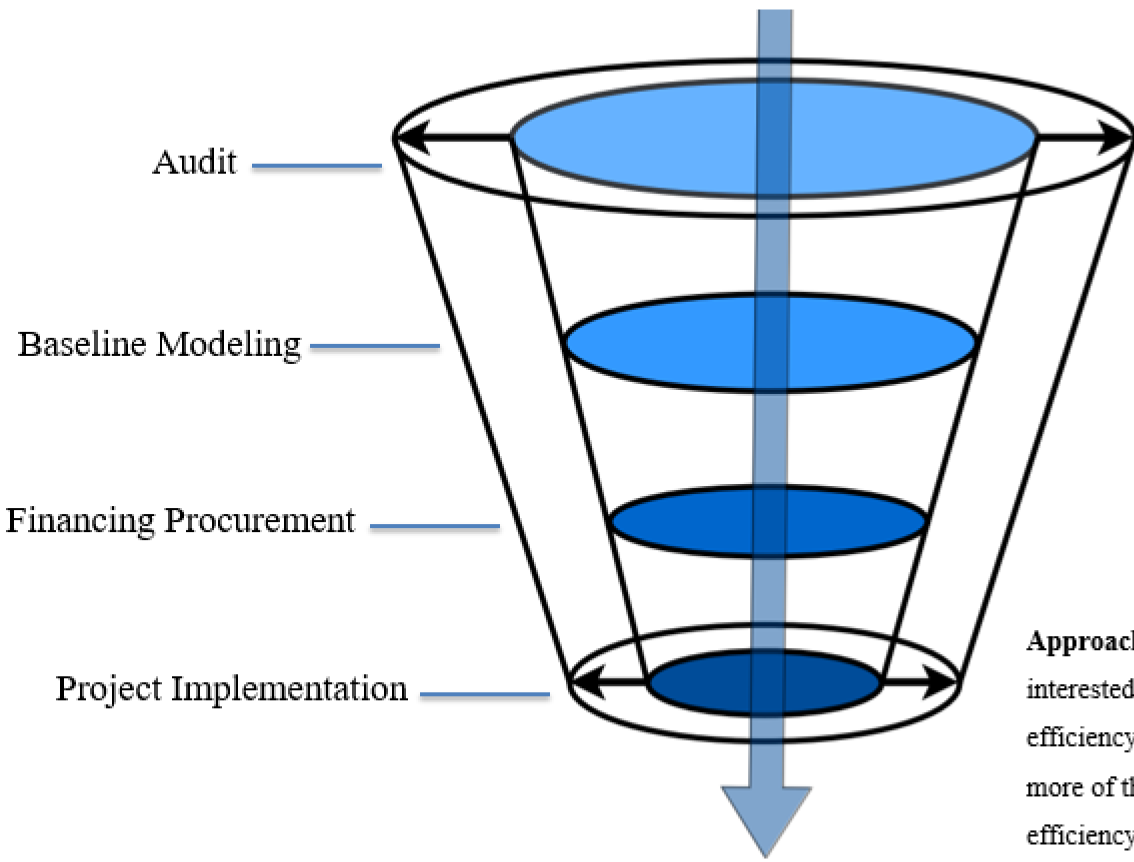
Application

In the first iteration, we used Approach B as we attempted to provide a turn-key solution for the life-cycle of a compressed air energy efficiency project.

In the second iteration, we used Approach B but with a narrow focus on solving the financing step of the project life-cycle. While we narrowed our scope in this regard, we expanded it by looking at industrial energy efficiency in general, not just compressed air energy efficiency.

In the third and current iteration, we have narrowed our scope further - by using Approach A to lower barriers for just the initial audit step of the compressed air energy efficiency project life cycle.

Approach in Context of an Energy Efficiency Project's Lifecycle



Approach A – increase the market of facilities interested in compressed air energy efficiency by lowering the barriers to the first step – the audit. Then, given the natural rate of project implementation in the industry, a great total number of compressed air energy efficiency projects are implemented.

Approach B – help facilities already interested in compressed air energy efficiency; alleviate pain-points at one or more of the life-cycle stages of an energy efficiency projects such that more projects are successfully implemented.

Supplement A: Industrial Compressed Air Systems

Compressed air systems are integral components of most industrial manufacturing facilities. Compressing air is very energy intensive and accounts for 10% of electricity consumption in the industrial sector.

System components

A typical industrial compressed air system has the following components:

a) Air Compressor

b) Water Separator

c) Air Dryer

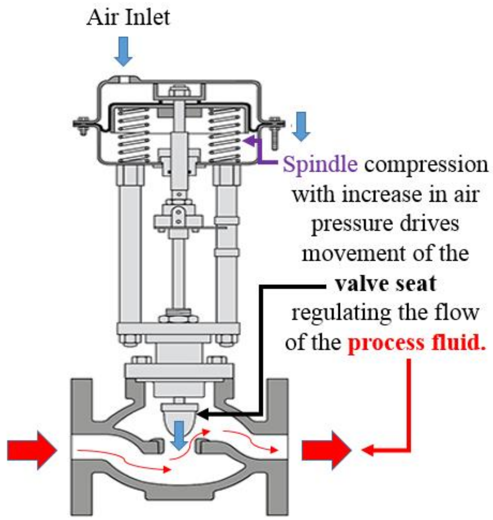
d) Air Storage Tank

e) Distribution Piping

Uses

The distribution piping carries the compressed air to the end-users within the facility. The primary use of compressed air is for pneumatics to operate air-tools, valves, and instruments within the industrial facility. It is also be used as a raw-material input in some manufacturing processes. A typical compressed air system is maintained at a pressure of 100 PSI. [3]

A typical air-operated pneumatic valve



System Leaks

An average industrial compressed air system consists of miles of distribution piping. This distribution system is prone to leaks. In fact, 20-30% of the energy used by a compressed air system is wasted due to air leaks. Air leaks typically occur at the junction of different sections of piping – these junctions are called flanges or pipe-joints. [4]

Piping components most susceptible to air leaks

Leak Detection

There are three leak detection methods:

1) Audio – air leaks make a hissing sound that can be detected given low background noise and a large enough leak.

2) Visual – a soap solution is sprayed on the piping. The formation of bubbles indicates that a leak is present.

3) Detection equipment – ultrasonic leak detectors are used to identify the location of leaks. This is the fastest, most convenient method for leak detection.

Business Opportunity Summary

Our current hypothesized business exists in the solution space represented by Approach A – increase the number of facilities interested in implementing projects. Enerficiency's distinct value proposition is to lower the barriers to industrial customers taking the first step – an audit of their compressed air systems.

Both primary and secondary research indicates that the primary barriers are the cost and efficiency of the audit. We believe that we can lower the cost and improve the efficiency of the audit through technological innovation - by replacing hand-held leak detectors, the current default technology, with drone-mounted leak detectors.

Timing

Drone technology has matured to a point that it has the capacity to perform audit functions and is already being used for this purpose in a limited capacity in the industrial sector (Ex: flare environmental compliance inspections). [5] Also, recent Federal Aviation Agency (FA) regulations have enabled wide-spread use of drones. [6]

"Generally firms are very receptive to having an audit performed. Comes down to timing - how much time (it takes) is a major factor."

- Energy Services Professional

At the same time, driven by government regulations and Corporate Social Responsibility (CSR), firms are increasingly investing in the efficiency of their operations. [7]

Enerficiency can enable compressed air energy efficiency service providers to capitalize on these trends. Our drone-mounted leak detection system offers the efficiency (reduction in audit time) that their end-customer desires.

Thus, Enerficiency hopes to be the first-mover that couples drone technology with leak detection technology, and packages it with a leak detection database management software catered to the industrial customer. We believe that our product solves the core customer problem, and thus will enable energy service providers to reach a larger segment of the industrial compressed air leak detection market.

Environmental Opportunity Summary

Energy waste attributed to compressed air leaks accounts for 2-3% of electricity consumption in the United States industrial sector. The life-cycle environmental impact associated with the production of the wasted electricity is significant. Most notably, it contributes 14.9 billion tons of CO_2 equivalents annually to GHG emissions. This is equivalent to the annual GHG emissions of 2.7 million cars.

Thus, the avoidance of life-cycle environmental impacts associated with electricity generation through efficiency improvement of compressed air systems represents a significant environmental opportunity.

GHG emissions from compressed air energy waste are equivalent to the annual emissions of 2.7 million cars.

Iteration 1 Summary

Solution Space – Approach B

Our first business model hypothesis was informed by Ankur's previous experience working in a chemical manufacturing plant as well as research into the life cycle of a compressed air leak management project. We studied the different stages and moving parts that are incorporated in compressed air leak management from start to finish and this revealed that a series of process issues synergistically prevent the implementation of compressed air system efficiency services.

A multitude of process issues combine to impede the success of leak management services in industrial compressed air systems. These issues range from a lack of internal staff resources, appropriate technology and tools, expertise and understanding of how compressed air systems work, and access to capital needed to fund these projects.

