SMART GRID TECHNOLOGY INVESTMENT OPPORTUNITIES WITHIN THE SCOPE OF VENTURE CAPITAL FIRMS

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SMART GRID TECHNOLOGY INVESTMENT OPPORTUNITIES WITHIN THE SCOPE OF VENTURE CAPITAL FIRMS

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Approval of the Graduate School of Social Sciences

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Arts in Sustainable Energy.

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ABSTRACT

SMART GRID TECHNOLOGY INVESTMENT OPPORTUNITIES WITHIN THE SCOPE OF VENTURE CAPITAL FIRMS

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In recent years, the emergence of minimum energy consumption- especially in transportation, industry and buildings- has started to reshape the electricity network infrastructure around the world. Both developed and developing countries strive to build or upgrade their electricity network in order to balance the energy demand and supply. As an introduction this study provides brief information on Smart Grids, and then it reviews the Smart Grid technology market with providing information on successful applications of Smart Grids and highlights Smart Grid technology investment opportunities within the scope of Venture Capital firms.

Keywords: Smart Grid Technology Market, Smart Network, Venture Capital Investment, Network Approach, Market Intelligence, Technology Analysis

ÖZ

RİSK SERMAYESİ ŞİRKETLERİNİN PERSPEKTİFİNDE AKILLI ŞEBEKE TEKNOLOJİLERİNE YATIRIM OLANAKLARI

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Son yıllarda elektrik tüketiminin minimize etme çalışmaları özellikle ulaşım, endüstri ve toplu konut alanlarında daha da ön plana çıkmıştır. Bu çalışmalar zamanla tüm dünyada'ki elektrik şebekelerinin gelişmesine aynı zamanda yeniden şekillenmesine neden olacaktır. Gelişmiş ve gelişmekte olan ülkeler, elektrik üretimini ve tüketimini dengelemek için yeni elektrik şebeke sistemlerini inşa etmeyi ve varolan şebekelerin iyileştirmeyi amaçlamaktadır. Çalışmanın giriş kısmında akıllı şebeke sistemleri hakkında kısa ve öz bilgi verilip, devamında akıllı şebeke teknoloji marketi analiz edilerek şu ana kadar yapılan başarılı akıllı şebeke uygulamarına yer verilmiştir. Buna ek olarak çalışma girişim sermayesi şirketlerinin akıllı şebeke sistemlerindeki yatırım olanaklarının incelenmesiyle son bulmaktadır.

Anahtar Kelimeler: Akıllı Şebeke Teknoloji Marketi, Akıllı Şebeke, Girişim Sermayesi Yatırımları, Piyasa İstihbaratı, Teknoloji Araştırması

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1. INTRODUCTION

Energy is the main input for human life, without energy it is not possible to create today's world. Everything surrounding us requires energy from production to consumption. It is obvious that having adequate energy is the main target for each country. Thus, energy is the main issue behind all the political concerns and wars. It is so crucial to have enough energy for both developed and developing countries to sustain their existence due to its significant impact on economy. Unfortunately, in the next future it will be harder to obtain sufficient energy for countries owing to the extensive population increase because while the population size is getting larger the more energy is needed, and to address required amount of energy becomes tougher for countries. On the other hand, the challenge of climate change is putting increasing pressure on the world's electricity network infrastructure because the existing electricity network designed when energy was at affordable price and spacious and meeting rising demand was the only dominant driver. In fact, "today main significant drivers are; energy security and reliability, increased renewable generation and reduced carbon footprint, enhanced energy flexibility and efficiency, reduced system operating costs, reduced end user consumption, consumer involvement and awareness, higher rate of innovation and creation of green tech jobs and support new applications such as electrification of transportation and distributed energy resources" (Statkraft, n.d, p. 5). In other words, the world is now at the point of transition to new era where clean energy will be at a premium, networks will need to be flexible to the corporation of new low-carbon technologies and consumers will demand greater insight and control over their own consumption. Hence, "smart grids are a necessary element to enable this transition" (World Economic Forum, 2009, p. 5). And this transition brings out government incentives on smart grid investments and collaboration between related market players, which are capable for implementing smart grid projects. Hereby, this study assesses the smart grid technology market and analyzes venture capital firms' funding on smart grid technology related start-ups at the next chapters.

In the near future energy demand expected to increase approximately by 150% due to increased electricity consumption per capita and increasing population. "The U.S Energy Information Administration (EIA) is expecting total demand for electricity in the commercial sector grows 42 percent by 2035" (Siemens, 2012, p. 2). Since current grid was built within the technology, which was found a long time ago, it has difficulties in supporting the increasing demand for power and customers' need for more information. "Over past 50 years the electricity grid evolved surprisingly little while the population has grown and the equipment using the electricity at the other end of the lines has become increasingly sophisticated" (Hicks C., 2012, p. 2). So that, in current state, the grid does not have a sufficient capability to handle robust electricity demand growth in the future.

As I mentioned in the first paragraph, smart grid integration is required due to its environment friendly feature in energy supply and consumption. It boosts renewable and distributed generation, energy storage systems and enhances energy efficiency in transmission and in energy consumption, therefore it enables to low carbon economy integration. As Spanish private multinational electric utility company Iberdrola mentions, "smart grids are emerging as the next strategic challenge for the energy sector and as a key catalyst to achieve the vision of a low carbon economy" (World Economic Forum, 2009, p. 3). Notably for European countries smart grids are key suite of technologies to achieve EU 20-20-20 targets by 2020. In short the 20-20-20 binding targets are: "20% reduction of EU greenhouse gas emissions from 1990 levels, 20% improvement of the EU's energy efficiency and increase in the share of the EU gross final energy consumption that is produced from renewable by 20%" (European Commission, 2014). From this scope, by integrating smart grid technology to current electricity network, countries can deal with future needs in the electricity sector and adopt low carbon energy technologies such as variable renewable energy sources and electric vehicles. Concurrently, smart grid enables to reduce carbon emission level as decreasing fossil fuel consumption in electricity production and transportation with efficient storage devices and electric vehicles. Consequently, smart grid is essential to combat with global warming and to avoid dramatic climate change.