Manufacturing facilities often lack the needed staff to give a necessary amount of attention to leak detection. Maintenance staff have a priority system that prioritizes projects related to production or other more ROI-intensive tasks over compressed air leak management. In addition to limited staff, technological resources and expertise also significantly disrupt leak management in manufacturing facilities. The difficulties of efficiently locating, fixing, and validating the savings from leak repair can discourage a facility from even attempting to take on leak management.

Our value proposition was to offer an integrated service that alleviated the process issues of all these stages and moving parts.

The more we studied our potential customers and competitors, we realized this value proposition is not as unique as we previously postulated. Compressed air equipment manufacturers and maintenance companies already offer efficiency and leak detection services but not as a core business offering.

After discovering that there are already competitors offering some form if not entirely integrated services for leak management, we reassessed ways we could still produce a competitive advantage. Our interviews and research led us to settle our new focus on helping already motivated customers get financing for compressed air system leak management.

Iteration 2 Summary

Solution Space – Approach B

Our second hypothesized business model shifted the focus away from project management and concentrated on financing. After customer research and competitor analysis failed to validate our first business model hypothesis, we sought to reassess what we thought were the primary barriers associated with successful implementation of energy efficiency services in compressed air systems. Our integrated service solution was able to alleviate many of the customer pains associated with process issues and limited resources, but this was still insufficient in swaying decision-makers to be willing to allocate internal capital to these services.

This led us to shift our focus to financing and to investigate what types of innovative strategies we could develop to circumvent this financial barrier. Exploration into financial solutions led us to discover energy performance contracting (EPC). Energy service companies (ESCOs) have been utilizing this financing method to fund energy efficiency services in select markets for several decades.EPC allows for third-party capital to be used in the financing of energy efficiency projects. Companies who own the machinery/equipment being serviced are able to pay back the financier through the energy savings that result from the service.

Our research found that EPC is only successful in select industries, i.e. the public sector (more specifically, the MUSH sector). This caused us to see potential in trying to modify current EPC practices so that we could apply it to compressed air leak management. During our interviews with EPC experts and customers, we found that the process issues associated with leak management were pretty uniform for energy efficiency services across the industrial sector. This discovery that leak detection was not the only type of energy efficiency service that could be facilitated by third-party financing via EPC led us to expand our market to energy efficiency services of any type that have difficulty obtaining internal financing.

We believed we could make EPC work in the industrial sector by bundling multiple projects into singular contracts and emulating the contracts that are successful in the public sector. This proved to be false as we found that bundling still did not provide enough value to third-party financiers for them to take on the risk of financing industrial customers. . The financial decision-maker may have changed, but process issues still made it difficult to achieve capital.

Supplement B: Energy Performance Contracting

Energy Performance Contraction (EPC) is a well-established model in which the customers pay for the capital costs of implementing energy efficiency projects through savings generated from the implementation of the projects. Typically, an Energy Services Company (ESCO) develops and implements energy efficiency projects for customers. The ESCO guarantees the energy savings from the project in an Energy Savings Contract (ESC) and helps the customer procure financing.[35] Private debt, private equity, and utility financiers are all prevalent in this model.

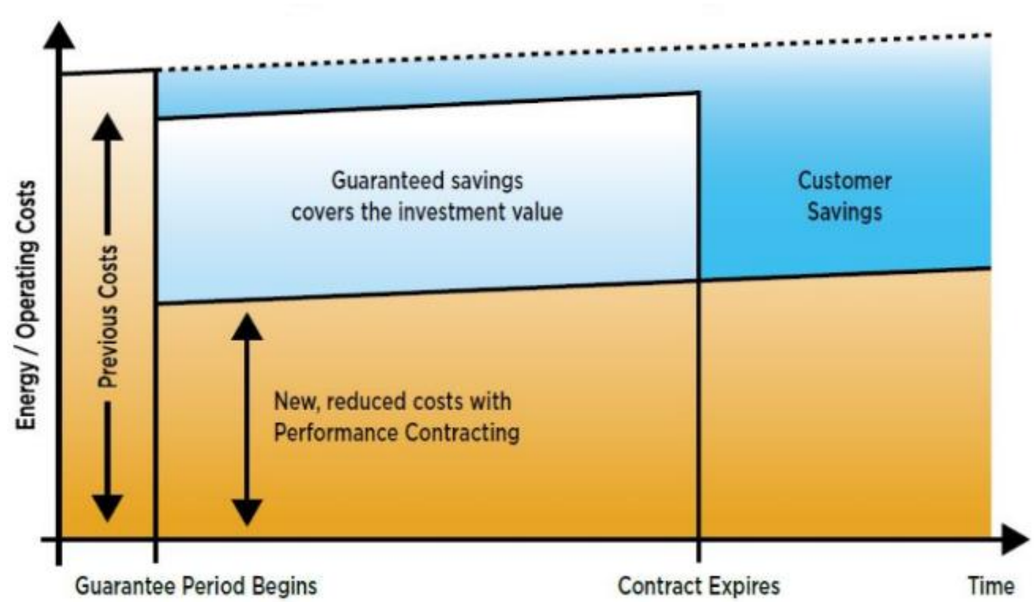


Photo: Institute for Market Transformation

Advantages

In simple terms, EPC shifts the burden of financing energy efficiency projects from a customer's capital budget to his/her operating budget. Customers typically have more flexibility in their operating budgets.

In addition, EPC lowers the financial risk to the customer implementing the energy efficiency project because the ESCO assumes financial risk if the guaranteed savings are not realized.

EPC Markets

EPC contracting is most prevalent in the MUSH market. That is, municipalities, universities, schools, and hospitals. This is mainly due to enabling legislation and partly due to the fact that the MUSH market is characterized by low-risk customers with large (>$5M) projects – the ideal customer profile from the financier and ESCO's perspective.[36]

Industrial Sector

The industrial customers do not fit the customer profile sought by financiers and ESCO's. That is, the projects in the industrial sector are small and the customers are considered a higher credit risk than the MUSH customers. Utility On-Bill Financing is the most common application of the EPC model to the industrial sector, but this is mandated by legislation. [36]

Iteration 3 Summary

Solution Space – Approach A

Our third proposed business model returned to our previous focus on compressed air leak management. Our previous two iterations had revealed that trying to solve the entirety of the process issues is incredibly difficult for a single business model to accomplish. They had failed to find an encompassing solution

This led us to pivot and focus on trying a new approach. We decided to narrow the scope of what we were trying to accomplish and try to focus on improving one part of the process issues. Research from our first iteration on compressed air systems and all the process issues associated with efficiency services led us to concentrate on the auditing phase of the leak management. Customer and competitor interviews had revealed that the low quality of current audit methods was a major issue and contributed to a multitude of subsequent process issues.

Around the same time we were exploring ways to improve leak detection audits, we attended an international energy services conference in New Orleans, Louisiana where we had the opportunity to attend a presentation on drone technology in energy services. The seminar gave an overview of various new applications for drones conducting surveys and inspections for utility service providers. We discovered that drones are being used in similar applications, but not directly for leak detection in compressed air systems. Further research via interviews showed us that drones' usage in inspection services is growing exponentially with applications in agriculture, buildings/infrastructure assessment, and pipeline monitoring.

We believe this is the most promising technology enhancement option available and our new business model utilizes drones in leak detection audits. Our product is a software tool that pairs with the drone sensing technology designed to streamline the data collection, analysis, and presentation. The hypothetical measurement and verification improvements are highly valued by financial decision makers that we interviewed in all three iterations. Our new customer segment changed from manufacturing companies who owned the compressed air systems to companies providing the leak detection services. Our new value proposition is to improve the first step in leak detection projects and in doing so, help our customer sell their service to their customer.

Business Model Environment

Industry definition

Enerficiency will operate within the *energy efficiency services* industry and more specifically in industrial energy efficiency services. The energy efficiency services industry constitutes a myriad of businesses which offer a variety of services to end-use customers to improve their energy usage intensity through implementation of energy efficiency measures. [8]

Industry analysis

The end-use customers are typically categorized into four distinct groups: public, industrial, commercial, and residential. The public sector is typically referred to as the MUSH market or municipalities, universities, schools, and hospitals. The MUSH sector is currently the largest market for energy efficiency services due to favorable financing schemes and government initiatives. However, the commercial and industrial sectors represent the largest opportunity for growth. [9]

The types of energy efficiency measures implemented vary somewhat between the four groups identified above. However, there are many common measures such as upgrades to efficient LED lighting and high efficiency boilers. Measures within the industrial sector include upgrades to advanced motors with variable frequency drives, lighting upgrades, and industrial energy management systems (IEMS). [8]

A diverse range of energy efficiency services are on-offer to end-use customers. Services offered include auditing of facilities to determine energy savings potential, procurement of financing for energy efficiency measures, technical consulting on projects, project development and implementation, etc.[10]

The diverse range of energy efficiency services are offered by an equally diverse range of businesses. Many of these businesses specialize in one or two services such as auditing or financing or have a specific technical expertise. Others offer integrated energy services. These are large businesses known as Energy Services Companies (ESCOs). ESCOs are the largest player in the market by some margin – they have 85% market share and had total revenue of $6.3 billion in 2015. [9] ESCOs utilize a model known as Energy Performance Contracting (EPC). Energy performance contracting is a method by which energy savings from a project are used to finance the project. EPC is alternatively known as project-financing or cash-flow financing. Currently, the MUSH market is the largest customer base for ESCOs and their EPC financing model. [11]

Macroeconomic forces

The price of electricity is the key driver of the energy efficiency services market. The price of electricity is in turn driven by the cost of fuels (coal, renewable energy, etc.); power generation, transmission, and distribution; and weather conditions. [12]

Another important driver of the market is the cost of human capital, particularly expertise in finance, accounting, law, and engineering. Availability of professionals has a substantial impact on businesses within the energy efficiency services market. In addition, availability of trained energy management professionals is important to the industry. Currently, there is a shortage of quality trained energy management professionals and demand is only expected to increase as the energy services market continues to grow. Finally, labor rates can impact the labor-intensive components of the business such as auditing and construction. [13]

Key trends

The energy efficiency services market is growing. This trend is driven by the economic demand for cost-savings and the development of a societal consciousness for sustainable use of resources. [14] These trends are reflected in the increasing volume of regulation designed to facilitate the adoption of sustainability practices across the market. This, in turn, is driving technological innovation that is enabling new business models in the energy efficiency services market. [15]

Regulatory

Policy pertaining to energy efficiency at the federal, state, and local level has been the most critical driver of the energy efficiency services market. Regulators affect the market by enacting legislation that fosters a demand for energy efficiency services. They do so in three distinct ways:

i. Enable implementation of energy efficiency measures by lowering the financial barrier.
ii. Enact legislation that establishes energy efficiency performance standards for equipment and/or buildings.
iii. Enact legislation that indirectly drives demand for energy efficiency services. [16]

Regulators have lowered the financial barrier by enacting legislation allowing the use of Energy Performance Contracting (EPC). Most states now allow EPC, although execution and terms vary considerably by state. [17] Some states have even mandated utilities to avail their end use customers of on-bill financing for energy efficiency projects. Another way in which regulators have lowered the financial barrier is through tax credits (federal, state, and local) and low-interest government bonds for financing of energy efficiency projects. The most significant among these over the past decade has been the American Resources Recovery Act (ARRA). [18]

Another powerful regulatory mechanism that has been driving a growth in the energy efficiency services market are energy efficiency performance standards. These include performance standards for lighting, boilers, cars, and industrial equipment to name a few. The Energy Star program for appliances is one example of such standards. [19]

Finally, legislators can facilitate the market through somewhat indirect methods as well. For instance, some cities have recently mandated energy use disclosure policies as well as building energy-use benchmarking. This has the potential to create a powerful social incentive for organizations to improve energy efficiency. [20]

The 2018 proposed budget has been a troubling development for the energy efficiency industry. The budget calls for the elimination of the energy star program and cuts 70% of the energy efficiency programs at the DOE. [21]

While the policy factors noted here have played a key role in driving growth of the energy efficiency services industry, the majority of this growth has occurred in the MUSH market. The industrial sector continues to remain underserved due to financing and informational barriers as discussed in the section *market forces* below.

Drone Regulations

Federal drone regulations released in 2014 allow for the use of drones for commercial/industrial operations but exemptions and waivers are required for most industrial operations. In addition, most states have their own laws pertaining to the use of drone technology.[22]

Federal drone regulations are contained within the Code of Federal Regulations (C.F.R.). While many parts of the C.F.R. code may apply to drones, the four most applicable are: Part

47, Part 48, Part 101, and Part 107. Most drone operations, from recreational to commercial and government, fall under Part 107. Part 107 lists the drone pilot certification requirements, the operating rules, aircraft requirements, and process for obtaining waivers for certain operations. [23]

Under current C.F.R., the use of drones for industrial leak detection would require a waiver. Due to the early stages of the application of drone technology, it is difficult to gauge the difficult of obtaining waivers for industrial operation. However, market research shows that drones are currently being used across the industrial sector for a variety of purposes, ranging from safety auditing at construction sites to environmental inspection of flare-stacks.

Some specific regulations that would impact Enerficiency's business directly include:

a) The total drone weight cannot exceed 55 lbs – if it does, the aircraft falls in a different, more restrictive class, and may not be allowed to perform the functions as necessitated by the Enerficiency business model.
b) The drone operator must be withing line-of-sight, or 400 ft of the drone.

Economic

Within the industrial sector, there is a long-standing norm of trying to increase output while at the same time reducing costs. In other words, despite budget and man-power cuts, organizations expect an increase in output. Thus, organizations are perpetually in the search for cost-savings measures. [24]

Despite the perpetual demand for cost-savings in the industrial sector, the drive for improvement of energy intensity as a means of cost-savings has not manifested itself as one would expect. Even though most industrial facilities could implement energy efficiency measures that deliver cost-savings on a short pay-back period, few do so. [25] While there is increasing regulatory pressure and incentives to accelerate the implementation of energy efficiency measures in industrial facilities, certain key financial and informational barriers, as discussed in the section *market forces* below, need to be overcome.

Technological

The main technological trend in the energy efficiency services market is the emergence of wireless monitoring and control of equipment and sensors coupled with advanced data analytics on a cloud storage system.[26] The specific technologies that are at the forefront of this technological change are smart meters, internet-of-things (IoT), machine-to-machine (MTM) interaction, and advanced data analytics software.[27] In the industrial sectors, these technologies are combined into Industrial Energy Management Systems (IEMS). These systems can track energy usage, maximize efficiency of equipment and even entire systems in real-time, and generate analytics including energy savings generated through real-time system optimization.[28]

IEMS represent the leading edge in industrial energy management technology. Their versatility is enabling new business models in the industrial energy efficiency services industry. However, IEMS require significant investment of resources, thus their adoption within the industry is slow – limited to large organizations with significant internal capital availability.

Market forces

Market issues

There are a variety of issues affecting the business of compressed air leak detection service providers. The primary driver of these issues are their end customers, industrial facilities. Table 1 summarizes the barriers faced by the end-customer that directly influence the business of compressed air-leak detection service providers.

The results of these barriers is that, while most customers want, and many actively seek, compressed air leak detection services, they have a very low willingness to pay for that service. As a result, compressed air leak detection services do not constitute a core business function for most service providers. Instead, leak detection services are often offered for free and bundled with other paid services. [29]

Despite this, most service providers consider leak detection services an essential part of their business – they feel that it is needed to remain competitive in the market. Thus, leak detection services are a cost borne by service providers without direct returns with the expectation that it will yield pay-off in

Economic & Financial
Internal competition for capital
Corporate tax structure
Program planning cycles
Split incentives
Failure to recognize non-energy benefits
Energy price trends
Regulatory
Utility business model
Industrial participation in ratepayer-funded energy efficiency programs
Failure to recognize all energy and
Energy resource planning
Environmental permitting
Informational
Adoption of systematic energy management system
Awareness of incentives and risk
Metering and energy consumption data
In-house technical expertise

terms of customer loyalty and willingness to purchase other services.

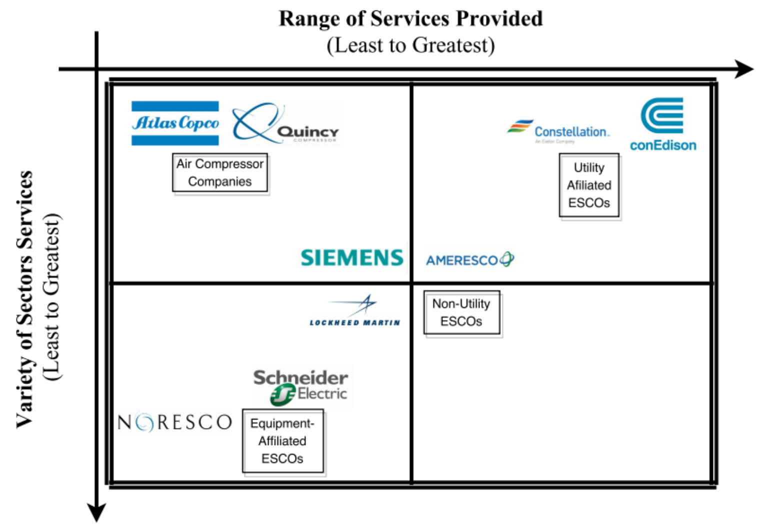
In addition, complex maintenance and capital project planning cycles on the customer end make it difficult for leak detection service providers to even execute the leak detection service free of cost. Largely, this is a matter of the timing and duration of the leak detection service.