The concerns for each region vary across the world, thus, it is hard to generalize the need for smart grids to a common reason. In North America, overload in transmission system and aging infrastructure causes blackouts, price volatility, cyber security threat and critical peak situations are main troubles that will be solved by smart grid deployment. In South America, the electricity distribution infrastructure needs to modernize with smart grid adoption due to consumption growth and energy theft and losses. For European countries, deregulation and distributed generation are required to create competitive electricity market for consumers and suppliers (IEA, 2011). Also, integration of renewable energy sources definitely is needed with maximum amount in order to reach 20-20-20 targets. Thus, to reach both targets; competitive market and to foster renewable share in final energy consumption, smart grids are needed among European countries. For the world`s two most powerful developing countries India and China, the concerns are similar to other regions. In India growing energy demand leads critical peak situations and increase in energy theft entails losses, however by utilizing from smart grids, peak point will be smoother and losses will be prevented. Likewise India, in China growth in energy demand and energy consumption create transmission congestion and have a negative impact on carbon dioxide (CO_2) emissions level, hence a capable and an environment friendly network infrastructure is required to be deployed (Schneider Electric, 2012).

Smart grids have benefits also in economics perspective for countries. Since most of the countries are highly dependent on energy, decreasing energy demand by smart grid applications will mitigate energy import expenditure for countries. Also, as the global population grows so does the demand for natural resources, and this causes prices to get higher. As a US study demonstrated that transmission congestion costs Eastern US consumers $16.5 billion per year higher electricity prices (World Economic Forum, 2009). The potential solutions are to add supply, reduce demand or implement combination of both. Since adding supply is costly and time consuming, it becomes far more favorable to mitigate demand, especially during peak times. According to the U.S Department of Energy's Electricity Advisory Committee, "A smart grid brings the power of networked, interactive technologies into an electricity system, giving utilities and consumers unprecedented control over energy use, improving power grid operations and ultimately reducing costs to consumers." (Siemens, 2010, p. 2), which enables electric market to become efficient and transparent with all participants has information at the same time and prices respond immediately to the current market, hence utilities and consumers will have cost benefit from smart grid technologies Apart from this benefit of smart grids, a study of multinational professional services firm Ernst Young on economic benefits of smart grid investment report advocates that smart grid development significantly more cost effective than deployment of conventional technologies in the long term, which appears as profitable investment opportunity for network operators (Ernst and Young, 2012). The other American based multinational company General Electric (GE) endorses that, smart grids offer the greatest investment opportunity in the first of half of the 21st century (Statkraft, n.d). In a wide scope smart grid integration has positive impacts on countries, utilities, consumers and investors, and in more detail the smart grid technologies as an investment tool will be explained at next chapters.

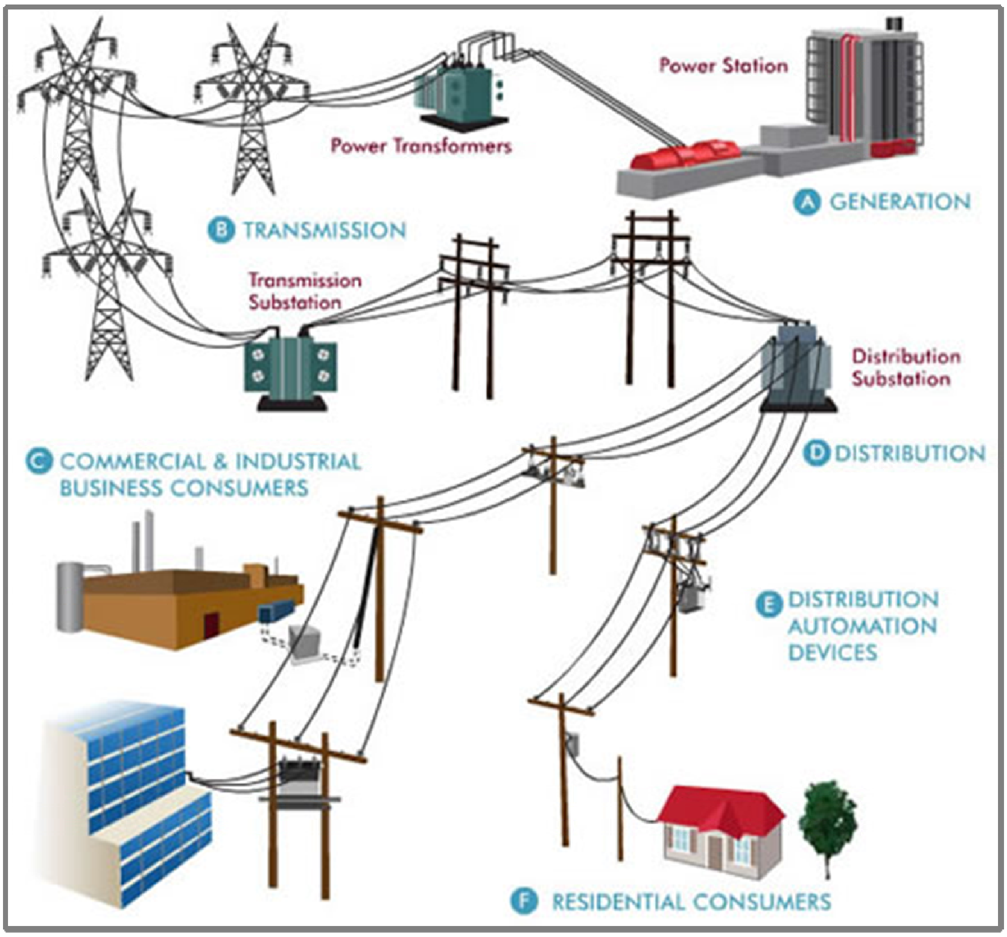
In short as International Energy Agency (IEA)'s "Impact of Smart Grid Technologies on Peak Load to 2050" report identifies, five smart grid specific drivers in the electricity sector are; demand increase, penetration of electric vehicles(EVs) and plug-in hybrid vehicles (PHEVs), deployment of variable renewable energy sources, peak load increase and ageing infrastructure (IEA, 2011). "The current grid is ill equipped to deal both conventional and unconventional sources, which are intermittent and less predictable than fossil fuel based generators. Furthermore, the current state of the grid limits the potential of energy efficiency efforts, as there are significant lags in the system such that; users of electricity typically are unaware of their usage level at any given time" (Hicks C., 2012, p. 2). Additionally, current aging network and infrastructures needed to be improved in order to meet the demand of near future generation, unless there will be frequent outages and some places even cannot feed by electricity. In this point a smarter network is required for overcoming lack of electricity on coming years (IEA, 2011). The report continues with explaining smart grid concept and delivers superior insight into market trends and analysis of the smart grid industry.