Market segments

The energy efficiency services market at its highest level can be broken down into the residential, commercial, industrial, and government sectors. Each of these can be further broken down in many ways – from behavioral characteristics of customers to firm size. There is a plethora of firms operating in these markets, some firms specialize and operate in only one sector while others are present in all sectors. [30]

Compressed air energy efficiency service providers occupy a small niche within the energy efficiency services market. For some firms, compressed air services are a core business while for others, it is part of a broader portfolio of services.[29]

Compressed air use is common across all sectors but there is considerable variation in size of the systems and the end-uses of the compressed air. Typically, firms cater their services to end-use applications within a specific sector, such as commercial compressed-air energy efficiency services. However, similarities between certain end-uses in different sectors enable some larger firms to economically deliver services to multiple sectors. For instance, the needs of



commercial and industrial compressed air energy services customers are very similar and thus firms are often found operating in both spaces. [30]

There is also considerable variation in the range of services on offer to the end-use customers. Some firms offer life-cycle support – installation, maintenance, and operation – of the entire compressed air system. Others offer life-cycle support for very specific components of the compressed air system, such as just the air-compressor. Yet others offer services in only a particular life-cycle stage of a compressed air system; for instance - just compressed air system maintenance.[30]

The compressed air efficiency market is just a smaller sub-set of the compressed air energy market and within this lies the compressed air leak detection sub-segment. While there are some firms that offer compressed air leak detection services as one of many leak-detection service offerings, most firms that offer compressed air energy efficiency services offer them as a part of their larger compressed air energy services business, which may include one or all of the following: maintenance, engineering, operating, and consulting services. [30]

Needs and demands

The most pressing need of the compressed air leak detection market is customer acquisition. More specifically, firms are struggling to find ways to make facilities go through with an audit of their compressed air system. Industrial facilities cite cost of leak detection services and the amount of time needed to complete an inspection as the primary barriers to them availing of the auditing service. The market has adapted by offering leak-detection services for free, seeing that it fulfills an important function in customer acquisition and customer retention. But, the market still needs a solution to the duration problem. -

Revenue attractiveness

The global industrial energy efficiency services market is projected to grow at a steady pace through 2021. The projected growth rates for the 3 key market areas are:

1. Auditing and consulting – 7.04%
2. Product and system optimization – 4.64%
3. Measurement and verification – 6.21%

For context, auditing and consulting has 42% market share; product and system optimization has 20.9% market share; and measurement and verification has 36.4% market share. [31]

China represent the strongest growth area for the industrial energy efficiency services market while Europe has been and remains the largest overall market. In the United States, regulatory requirements, at the federal and state level, and government incentives are the primary driver of energy efficiency in the industrial sector. [32] Thus, the market revenue attractiveness for energy efficiency services in the US is strongly influenced by state and federal level regulation. Consequently, there is wide variability in revenue attractiveness by region and by administration.

Industry forces:

Competitive analysis

Within the compressed air leak detection services market, businesses compete on cost, variety, and expertise. In other words, key differentiating factors are:

1. Ability to provide services at a lower cost.
2. Offering a wide-variety of synergistic services to the customer.
3. Offering high quality differentiated service or exceptional technical expertise for the customer with quality in mind. [33]

For compressed air efficiency services, the primary driving factor is cost – thus firms that offer free leak detection services fare better than those that charge for service, even if the charge is attributable to some differentiated quality in the service. Regardless, due to the price sensitive nature of the leak detection service, the ability to keep the internal costs of leak detection services low is a key determinant of the profitability of the business. [33]

Enerficiency's business model will be a competitive threat to a few key existing services:

1. Hand-held leak detection services – all direct providers of hand-held ultrasonic leak detection services as well as those involved in this supply chain would represent direct competition.
2. Consulting services – the analytics component of Enerficiency's software tool will offer direct competition to the consulting service businesses for whom analytics are a core offering.
3. Facility operators – facility operators who detect leaks by audio or visual detection as part of their routines

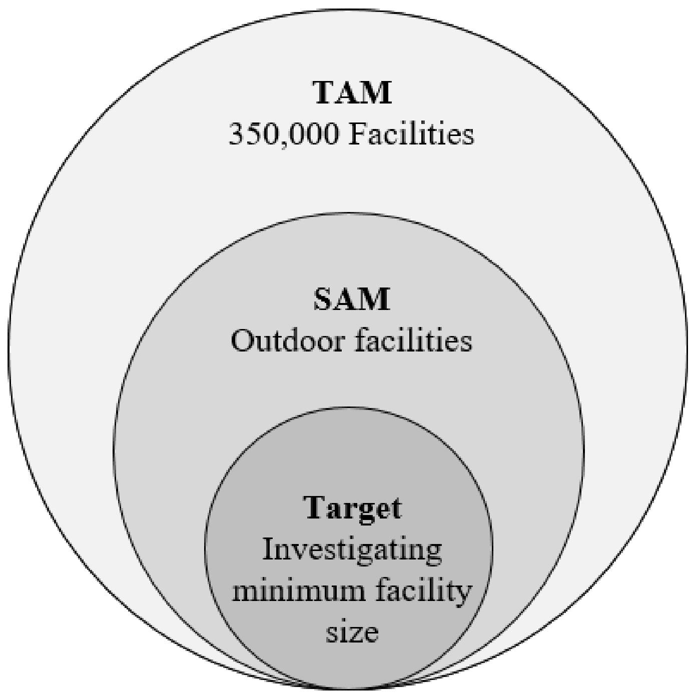
Market analysis

Market type

The market type can most closely be defined as perfect competition – one in which there are enough buyers and sellers that no minority entity can influence the market price.

Market size

The market size for Enerficiency is best represented by the market size of its direct customers – compressed air leak detection service providers. The total available market (TAM) for compressed air leak detection services consists of all industrial facilities with a compressed air system. Based on an assumption that all industrial facilities have a compressed air system, it is determined that the TAM size is 350,000 facilities.[34] The serviceable available market (SAM) is all outdoor facilities – regulations do not allow the operation of drones inside buildings. Finally, the target market may be limited by a financial viability question. That is, what is the minimum facility size required for leak detection with drones to be a more economical choice than ultrasonic or audio/visual leak detection?



Proposed Business Model

Customer Segments

Companies that offer leak management and auditing services to industrial facilities will be our target customers. These types of companies come from two segments:

1) Energy service/consulting companies.
   Ex: Atlas Copco, Sullair, Quincy

2) Original compressed air equipment manufacturers [37]
   Ex: Ameresco, ConEdison, Regional compressed air energy service providers such as Aerometrix, ACES, etc.

Our customer and industry research from our first iteration identified these two categories of companies as the two primary customer segments in which we will be selling our product.

Value Proposition

Our value proposition to companies offering leak detection services is a software tool coupled with drone-mounted ultrasonic leak detection technology that improves the existing solution in two ways:

1) Streamline the audit process

The mobility and precision of the drone technology will enable our customers to complete audits in a much shorter duration than they can through a technician using a hand-held detector. The shorter duration of audit will lead to lower labor costs. In addition, it will enable improved customer acquisition and retention because the duration and cost of the audit are key criteria for their customers.

2) Improve the quality of the audit

Our technology will improve on the quality of the audit in two ways: a) find more leaks due to greater precision and coverage b) show leak locations mapped on a 3D facility map and provide analytics capabilities in the database – designed to enable in-house energy managers to make the case for investment in a leak repair program or project. This is a significant improvement over the existing method for leak documentation – a spreadsheet listing the location and size of leaks.

In short, since one of the major process issues associated with the low implementation rate of leak management services is the quality of auditing methods, our value proposition has been confirmed via customer interviews. The current approach of using a human technician and handheld ultrasonic sensor results in time-intensive audits that are imprecise and lead to locational issues. Our drone and software tool will help solve these pains and improve the quality of the audit techniques. The fuzzy logic of a human technician is inherently less accurate and efficient when compared to a well-designed, automated sensing technology.

Channels

The primary approach by which we will acquire customers is through outreach via a sales team. Directly contacting compressed air service companies and compressor manufacturers is the most effective way to sell our product since it is innovative and not currently offered. This will be a new application for drones and requires that we inform our customers that our product exists.

We will also reach out to trade associations and other industry organizations who can help advertise our product. The benefit of being recognized by these organizations will also benefit our company by instilling credibility in our product via their advertisements and endorsements

Customer Relationship

Personal assistance

The primary customer relationship that we will engage in is personal assistance. Interaction with our customers will be help to communicate the full usability and benefits of our tool. Our software interface will be designed such that it can be applied universally to compressed air systems that require leak detection. Although in some cases, more dedicated personal assistance and customization may be required if a customer wants a more specific type of tool. This will lead to our second customer relationship, co-creation.

Co-creation

The prototype for our software will be heavily informed by research and understanding into what our customer needs to improve the quality of leak detection. This interaction with our customers will continue to shape the way we design our product.

We will also base our product's evolution based on interactions and research on our customers' customer. Even though our product will be sold to compressed air efficiency service companies, the value proposition stems from our understanding of the process issues, specifically in the audit phase, that exist at the manufacturing facility who owns the compressed air system. This requires us to keep in touch with the needs of both the companies that purchase our product, and the customers that they will use it to service.

Revenue Streams

While Enerficiency is still investigating possible revenue stream models, the current hypothesized revenue streams are:

1) Usage fee per drone rental

The customer a flat-rate fee for each instance in which they rent a drone. The rentals can be short-term or long-term with discounts offered for long-term rental. The rentals would come with a certified pilot.

2) Subscription

The customers pays a subscription fee for access to the latest to the latest software upgrades and technical services.

We expect the largest part of our revenue to be from the the usage fee revenue stream. The subscription model will be harder to sell but represents higher margins. The target market for this would be larger firms that have long term contracts with their customers for compressed air energy efficiency services. Atlas Copco and Sullair are examples of such firms.

Key Resources

Intellectual Resources

Our most important resource will be the intellectual property that goes into the creation of our software tool that is paired with the drone technology. The software tool itself represents the end product of a series of smaller intellectual properties that we possess from our customer and industry research. Our detailed understanding of all the process issues and actors involved within the life cycle of a leak detection project are invaluable in shaping our product.

Human Resources

A series of labor resources will be required to run our business and support all the needs of our customers. These labor needs fall into include four primary categories that incorporate all of the customer service and ongoing research and development that our proposed business model requires.

1) Software engineers
2) IT service representatives
3) Sales representatives

4) Legal advisors specializing in drone law

Key Activities

The key operational activities for Enerficiency will be the certification of drone pilots, acquisition of the correct exemptions to operate drones in industrial facilities, and site-specific training for the drone pilots from the industrial safety board so that they can work in industrial facilities.

The marketing team will advise the R&D activity. Specifically, this will include updates of the software to address customer needs and demands. In addition, the marketing team will serve a business development function by identifying other synergistic applications for drone-mounted detectors in industrial facilities. The information obtained by these business development activities will be used to collaborate with our partners, sensor and drone manufacturers, to develop the hardware and software to bring the service to new applications for existing customers.

Key Partnerships

As mentioned, drone manufacturers and sensor manufacturers will be critical partners for Enerficiency. We will help them by expanding their business to new customer segments by enabling the use of their technologies through our proprietary software and customer expertise.

Cost Structure

Enerficiency's business model is heavy on fixed costs. The key costs are:

1. Purchase of drones
2. Purchase of sensors
3. Wages
    a. Sales and marketing team
    b. Drone pilots
    c. Drone specialized lawyer services
    d. IT & Engineer team for software development and customer support.

Key Assumptions:

Our business model is contingent upon a few key assumptions:

1) Drone mounted ultrasonic leak detectors can be operated in industrial facilities and the acquisition of exemptions for this activity from the FAA will not be a bottlenecking

process that significantly affects the cash-flow operations of Enerficiency.

2) The costs associated with drones plus a pilot are greater than the costs associated with technician plus a hand-held leak detector. A key assumption is that the efficiency gained by the drone-mounted operation is enough to overcome the higher costs associated with the service. This assumption is the key to the viability of Enerficiency’s business model and is under investigation.

Minimum Viable Product

Our software tool itself will not be sufficient as a minimum viable product (MVP). Currently, there are no commercially produced drones paired with the ultrasonic sensing technology required to perform leak detection audits of compressed air systems. Therefore, we plan to purchase our own drone and sensor payloads that we will pair together and use for a pilot project. Upon completion and demonstration that the product works, we expect drone manufacturers to offer the hardware.

Drone technology

To accomplish this we will need to purchase a commercial drone with a payload capacity sufficient enough to carry the sensor equipment necessary for leak detection. The drone manufacturing company, Vulcan, is a leader within the industry and with models like the Airlift (shown below) that currently possess the ability to carry a maximum payload of 30 kg.

Photo: Vulcan

Sensor technology

Currently, efficiency service providers use ultrasonic sensing equipment is to find leaks in compressed air system piping(ref). The ultrasonic device will be attached to the drone and used to detect the leaks in the same general fashion that human technicians currently detect them by hand. These sensors are able to detect sounds that are otherwise inaudible to the human ear and function as depicted in the picture below.

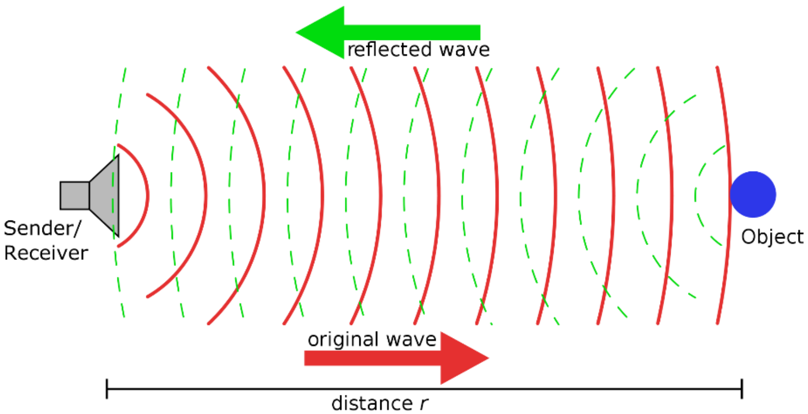


Photo: Wikipedia

The object in the picture above represents an air leak and the sender/receiver would be attached to the drone conducting the inspection on a compressed air system.

Imaging and 3D mapping technology

Drones are already used for 3D mapping of buildings and other infrastructure using photogrammetric sensing equipment (ref). The process of 3D mapping is straightforward and requires photos captured from top-down angles and lateral angles to build accurate 3D models (ref). This 3D mapping will be used to build a map of the location of leaks so that the implementation phase is easier for the facility or service company to complete. Currently, audit technicians will tag leaks and record them into some form of a list that is difficult for maintenance technicians to use when they wish to return to the located leaks and fix them (ref). This is a major component of our value proposition and will help substantially alleviate this issue of going back to find previously located leaks during the repair phase of leak management projects.

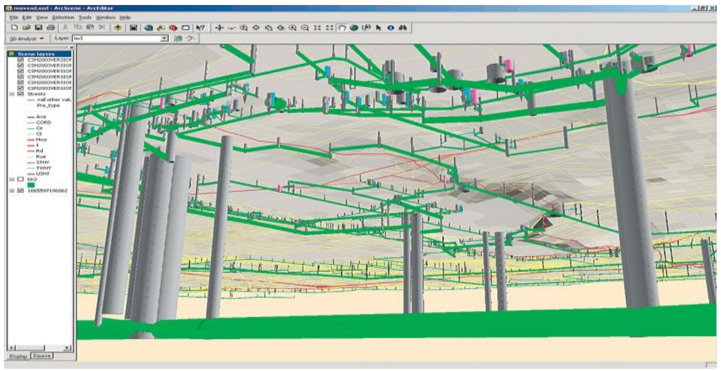


Photo: ESRI

Data analysis and presentation software

Once the hardware has been developed, the software that will take all of this information and compile it into an easily presentable fashion that is simple to interpret will be vital to our MVP. The ultrasonic sensor will identify leaks and then input that information onto the 3D model that the drone is concurrently producing as it scans the facility. Once an audit is completed, the software tool will produce a series of output graphs, figures, tables etc. The quantification of total leaks and general calculation of sizes of those leaks will be presented in a fashion that does not require any additional analysis by the customer.

The ultimate goal of our product is to remove as much of the work needed to show and locate leaks from the customer as possible. This simplification of the audit phase will help lessen some of the process issues that develop later on in the life cycle of leak detection services. By possessing a more credible baseline knowledge of the leaks that exist within a compressed air system, the successive steps of repair and validation will become simpler to manage and execute.

Environmental Benefit

It is difficult to ascertain how much new customer acquisition or customer retention through the life-cycle of the compressed air energy efficiency project we will be able to deliver for our customers. Further research is required to make this determination. However, the environmental benefit potential of Enerficiency's business can be evaluated through a case study.

We take a typical mid-size industrial facility with a compressed air system size of 2,000 SCFM operating at a pressure of 7 bar for 8760 hours per year. In addition, we assume that 25% of this energy is wasted due to air leaks as a representation of the industry average. The table below shows the environmental impact that could be minimized across a variety of environmental impact categories by eliminating the compressed air leaks at the sample facility. The most notable impact is the reduction of greenhouse gas emission equivalent to that of the annual emissions of 380 cars. This case study assumes 100% elimination of leaks, which is difficult in application, but it serves to illustrate the order-of-magnitude environmental benefit potential from Enerficiency's business.

Environmental Impact Category	Annual Quantity	Units
Acidification	6,459	[kg SO2-Equiv.]
Ecotoxicity	49,559	[CTUe]
Eutrophication	261	[kg N-Equiv.]
Global Warming Air	2,059,343	[kg CO2-Equiv.]
Human Health Particulate Air	490	[kg PM 2.5-Equiv.]
Human toxicity	< 0.1	[CTUh]
Smog Air	56,148	[kg O3-Equiv.]

Appendix A: Customer Discovery Research

Iteration 1: Air Compressor Systems

Summary

The first business model conceived had the main goal of addressing the high amounts of lost energy and money due to air compressor leaks. The initial idea stemmed from Ankur's experience working in an industrial manufacturing plant and noticing the problem and wondering why nothing was done to audit, repair and maintain compressors to prevent these constant energy and monetary losses.