1.1. CURRENT GRID

Grid refers to electrical distribution system, which transmits electricity from the generation to the end users where it is needed. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and then converts the voltage in lower form and sends distribution lines that connect commercial and industrial business consumers, and residential consumers as shown at figure 1 (Kaplan, 2009). "The grid is dominated by centralized generation widespread limited control and one way or limited two way communication network between utilities and the end users. Residential customer energy consumption is often projected rather than measured. Grid maintenance is time based and often reinforced when system components have failure or reach their lifetime. Outage management practice relies on consumer's notification to the utility when power failure has occurred" (World Economic Forum, 2009, p. 7). Also, remarkable amount of electricity, which enters to network is lost either through technical poverty or theft that decreases the efficiency of the network and the system requires more volume of electricity to feed the consumers. According to World Economic Forum cited in Connected World Magazine the lost from inefficiencies or theft is 4-10% in Europe to more than 50% in some developing cities. And the total estimated annual cost to the US economy from power outages and power quality disturbance is over $100 billion, which can be saved through smart technologies (World Economic Forum, 2009). The current distribution grid infrastructure is primarily designed for one-way flow of electricity and limited consumption in customer side. With the growing implementation of large-scale, intermittent renewable energy generation, distributed generation and electric vehicles, it is not possible to satisfy the operations with the current network as smart grid designed to be reached.

Next to it, without providing consumers any information on how to manage electricity consumption and when to use electricity via a customer side management system, the current grid hinders to use energy less and efficient at commercial and residential buildings, which entails increase in carbon emission. Siemens Building Technologies paper declares that buildings account for approximately 40 percent of the world's energy consumption and 20 percent of total CO_2 emissions; which demonstrates the huge impact of energy consumption in buildings towards carbon emission. Hence, a smarter network is needed to add intelligent, integrated communication and full transparency to the grid. The resulting smart grid will be more efficient, more reliable, more secure and more environmentally sustainable (Siemens, 2010).

Figure 1: Electric Grid

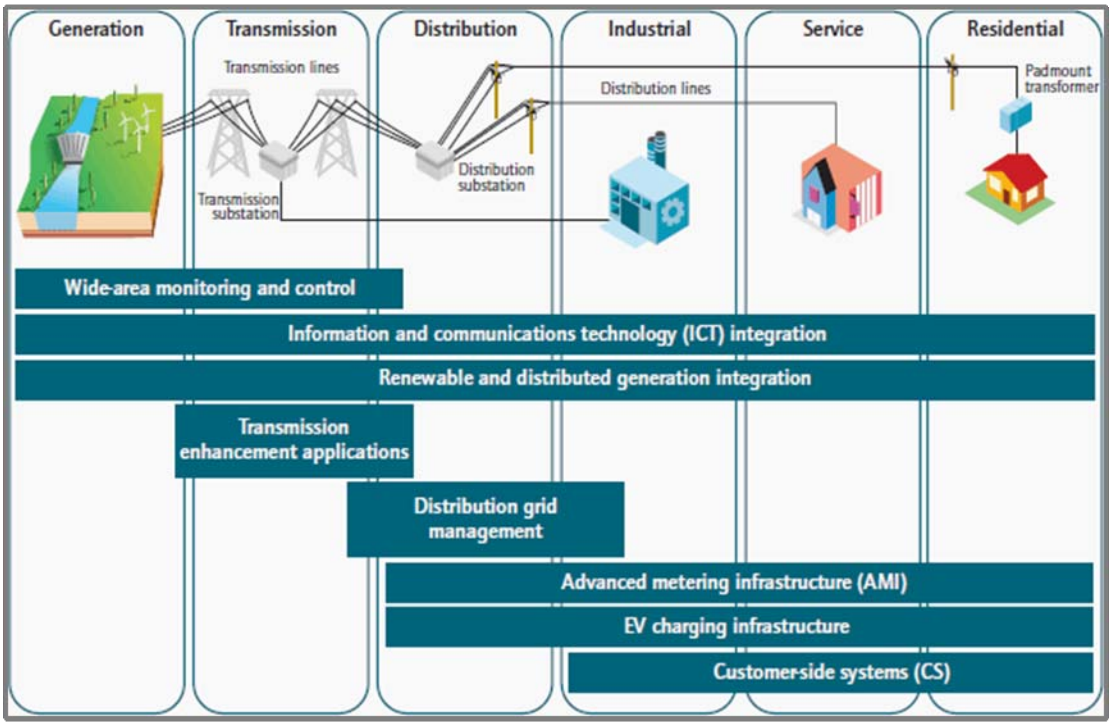


Source: Oncor.com

1.2. SMART GRID

As International Energy Agency defines, smart grids are networks that comprise advanced technologies to monitor and manage the transmission of electricity from all generation sources to meet the varying electricity demands of end users (IEA, 2011, p. 6). Smart grids are especially crucial as they are creating the platform for a wide range of advanced and low-carbon technologies such as variable renewable energies and electric vehicles. They incorporate embedded computer processing capability and two-way communication advancement to the current electricity infrastructure, which facilitate to maintain the grid in secure. Smart grids encompass a variety of technologies that span the electricity system these are: wide area monitoring, information and communications technology (ICT) integration, renewable and distributed generation integration, transmission enhancement applications, distribution grid management, advanced metering infrastructure, electric vehicle charging infrastructure and customer side systems (IEA, 2011).