Hypothesis Tested

We wanted to discover why air compressor efficiency projects are deprioritized relative to other projects within a plant. Thus, we came up with our initial value proposition hypothesis of whether or not manufacturing facilities with air compressor systems could be incentivized if the entire process of repairing these systems was made easier. In order to make the process easier we theorized that we could offer a comprehensive solution by offering the totality of audit, repair, as well as maintenance and savings verification all in one succinct package. This would essentially remove the hassle and trust issues of having to find and contract out engineers from separate companies that specialize in each stage of the process. It would also cut down the total amount of time the entire process would take, and thus allow for investment returns of the project via energy savings to come in sooner.

We also delved into the technology behind leak detection, with the majority of facilities implementing the use of ultrasonic sensor devices. The current method seemed to be slow and time-consuming, especially due to the fact the air compressor pipes may be quite intricate and travel long stretches depending on the size of the facility. We delved into enhancing this tech to make the sensing process easier. Ideas included making an autonomous robot to travel along the pipes to detect and signify leaks, as well as using remote sensing technology to map out leaks along the piping network in order to locate them easier.

Research Methods

In order to gain more background into why air compressor systems were rarely serviced and audited, despite energy and monetary losses from leaks, we went out to call experts within the industrial sector. These included possible customers for the service we hoped to provide, in the form of plant managers and sustainability managers within a range of manufacturing facilities. These also included possible competitors in the form of sales representatives from air compressor manufacturing and supply companies, as well as compressed air auditors… specifics

A useful tool that was utilized in our research was the Industrial Assessment Center website. Within it contained data on energy audits on manufacturing facilities performed by students and their overseers in colleges all over the United States. This data included the types of facilities audited, as well as specific energy and monetary savings of energy projects within the facility, including air compressor maintenance.

Results

Following our research, there were two major takeaways. The most important one was discovering that there were major financial burdens preventing air compressor maintenance projects going through. This was opposed to the inconvenience of acquiring contracts and trust issues between parties as initially hypothesized. Projects that had more immediate returns tended to go through with a higher success rate. As a result, many energy efficiency projects in general, with larger upfront costs and longer return periods are thrown to the wayside.

The second, more minor, takeaway was that our intrigue of enhancing leak-detection technology was largely un-feasible. This was found through our discovery of the existence of the booming sensory technology industry. The ultrasonic leak detection equipment that these companies produce are already incredibly advanced. The science behind leak detection essentially prevents any way to find leakages within pipes utilizing remote sensing or autonomous devices that we hoped to utilize within our business model. The original process that we deemed cumbersome and slow is in fact the only efficient way to go about finding pipe leaks.

Iteration 2A: Innovative Financing within ESCo Market

As we discovered financing was the major issue, we pivoted away from solely trying to service air compressor leaks, and instead try to learn why energy efficiency projects lacked the capital needed to go through. Continuing in our research on the financing behind projects lead us to discover Energy Performance Contracting (EPC).

Hypothesis Tested

The ESCo business model essentially solves many of the financial barriers through the use of Energy Performance Contracts (EPCs). The problem of upfront costs for a client becomes negligible as financiers partnered with the ESCo are able to loan out the capital needed for their client to pursue energy efficiency projects. The client is bounded by the EPC that ensures they pay back the ESCo and the financier over time as monetary savings accumulate through reduced energy costs from the project. Our main focus here was to determine whether there were any gaps in the ESCo business model. EPC process – involves customer, financer, and ESCo

Research Methods

The research during this iteration started with a review of existing literature on the ESCO business model and the EPC financing model. This research became the basis for our hypothesized business model. Then, primary research, through interviews with persons employed within the ESCO industry was used to test the business model hypothesis.

We interviewed a broad spectrum of people associated with the ESCO industry. The functional duties of our interviewees included strategic management, energy efficiency program design, energy efficiency program implementation, marketing and sales of energy efficiency programs to industrial customers etc. These interviewees worked across the spectrum of the ESCO industry including with utlities, private ESCOs, 3rd party implementers, technology providers to the ESCO industry, etc.

The Association of Energy Service Professionals conference in New Orleans in February, 2018 was critical to the validation of our business model hypothesis during this iteration as it enabled primary research on a scale that was difficult given the niche nature of the industry and the responsibility level of the people we need to reach in order to validate our ideas.

Results

1. There are underserved markets when it comes to EPC projects
    - Low income residential
    - Multi-family housing
    - Small commercial and industrial facilities (which we want to focus on)
2. ESCOs are efficient at energy projects within the MUSH market (public sector, municipalities, universities, schools and hospitals). These MUSH projects are typically large, >$5 million, and larger projects in public sector means less risk, which in turn means that financiers are more likely to fund the project.
3. The EPC model does not work in the industrial sector because the projects are too small. The life cycle transaction costs associated with a project are too high for the ESCOs to be interested in small projects because it is not a financially viable business opportunity.

Iteration 2B: Project Bundling (something more formal)

Hypothesis Tested

Does bundling of smaller industrial sector projects at multiple facilities owned by the same firm into one EPC contract resolve the project size issue?

Research Methods

The research methods employed during this iteration were identical to those used for iteration 2a.

Results

While bundling seemed to resolve the project size issue, there were other concerns that prevented it from being a viable business opportunity. Specifically, it seemed that the transaction costs would only increase as a result of the bundling. In addition, the internal issues with the customer that prevented them from availing of energy efficiency services would be multipled many-fold with the bundling value proposition. That is, even if one facility pulled out of the contract (due to any one of the internal process issues noted in this report), the contract would be void. The risk of this happening was considered too high for the financiers to entertain the idea of investing in the bundled projects despite short-ROI payback times.

Appendix B: Business Model Canvas

Iteration 1 – Life-cycle solution to compressed air leak management

Key Partners 8
Who are our Key Partners

- Project Management/Maintenance firms Ultrasonic leak-detector providers

1

Key Activities 7
What Key Activities do our Value Propositions require

- Coordination with partners & contractors
- Sales & Marketing

2

Key Resources 6
What Key Resources do our Value Propositions require

- Engineers
- Service technicians

2

Value Propositions 2
What value do we deliver to the customer?

- Integrated compressed air leak management service - audit, repair, validate

1

Customer Relationships 4
What type of relationships do our Customer Segments expect?

- Personal assistance

1

Channels 3
How do we reach our Customer Segments?

- Direct sales

1

Customers Segments 1
Who are we creating value for?

- Industrial manufacturing facilities

1

Cost Structure 9
What are the important costs inherent in our business model?

- Wages - labor & engineers
- Sales & marketing
- Travel

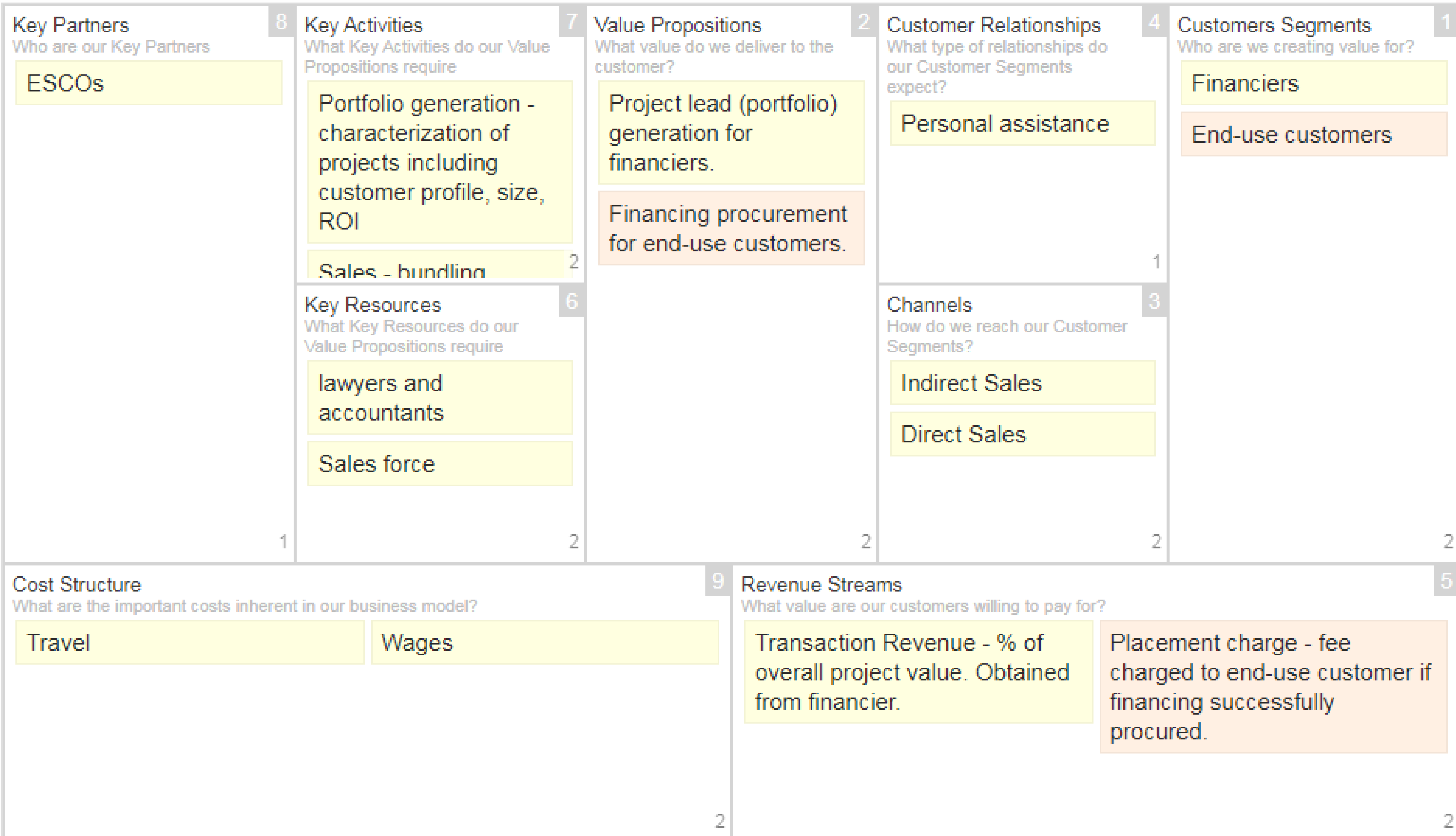
3

Revenue Streams 5
What value are our customers willing to pay for?