Figure 2: Smart Grid Technology Areas



Source: IEA, 2011

Smart grids will use sensors and data communication systems to manage and control power inflows from thousands of distributed sources as well as the timing of power demand. With the integration of advanced metering infrastructure and demand response programs, "smart grids can reduce the peak demand by providing information and incentives to consumers to enable them to shift consumption away from the periods of peak demand" (IEA, 2011, p. 13). Also, smart grids can change the power quality for the range of needs, which will ease network. The need for customers differs according to consumption area. For instance, commercial enterprises and residential customers do not need same quality of power. Therefore, smart grids supply varying prices of power, which creates opportunities for consumers in a flexible mechanism. On the other hand, with information technology system (ICT) integration network operators will be able to obtain real time system information, which enables them to manage electricity supply and demand so that the system become flexible and maintain stable and these assists utilities to obtain maintenance savings. In addition to that, smart grids will enhance the efficiency of whole network system from generators to end users by providing information to maintain system efficient with reducing interruptions and losses, which also assists rural electrification and transforms the network to a more reliable system. The transition from current to modern utility presented by table 1.

Smart grids enable low carbon energy technologies such as; electric vehicles and variable generation technology to connect network. In this sense, it promotes energy security by increasing security of supply and combat climate change by fostering renewable energy sources, decreasing carbon emission as well as decreasing imported fuels. In this circumstance, smart grids will play a crucial role in mitigation of the greenhouse emission and energy dependence. Furthermore, smart grids enable households to integrate the network, which will increase value chain in transmission capacity and create competitive market and provide affordable price. According to expert opinion, Peter L. Corsell, Chief Executive Officer at GridPoint, “Ultimately, smart grids empower consumers by providing unprecedented visibility and control over energy usage and will change the way we all think about and buy energy. This new system will also transform the relationship between the utility and consumer from a one-way transaction into a collaborative relationship that benefits both, as well as the environment.” (World Economic Forum, 2009, p. 3)

Updating the current grid would not only improve current operations, but would also open new markets for electricity market stakeholders. Smart grid equipment and systems are provided by many industry sectors, such as electrical equipment manufacturers, ICT providers, the building industry and consumer products and service providers. A broad range of product and service providers who have not worked together in the past will have to collaborate in smart grids deployment (IEA, 2011). The collaboration is essential in order to build up precise solutions to monitor and manage the transport of electricity from all generation sources to end-users. The whole market opportunities and on-going projects will be presented at next chapters in detail.

As IEA Technology Roadmap report summarizes the vitality and benefits of smart grids, "The world's electricity systems face a number of challenges, including ageing infrastructure, continued growth in demand, the integration of increasing numbers of variable renewable energy sources and electric vehicles, the need to improve the security of supply and the need to lower carbon emissions. Smart grid technologies offer ways not just to meet these challenges but also develop a cleaner energy supply that is more energy efficient, more affordable and more sustainable" (IEA, 2011, p.6). In short, smart grids maximize system reliability, resiliency, and stability simultaneously minimize cost and hazardous environmental impact of energy consumption. Regarding these issues investments are inevitable in power grid and urban infrastructure that will effectively accommodate these technologies at large scale deployment.

Table 1: Transition to a Smart Grid

Current State	Modern Utility
Analogue/electromechanical	Digital/microprocessor
Centralized (generators)	Decentralized (generation)
Reactive (prone to failures and blackouts)	Proactive
Manual (field restoration)	Semi-automated (self-healing)
One price	Real time pricing
No/limited consumer choice	Multiple consumer products
One-way communication (if any)	Two-way/ integrated communication
Few sensors	Ubiquitous monitors, sensors
Manual restoration	Condition / performance-based maintenance
Limited transparency with customer and regulators	Transparency with customers and regulators
Limited control over power flows	Pervasive control systems
Estimated reliability	Predictive reliability

Source: World Economic Forum

2. SMART GRID TECHNOLOGIES

Since technological developments have direct impact in our lives, life is getting much easier than in the past. With smarter network system our life style will also shaped in a good way by controlling energy from the start point; production to end point; consumption. Next to this, transmission and distribution line will be more secure and efficient with less loss and disruption. There are many smart grid technology areas span the entire grid. Various technologies that enable smart grid operation grouped into eight key technology areas by International Energy Agency's "Technology Roadmap: Smart Grid" report.

Wide-area monitoring and control

"Wide area monitoring systems are essentially based on the new data acquisition technology of phasor measurement and allow real time monitoring transmission system conditions over large areas in view of detecting and further counteracting grid instabilities. Current, voltage and frequency measurements are taken by Phasor Measurement Units (PMUs) at selected locations in the power system and stored in a data concentrator every 100 milliseconds. The measured quantities include both magnitudes and phase angles, and are time-synchronized via Global Positioning System (GPS) receivers with an accuracy of one microsecond. The phasors measured at the same instant provide snapshots of the status of the monitored nodes. By comparing the snapshots with each other, not only the steady state, but also the dynamic state of critical nodes in transmission and sub-transmission networks can be observed. Thereby, a dynamic monitoring of critical nodes in power systems is achieved. This early warning system contributes to increase transmission capacity and reliability by avoiding the spreading of wide area disturbances, and optimizing the use of power system components." (Gridtech, n.d) Next to these, it facilitates deployment of variable energy resources.

Information and communication technology integration

ICT support data transmission for deferred and real-time operation, and during outages. “Along with communication devices, system control software and enterprise resource planning (ERP), to support 2-way exchange of info between stakeholders, and enable more efficient use and management of the grid” (IEA, 2011, p. 18) US Department of Energy report on “Communications Requirements of Smart Grid Technologies” mentions, many communications and networking technologies can be used to support Smart Grid applications, including traditional twisted-copper phone lines, cable lines, fiber optic cable, cellular, satellite, microwave, WiMAX, power line carrier, and broadband over power line, as well as short-range in-home technologies such as WiFi and ZigBee (U.S Department of Energy, 2010).

Renewable and distributed generation integration

“Renewable and distributed energy integration focuses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies, and demand response into the electric distribution and transmission system” (Office of Electricity Delivery & Energy Reliability, n.d). “Distributed generation (DG) refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution” (What is Smart Grid, n.d). Distributed generation is using small-scale power generation technologies typically in the range of 3 kW to 10,000 kW to provide an alternative to or an enhancement of the traditional electric power system (World Economic Forum, 2009). With the increased integration of intermittent renewable energy generation, network can present difficulties in dispatchability and controllability of these resources (IEA, 2011). However, smart grids can help through automation of control of generation and demand to ensure balancing supply and demand. Moreover, smart grids are core component for facilitating a low carbon transformation of the entire energy ecosystem.

Transmission enhancement applications

There are several number of applications for the transmission system as International Energy Agency's "Technology Roadmap: Smart Grids" report defines,

- Flexible AC transmission systems (FACT) increase controllability of transmission networks and enable maximum power transfer capability.
- High voltage DC used to connect offshore wind and solar farms with decreased losses enhanced controllability, allowing efficient use of energy sources remote from load centers.
- Dynamic line rating, which uses sensors to identify the current carrying in real time, can optimize utilization of existing transmission assets, without the risk of causing overloads.
- High temperature superconductors can significantly reduce transmission losses but there is a debate over the market readiness of the technology.

Distribution grid management

"Distribution and sub-station sensing and automation can reduce outage and repair time, maintain voltage level and improve asset management. Advanced distribution automation process real time info from sensors and meters for fault location, automatic reconfiguration of feeders, voltage and reactive power optimization or to control distributed generation. Sensor technologies can enable condition and performance based maintenance of network components, optimizing equipment performance and hence effective utilization of assets" (IEA, 2011, p. 18). Thus, this technology will prevent losses at utilities from vulnerable network blackouts by controlling the flow of energy better in terms of anticipating disruptions and resuming service quickly during an outage. And these capabilities enable operational savings for network operators. According to Galvin report in 2009, “In the U.S, interruptions in the electricity supply cost consumers an estimated $150 billion for a year” (World Economic Forum, 2009, p. 9). In this sense, advancements at distribution management have clear benefits for utilities and consumers as well.

Advanced metering infrastructure

Advanced metering infrastructure (AMI) refers to “smart” meter communication technology, which enables utilities to remotely track real-time consumption, and interact with their customers via two-way communication and provide data on electricity price to improve the efficiency of their energy consumption. Indeed, it provides not only time-of-use pricing information in near time also collects, stores and reports customer energy consumption data for any required time intervals. Eventually, end-users change their consumption attitude in response to instant price, and this reduces peak demand, provide flexibility to system. Furthermore, AMI has ability to prevent losses and theft detection with remote connection and disconnection capability (IEA, 2011). The operational and maintenance cost to the utility for the manual meter reading is very high. Beside that the conventional meter reading method has never been accurate. In the present deregulated environment, the utilities need to improve customer service and reduce their operating costs. There is a need to meter and charge the consumer in a smarter way (Ecolibrium Energy, n.d). Many utilities implementing smart meters offer services that will e-mail or text the customer when their electricity usage is nearing a price basket, allowing consumers to adjust their electricity usage accordingly.

Electric vehicle charging infrastructure

Electric vehicle charging infrastructure handles billing, scheduling and other intelligent features for smart charging with grid–to-vehicle during low demand. In the long run large charging installations will provide power ancillary services such as capacity reserve, peak load shaving and vehicle grid regulation. The technology includes interaction both AMI and customer side systems. Charging infrastructure, batteries, inverters are hardware products of electric vehicle charging infrastructure. Electric vehicles are categorized into 3. These are hybrid, plug-in hybrid and electric vehicles. According to U.S Department of Energy Vehicle Technologies Program definition, "hybrid electric vehicles (HEVs) are powered by conventional or alternative fuels as well as electrical energy stored in a battery. The battery is charged through regenerative braking and the internal combustion engine or other propulsion source and is not plugged into charge. Plug in hybrid electric vehicles (PHEVs) are powered by conventional or alternative fuels and electrical energy stored in a battery. The vehicle can be plugged into an electric power source to charge the battery in addition to using regenerative braking and the internal combustion engine or other propulsion source. Electric vehicles (EVs) a battery stores the electrical energy that powers the motor. EV batteries are charged by plugging the vehicle into an electric power source" (U.S Department of Energy, 2011, p.1).

Customer side systems

"Customer side systems are used to help manage electricity consumption at industrial, service and residential levels include energy management systems, energy storage devices, smart appliances and distributed generation. Smart routers, in-home display, building automation systems, thermal accumulators and smart thermostat are all parts of customer side systems and with those solutions energy efficiency and peak demand reduction can be accelerated. In addition to that, residential small-scale generation equipment on customer premises falls under both categories of customer-side systems and renewable and distributed energy systems" (IEA, 2011, p. 19).

Demand response term is used very often, which "includes both manual customer response and automated, price-responsive appliances and thermostats that are connected to an energy management system or controlled with a signal from the utility or system operator" (IEA, 2011, p. 19). According to a smart grid communication platform provider, "Dynamic pricing offers consumers new ways to save energy and reduce their electric bills. Home area network devices make it easier for consumers to participate in energy efficiency and demand response programs. And entirely new channels for communication, such as in-home displays, offer utilities ways to improve program performance and increase customer satisfaction" (Trilliant, n.d).