- Life-cycle solution: auditing, development of project, coordination of contractors, validation of savings generated etc.

1

Iteration 2 – Financing for energy efficiency projects through bundling



Iteration 3 – Technological innovation for Audit' step of a compressed air leak management life-cycle.

Key Partners 8	Key Activities 7	Value Propositions 2	Customer Relationships 4	Customers Segments 1
Who are our Key Partners	What Key Activities do our Value Propositions require	What value do we deliver to the customer?	What type of relationships do our Customer Segments expect?	Who are we creating value for?
Sensor Manufacturers Drone Manufacturers	Software updates (collaborate with partners) Certification of pilots. Business development	Cheaper, faster, more reliable leak detection with drones -> improved customer acquisition and retention	Personal assistance with long-term support	Compressed air energy efficiency service providers: Consulting/Service Companies OEMs
	Key Resources 6 What Key Resources do our Value Propositions require		**Channels 3** How do we reach our Customer Segments?	
	Software & Hardware Engineers Sales Team Drone Law Specialists		Direct sales	

Cost Structure 9	Revenue Streams 5
What are the important costs inherent in our business model?	What value are our customers willing to pay for?
Wages - pilots, lawyers, engineers Software development Sales & Marketing	Subscription fee for access to drones, latest technology, and service Usage fee per drone rental

Appendix C: Environmental Benefit Calculations

The annual environmental impacts from compressed air system losses in the US Industrial Sector in 2016 based on a life cycle assessment impact analysis using GaBi LCA Software. This analysis used a compressed air process that utilized a US average electricity grid mix (1kV – 60 kV) and a compressed air 7 bar set under medium power consumption.

Environmental Impact Category	Annual Quantity	Units
Acidification	46,740,916	[kg SO2-Equiv.]
Ecotoxicity	358,652,539	[CTUe]
Eutrophication	1,887,076	[kg N-Equiv.]
Global Warming Air	14,903,134,062	[kg CO2-Equiv.]
Human Health Particulate Air	3,546,529	[kg PM 2.5-Equiv.]
Human toxicity	275	[CTUh]
Smog Air	406,334,745	[kg O3-Equiv.]

Here, the environmental impacts of wasted electricity due to compressed air inefficiencies in the overall US Industrial sector for 2016 show the massive potential for reductions in greenhouse gases and smog. There is also the potential for large reductions for environmental acidification and ecotoxicity deposition as well. Essentially, the production of this wasted electricity used for compressed air produces the equivalent amount of greenhouse gases as that of over 2.7 million cars on the road in the US.

The annual environmental impacts from compressed air system inefficiencies in an average US facility utilizing an air compressor system that produces 2,000 standard cubic feet per minute worth of compressed air. This analysis also was done on GaBi LCA Software, using a compressed air process that utilized a US average electricity grid mix (1kV – 60 kV) and a compressed air 7 bar set under medium power consumption as in table below.

Environmental Impact Category	**Annual Quantity**	**Units**
Acidification	6,459	[kg SO2-Equiv.]
Ecotoxicity	49,559	[CTUe]
Eutrophication	261	[kg N-Equiv.]
Global Warming Air	2,059,343	[kg CO2-Equiv.]
Human Health Particulate Air	490	[kg PM 2.5-Equiv.]
Human toxicity	< 0.1	[CTUh]
Smog Air	56,148	[kg O3-Equiv.]

The potential environmental impacts of an average facility through wasted electricity due to lost compressed air alone. For every facility that goes through an air system retrofitting, an equivalent of around 380 cars worth of greenhouse gas would be saved from being emitted.

Appendix D – Technical Literature Review

Energy Efficiency

Improving energy efficiency is a strategy to cost-effectively continue economic production and growth without necessarily increasing energy consumption. Reducing or halting energy consumption also reduces the negative externalities that stem from energy production and distribution. These may include greenhouse gas emissions and monetary losses for the consumer. We look to lower barriers that prevent clients from improving energy efficiency at their facilities.

Technical Limitations

Natural problems with energy efficiency stem from the physical processes in which energy conversion occurs, decreasing the amount of useful output a process provides per unit of energy input. There is also an *energy efficiency gap paradox* preventing the social optima of energy efficiency from being obtained.1Social and economic problems are attributed to this energy efficiency gap. They include energy efficiency projects being de-prioritized over revenue-generating projects, market barriers, as well as the lack of awareness and information of the types of services that exist.[40]

Energy efficiency is defined as the ratio of the conversion of a unit of input of energy into a unit of *useful output* of energy. Different devices convert different energy from one form to another, such as thermal, electrical, mechanical and chemical energy. Different devices also have varying forms of efficiency in energy conversion. Incandescent light bulbs for example convert approximately 1.5 - 2.5% of electrical input to useful output in the form of light, and the rest is lost to the environment as heat.[40] The conversion rate from electricity to light is approximately 7-10% in a relatively more modern compact fluorescent light bulb.[41] A fluorescent light bulb thus utilizes less electricity than an incandescent one to produce an equivalent amount of light. Higher efficiency within the physical system of a device translates directly into lower energy costs assuming the amount of useful output created remains the same.[42]

Socio-Economic Problems

The *energy efficiency gap* is attributed to numerous problems within the market. The gap is attributed to consumer behavior in the context of taxation, pricing policies, and general energy market issues. It is also attributed to consumer behavior in the context of psychological and social drivers. Both social and economic drivers should be considered when explaining this gap as they overlap and influence one another heavily.[43] Important to note is that there is no defined agreed size of the energy efficiency gap due to the undefined optimal level of energy efficiency. The optimal level fluctuates based on values such as the variance of uncertainty and discount rates, the ability to eliminate energy market failures, and the justification of environmental externalities.[42]

Trust Issues

There is a strong social science aspect that contributes toward the energy efficiency gap. The market failures that prevent energy efficiency projects going through may be largely attributed to the decision-makers of a facility's characteristic human behavior. These include aversion to risk with the uncertainty of future return on investment (ROI), due to the irreversibility of energy projects should price developments not materialize as expected.[4] The differences of energy preferences among different populations and the sensitivity of changes in the attributes of energy characteristics within an area play a defining role in a financial decision maker's behavior as well.[43] Trust issues may also occur between the decision-maker and the ESCO that measures and validates upfront savings due to possible incentives for the ESCO to overstate efficiency.

Information Gaps

The inaccessible and missing information is a major aspect of the energy efficiency gap. Decision-makers often lack the necessary information or do not have the time and resources to obtain the information to compare different options with regards to energy projects. The positive externality of information is another factor contributing towards hidden information. Facilities that have acquired the information on how to adopt newer technologies and the savings that come with them may not want to share with other entities without compensation.[44]

De-Prioritization of Projects

The major factors regarding the de-prioritization of energy efficiency projects over others within a facility are the limited availability of capital, the length of time for ROI to be achieved, as well as resulting liquidity restraints to fund projects. This is due to energy efficiency investments generally having higher upfront costs, despite having lower costs during operation through energy savings.[45] If an energy efficiency project does have an ROI found to be large enough within a given amount of time, it may still be de-prioritized over revenue-generating projects.

Energy Marketplace: Consumers

Commercial Sector

The commercial sector is defined as private businesses, federal, state, and local governments, as well as other any other private or public organizations. Some examples include malls, stores, office buildings, schools, hospitals, hotels, and churches.