Also, IEA Technology Roadmap claims that, pilot projects have shown customer side technologies enhance the ability of smart grids consumers to adjust their consumption and save on their electricity bills. These enabling technologies also improve the sustainability of end user behavior change over time. Customer-owned smart appliances, energy management systems and electric vehicles need to communicate with the smart grid (IEA, 2011).

Multinational consulting and technology firms continue making progress in the development of solutions aimed at energy efficiency and sustainability in the field of smart grids. "The whole technology being used in smart grids enables the electricity grid to be observable, controllable, automated and fully integrated" (World Economic Forum, 2009).

Table 2 represents applied hardware, systems and software for each smart grid technology.

Table 2: Smart Grid Technologies

Technology area	Hardware	Systems and Software
Wide-area monitoring and control	Phasor measurement units(PMU) and other sensor equipment	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA), wide-area situational awareness (WASA)
Information and communication technology integration	Communication equipment (Power line carrier, WIMAX, LTE, RF mesh network, cellular), routers, relays , switches, gateway, computers (servers)	Enterprise resource planning software (ERP), customer information systems (CIS)
Renewable and distributed generation integration	Power conditioning equipment for bulk power and grid support communication and control hardware for generation and enabling storage technology	Energy management system (EMS), distribution management system (DMS), SCADA, geographic information system (GIS)
Transmission enhancement	Superconductors, FACTS, HVDC	Network stability analysis, automatic recovery systems
Distribution grid management	Automated re-closers, switches and capacitors, remote controlled distributed generation and storage, transformer sensors, wire and cable sensors	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS)
Advanced metering infrastructure	Smart meter, in-home displays, servers, relays	Meter data management system (MDMS)
Electric vehicle charging infrastructure	Charging infrastructure, batteries, inverters	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
Customer-side systems	Smart appliance, routers, in-home display, building automation systems, thermal accumulators, smart thermostat	Energy dashboards, energy management systems, energy applications for smart phones and tablets

Source: Technology Roadmap, IEA

At table 3, maturity levels of each technology area given. Some technologies have proven themselves over time, but many have yet to be demonstrated or deployed on a large scale. It is seen that the most available technologies are information and communication technology (ICT), transmission enhancement applications and advanced metering infrastructure (AMI).

No	Technology area	Maturity level	Development trend
1	Wide area monitoring and control	Developing	Fast
2	Information and communication technology integration	Mature	Fast
3	Renewable and distributed generation integration	Developing	Fast
4	Transmission enhancement applications	Mature	Moderate
5	Distribution management	Developing	Moderate
6	Advanced metering infrastructure	Mature	Fast
7	Electric vehicle charging infrastructure	Developing	Fast
8	Customer side systems	Developing	Fast

Source: IEA Technology Roadmap

When the firms are analyzed, it is seen that research companies and many firms denominate their solutions in a more detail technology areas rather than the technology areas prepared by IEA reports. Thus, starting from the smart grid market overview, which is presented at Chapter 3, the study classifies firms based on more significant technology areas. Such as, home/building automation and energy management, grid optimization, demand response, advanced metering, security, communication, data analytics, distributed generation and electric vehicle. According to IEA reports, wide area monitoring and control, transmission enhancement applications and distribution management technologies are gathered at grid optimization technology area. On the other hand, advanced metering, information and communication, and electric vehicle technology areas remain same. Also, renewable and distributed generation technology named as distributed generation.

When each category is analyzed a relation comes up. It is seen that communication firms are very important to adopt smart grid concept, which enable 2-way communication between all partners in the network generation, transmission, distribution and end user. Also security firm are crucial to provide a reliable network with preventing the system from cyber attacks. Hence, the critical nodes are seen as communication and security categories. With commonication enhancement, home and buildings can uses smart appliances and these appliances could communicate with new protocols and enable consumers to control their home with devices and learn the consumption amount. Advanced metering products collect the data by utilities and when the collected data is analysed , utilities are able to apply demand response programs in order to shift the peak demand and balance energy supply and demand. Integration of electic vehicle will reduce the fossil fuel consumption concurrently assist for load curtailment. Distributed generation, which is also called on site generation will eliminate losses or inefficiencies associated with transmission and distribution. Grid optimization firms, used to optimize equipment performance and hence effective utilization of assets. For instance; prevent losses from vulnerable network blackouts

3. SMART GRID MARKET

Many regions have already begun to “smarten” their electricity system, but still all regions will require significant additional investment and planning to achieve a smarter grid. As smart grid is an evolving set of technologies, it will be deployed at different rates in a variety of setting around the world, depending on local commercial attractiveness, compatibility with existing technologies, regulatory developments and investment frameworks (IEA, 2011, p. 6).

“Smart grid will act as a backbone infrastructure enabling a suite of new business models, new energy management services and new energy tariff structures. Smart grid will enhance the way that utilities manage assets and offer consumer relevant products and services, how consumers interact with their energy supply, and how governments respond to the challenge of maintaining security of supply and reducing carbon levels while managing costs of energy delivery” (World Economic Forum, 2009, p. 3). Therefore, study prioritizes region and country based smart grid implementation progress and continues with a brief market overview and venture capital opportunities in the market.

3.1. INTERNATIONAL PROGRESS

Governments are main decision makers in energy subject and their strategies are crucial in adapting smart grid into current network. Of course, governments alone are not sufficient to plan the best approach and set the strategies. Hence, many governments collaborate with companies to reach a wider perspective and support them to achieve the settled targets respect to the given decision. In this sense, a solid team work needs to be done between governments and companies to reach the goals and integrate smart grid technology to be part of our lives. Since market opportunities come along with output of these collaborations, a brief research is done to see the progress of countries.

The best approach for analyzing countries smart grid implementation acceleration is to begin with checking the countries' infrastructures to perceive their attempt distinctly. Table 4, represents the outputs of the regional scenarios for smart grid deployment to 2050.

Table 3: Regional Assessment

No	Country	Critical point	Situation	Solution
1	China	Have more growth electricity demand than other regions because of high economic growth	Has the opportunity to deploy smart grid technologies to better plan and design the new infrastructure that is being built	Minimize growth of electricity demand and reduce peak demand; demand response, electricity storage, EV
2	OECD Europe	Highest peak demand of the OECD regions considered; North America, Pacific	Must manage deployment within older infrastructure base and with higher deployments of variable generation technology	Deployment of distributed generation
3	OECD North America	Largest electricity market in the world	Has ageing infrastructure especially at transmission level. Increase in peak demand only %1 by 2050	Focus on: Demand Response, Transmission system monitoring and management

Source: IEA Technology Roadmap (According to Regional scenarios for smart grid deployment to 2050)

Customer applications will likely be adopted more rapidly in North America and Europe, while in markets like China the focus will be exclusively on meters and the grid. In order to see the common and different points at the United States, China and Europe analyzed more detailed by comparing the region conditions and smart grid strategies. In addition to that, smart grid applications and on-going activities in Turkey will be presented in briefly.

THE UNITED STATES

“President Obama has announced the largest single grid modernization investment in U.S. history, funding a broad range of technologies to spur the nation's transition to a smarter, stronger, more efficient and reliable electric system” (Office of Electricity Delivery& Energy Reliability, 2014). And he has named CleanTech as a driver of job creation and it can create a huge export opportunity. “The government investments that are flowing in are accelerant for adoption and contribute to establishing the smart grid reference architecture as a blueprint.” (McKinsey, 2010, p. 58) The $3.4 billion in investments of the American Reinvestment and Recovery Act had a prominent impact on market movement and created more appetite for scale across applications. However, for grid applications utilities need an economic model that makes sense for adoption of smart grid technologies. According GE representative Bob, the econometric models describing the returns for grid applications depend on a price for carbon and a price or penalty for reliability and regulatory needed to set time of use pricing for energy consumers program, and if these three things addressed well, then utilities have business case for making grid smarter (McKinsey, 2010, p. 57). From 2014 point, it is seen that policy side, regulation, legislation, and standards adopted perfectly. Hence, many startups supported by venture capital firms and expanded their products to international market, which will be proven at Chapter 4.

CHINA

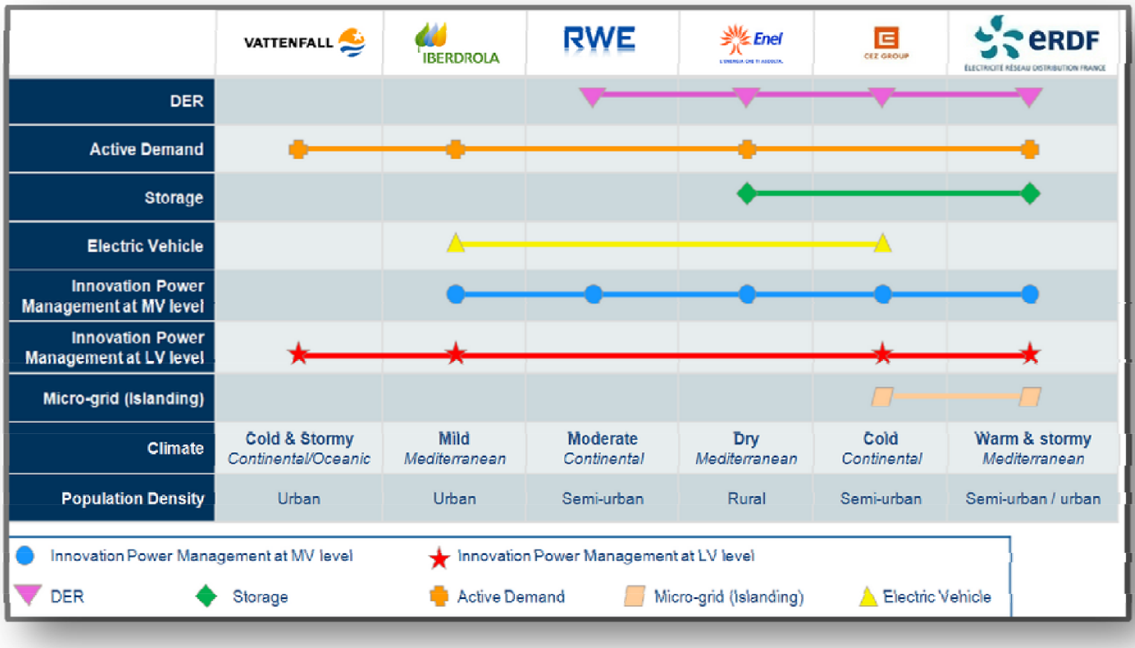
China has become the world’s largest market for power transmission and distribution and certainly it will become a major consumer of smart grid technology. The increase integration of renewable energy sources promise a massive transformation of the nation’s energy landscape. In addition to that, government’s ambitious plans have attracted top equipment makers, communication device players and integrated solution providers through the world.(McKinsey,2010, p.21) According to McKinsey report, “State Grid, the larger of China’s two state owned grid companies, has pledged to roll out a smart grid system with AMI and improved grid applications by 2020. Transmission grid applications are getting particular attention in the short term, as China seeks to develop an ultra-high voltage transmission system to improve the relay of electricity from energy-rich central and western regions to power-hungry coastal markets” (McKinsey, 2010, p. 5). Based on Bloomberg New Energy Finance’s news, China spent more on smart grids than the U.S. for the first time in 2013; with the $4.3 billion it invested accounting for almost a third of the world’s total (Downing L., 2014).

EUROPE

“The European Commission recently launched an ambitious Energy Infrastructure Package that promises to deliver the hardware aspects of a smart grid. In Europe, over €5.5 billion has been invested in about 300 Smart Grid projects during the last decade” (Frokier C., n.d).