In terms of currently serviced customers this segment is currently dominated by the "MUSH" market. The MUSH market is comprised of municipalities, universities, schools, and hospitals that have large project potentials and aggregated organizational structure. The large size and reliability of public institutions make them ideal for current energy service companies as these attributes reduce the risk of investment.[46] As a result, these government organizations are able to obtain investment grade credits, reducing the risk of investment even further.[47]

Energy Consumption and Environmental Impact

The commercial sector accounted for about 19% (18.2 quadrillion Btu) of the total national end-use energy consumption in the United States in 2016.10 As a result of this energy consumption, 901 million metric tons of CO2 was emitted. These figures were calculated using energy consumption data from the Department of Energy and fuel emission factors defined by the Energy Information Administration.[49]

Energy needs vary across different commercial buildings who possess different needs but space heating accounts for about 25% of total energy with lighting, refrigeration, and ventilation being the next highest consumers at about 10% each. Out of all commercial building types, private mercantile and service buildings use the most total energy at about 15%. Education and healthcare buildings accounted for about 18% with professional and government office buildings account for 14% of energy consumption.[50]

Residential Sector

The residential sector is defined as being all privately-owned households. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and running a variety of other appliances. The residential sector has become increasingly dynamic as the way energy utilization in homes has changed rapidly with advances in technology and increasing rates of ownership of appliances and electronics. The residential sector also possesses large regional differences in type of energy use due to geographic variation in climate.[51]

Energy Consumption and Environmental Impact

The residential sector accounted for about 21% (20.5 quadrillion Btu) of the total national end-use energy consumption in the United States in 2016.[49] About 996 million metric tons of CO2 were emitted to produce the energy that was consumed by the residential sector. These figures were calculated using energy consumption data from the Department of Energy and fuel emission factors defined by the Energy Information Administration.[52]

Over the past 30 years, the total residential energy consumption has varied between 9.5 and 10.5 quadrillion Btu despite the population growing by 40% in that same time period. Improvements in building insulation and other efficiencies are offsetting this population increase. About 80% of residential energy use is consumed by single family homes with 15% going to apartments and 5% to mobile homes.[52]

Industrial Sector

The industrial sector is defined as all facilities and manufacturing entities that produce, process, or assemble goods. The United States is a highly industrialized country that has historically seen a significant portion of its energy devoted to this sector. Energy intensive processes require large amounts of self-produced power and purchased electricity in order to operate equipment and machinery.

Energy Consumption and Environmental Impact

The industrial sector accounted for about 32% (31 quadrillion Btu) of the total national energy consumption in the United States in 2016.[49] About 1.4 billion metric tons of CO2 were emitted in order to produce the energy that was consumed by the industrial sector.[50] Petroleum refining and chemical manufacturing are the two largest consumers of energy in the industrial sector accounting for 31% and 27% of total energy consumption in 2014. In terms of energy sourcing, on-site energy production accounted for 38% of energy used in industry with natural gas being the second largest source at 29%.[53] On-site feedstocks for energy production vary significantly but the largest single source is liquefied petroleum gas at 25% that alone accounted for about 339 million metric tons of the CO2 emitted by the industrial sector. Despite representing a smaller portion of sourced energy, purchased electricity was responsible for 459 million metric tons of CO2 emissions.[49]

Energy Efficiency Financing

Financiers

Financiers enable energy efficiency projects by providing the upfront capital required for the project. There is a wide variety of financiers serving the energy efficiency marketplace. These financiers employ a wide range of financial models and strategies to reach various segments of the market. Some financing models and strategies target almost the entire breadth of the market while others are tailored to specific subsegments of the market.

Private capital

Private capital such as commercial banks and credit unions provide the largest share of capital for financing energy efficiency projects. These institutions are risk averse. Thus, they work with proven partners, avoid credit risks, and target above market returns.[54]

Mission-based lenders

Mission-based lenders have dual bottom-lines - they seek to maximize gains while at the same time meeting social objectives. Community Development Financial Institutions (CDFIs) represent the largest of the mission-based lenders. Their goal is to finance energy efficiency projects in low-income areas. Due to their dual mission, these lenders are more risk tolerant and are willing to accept lower return.[56]

Utilities

Utilities leverage rate-payer dollars to finance energy efficiency projects. Typically utilities' participation in the financing market is driven by regulatory requirements. As a result, are risk tolerant and accept below market returns.[56]

Federal/State Government

Federal and State governments are the largest source of risk capital. They are very risk tolerant. They invest with the goal of leveraging private capital to stimulate the market. They accept below market returns.[55]

Socially responsible investors

Socially responsible investors such as philanthropists are another source of risk capital. They also seek to leverage private capital and may be willing to accept below average returns.[56]

Financing Models

There are a plethora of financing models for energy efficiency projects. The models most relevant to the market-space of Enerficiency are described below. Appendix A provides a more comprehensive listing of financial models.

Energy Service Performance Contracting (ESPC)

ESPC is a well-established model in which the customers pay for the capital costs of implementing energy efficiency projects through savings generated from the implementation of the energy efficiency measures. Typically, an Energy Services Company (ESCO) develops and implements energy efficiency projects for customers. The ESCO guarantees the energy savings from the project in an Energy Savings Contract (ESC) and helps the customer procure financing. Private debt, private equity, and utility financiers are all prevalent in this model.[57]

Utility On-Bill Financing

Utility on-bill financing is a means by which customers can finance energy efficiency projects through utilities and then repay the debt via their utility bill. This model allows the customer to pay for efficiency upgrades through operating budgets instead of capital budgets. This model exists as a result of federal/state mandates for its provision.[56]

Property Assessed Clean Energy (PACE)

PACE is a financial model which allows customers to pay for energy efficiency projects via their property tax bill. PACE has grown in relevance in recent years due to state policies enabling the program. Financing for PACE is typically in the form of risk capital from the state/federal government or other specialty investors.[58]

Financing Strategies

As with financial models, there are a range of financing strategies for energy efficiency projects. Each financing strategy is usual coupled with a specific financial model. The financing strategy most applicable to the Enerficiency market-space, *risk reallocation*, is described below. Appendix B provides a more comprehensive listing of financing strategies.

Risk reallocation

As the name suggests, this strategy is geared towards reducing or reallocating the risk of financing in order to facilitate financing of energy efficiency projects. This is done through a reserve fund which serves as insurance against losses from defaulted loans. Government agencies usually organize the reserve fund. Fund allocation to the reserves is based on the anticipated default rate on the loans insured by the fund. In short, risk reallocation is an enabling mechanism used by government agencies to facilitate funding of energy efficiency project by third party investors.[55]

The ESPC financing model is frequently coupled with the risk-reallocation financing strategy to insure the financier against credit-risk.[56]

Underserved Markets

There are four key underserved markets in the energy efficiency space. These are multi-tenant housing, low income residential, low rated government entities, and small commercial. Poor-credit is the primary concern in the multi-tenant housing, low income residential, and low rated government entities market segments. While poor-credit does contribute to the small commercial and residential market being underserved, other issues such as high transaction costs are the primary concern in this market.[59]

Small Commercial and Industrial

The small commercial/industrial market is underserved for a variety of reasons. The primary reasons are risk-averse owners and high transaction costs associated with financing energy efficiency projects at these entities.[60]

Market Size

A series of studies conducted by the international management consulting firm, McKinsey & Company, quantified the various potential energy savings for a number of markets within both the public and private sectors. Researchers aggregated potential stationary end-use energy savings for various sectors that could be achieved by 2020 if implemented. For the commercial and industrial sub-sectors, Department of Energy and NAESCO databases were used to analyze 330,000 businesses. An estimated end-use energy savings potential of 2.5 quadrillion Btu was calculated for energy service projects that range from lighting/space heating efficiencies to best practices energy management for industrial processes.[61]

Low Income Residential

Lender concerns regarding the credit of consumers is the primary reason why this market is underserved. To begin with, this market suffers from a lack of demand because energy efficiency falls low among the priorities of low income residents. The problem of poor credit is difficult to solve. One solution on the market is offered by community development financial institutions (CDFIs). CDFIs are mission-based lenders. Their mission is to bring energy efficiency to low income regions. Thus, they are willing to accept higher risk that commercial capital.[62]

Market Size

For the residential sector, the aforementioned study by McKinsey & Company assessed 129 million homes and 2.5 billion devices/appliances to calculate estimated potential energy savings. For the low income residential sub-sector, 600 trillion Btu in potential energy savings were calculated for existing buildings. An additional 948 trillion Btu in energy savings were calculated for devices/appliances in all residential sub-sectors' buildings. A portion of these came from low income housing but degree of specificity is unknown.[62]

Multi-family housing

Affordable multi-family housing is underserved during certain periods in its life-cycle. While energy efficiency projects are easily financeable at the time of construction, financing becomes a challenge during capitalization periods. This is because these properties tend to be highly leveraged and the costs of efficiency upgrades can exceed the appraisal value of the properties. Similar to the low-income residential sector, this sector also suffers from lack of demand from the often risk averse owners of the properties.[63]

Market Size

Multi-family housing is categorized as part of the low income sub-sector by much of the ESCO industry as well as the McKinsey studies that our market segmentation and sizing is primarily based upon. Therefore, the market size for multi-family homes is included in the larger low income housing sub-sector.

Government entities with bad credit rating

As is the case with low-income residential and multi-family housing market segments, state and local governments with bad credit are underserved because they're higher risk investments for financiers.

Market Size

The McKinsey study found that for existing government buildings, there was a potential energy savings of 572.5 trillion Btu. It is difficult to ascertain what fraction of the government buildings that possess energy savings potential fall into the category of public entities that have poor credit ratings or difficulty obtaining funding for other reasons.[62]

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