A recent report by JRC Reference Reports cited in Pike Research forecasts that “during the period from 2010 to 2020, cumulative European investment in Smart Grid technologies will reach €56.5 billion, with transmission counting for 37% of the total amount” (Pike Research, 2011). According to the International Energy Agency (IEA), Europe requires €1.5 trillion investments in the period 2007-2030 to update the electrical system across the generation, transmission and distribution (IEA, 2008). According to Pike Research 2011, in Germany, integrated systems and smart meters have the highest share for investment and followed by home application and transmission automation (Pike Research, 2011).

Figure 3: Interactions and Synergies Between the 6 Demonstrators



In line with Germany's transition to alternative energy sources, plans call for generating 80 percent of its electricity from renewables by 2050. The associated expansion of wind, photovoltaic, and biogas generation will compel an enhanced grid infrastructure to transport electricity. To date, power in Germany has come from a limited number of large-scale plants; in the future it will be supplied by millions of small-scale distributed generators. This transition will have impacts for the existing power market, likewise anyone with panels on his roof can become a "prosumer" — both a producer and a consumer of power (Müller B., 2012).

Grid4EU is the largest smart grid project that funded by the E.U. The project positions as the base stage for the improvement of tomorrow's electricity networks. It is financed to the tune of €25 million by the European Commission, and costing

€54 Million in overall. Grid4EU brings together a consortium of 6 European energy distributors (ERDF, Enel Distribuzione, Iberdrola, CEZ Distribuce, Vattenfall Eldistribution and RWE). It tries to demonstrate the potential of smart grids in areas such as renewable energy integration, electric vehicle development, grid automation, energy storage, energy efficiency and load reduction. Grid4EU also presents example on the know-how of other industrial and scientific partners, combining with thirty or so partners from around ten different EU countries (Grid4EU, 2012).

TURKEY

Smart grid issue is taken so serious by Turkish government. Until now 3 International Istanbul Smart Grid Congress and Exhibition were held in Turkey and each congress had visitors from the Minister of Energy and Natural Resources. Prime Minister Recep Tayyip Erdoğan made opening speech in 2013 and pointing out the importance of smart grid integration to the current network. "Minister of Energy and Natural Sources Taner Yıldız, highlighted at the speech he made at the conference that distribution networks of natural gas and electricity has been expanded largely and pointed out that Smart Grids has a big importance for these networks to provide more qualitative service. Also, minister of Science, Industry and Technology Nihat Ergün pointed out that they are planning to change 35 million electricity meters with Smart Meters according to their aim plans for 2023" (CEE Enerji, n.d.). However, the government is very attentive to switch smart grid concept due to potential cyber-attacks, hence the Scientific and Technological Research Council of Turkey (TÜBİTAK) needs works about this issue regarding cyber defense systems. In addition to that, regulations needed to be set with necessary minimum conditions. On the other hand, based on the Gigaom news," Turkey will be among one of the first countries to work with a new $5.2 billion Clean Technology Fund managed by the World Bank that will provide money and loans for clean power and energy efficiency. In May 2009, the World Bank approved a project in Turkey that will use $100 million of the Clean Technology Fund resources combined with a World Bank loan of $500 million for clean power and industrial energy efficiency projects, including "smart grid solutions aimed at helping better integrate renewable resources into the transmission grid." The cleantech funds from the World Bank are also intended to start the ball rolling on local investments, so the smart grid project will likely have local and other international investors involved" (Fehrenbacher K., 2009).

In 2013, Siemens started to install the smart meters into operation at Turkish utility Enerjisa Baskent EDAS. An important aspect of the project was the integration of the existing metering infrastructure, with more than 20,000 meters from local manufacturers, in the smart metering system (Siemens, 2013). In addition to that, "Together with the strong business partner VIKO, Kamstrup has signed contract on two smart metering pilots in Turkey, with Türk Telekom Group, and the regional electricity distributor, EnerjiSA group. The two projects are among the first pilots in Turkey and are expected to be a harbinger of a Turkish Smart Grid, setting the standard for future deployments" (Kamstrup, 2013). Although, integrating smart meter to the network is a small and the beginning step of the smart grid concept, regulations need to be set and awareness needed to be created for end-users in terms of explaining smart grid concept and necessity of modern infrastructure.

Government smart grid investment programs seem very relevant after taking into account the infrastructure status for each region, when the on-going projects are considered, it is seen that needs and actions are parallel to solve the problems.

Even each region has challenging with different problems, here are the list of the main barriers for deploying smart grid, which need to overcome in order to have a transparent market for companies at the same time for investors. Since, these problems are handled; forecasts toward smart grid market can be precisely made.

According to IEA Roadmap report here are the leading barriers; (IEA, 2011)

- High cost of technologies,
- Lack of consumer awareness,
- Insufficient technological development,
- Lack of appropriate regulation,
- Insufficient or unclear benefits,
- Data privacy and protection problems,
- Lack of real life experience,
- Lack of standardization,
- Cyber Security.

And here are the actions that must be done for integrating smart grid into the network;

- Smart grids must be installed with minimum disruption to daily operation of electricity system.
- New regulations are needed, current regulatory and market system hinder deployment of smart grids.
- Public engagement is needed to ensure customer benefit from smart grids. Clear and consistent policies must be set.
- Governments, research organizations, industry, financial sector, and international organization must work together.
- Governments shy away from taking ownership and responsibility of new electricity system, which means regulations, policy and technology. They should promote smart grids.

- Large scale pilot projects are needed. Then adopt them to the local circumstances.
- Local commercial attractiveness, compatibility with existing technology, regulatory developments and investment frameworks. Thus, regulatory award utilities for helping customers' energy savings.

3.2. MARKET OVERVIEW

The smart grid sector faltered in 2013, brought in $188 million compared to $340 million in corporate and VC investment in 2012. The blazing drop was due in part to large equity investment from 2012, which most of them outlier for the sector overall. However, number of deals remained strong, demonstrating a healthy appetite for smart grid investment with one off investments based on 2012. A successful exit from grid networking and communication company Silver Spring Networks, set off excitement as the sector begins to mature. Grid optimization and distribution automation getting a lot attention in 2013; grid security and asset monitoring secure are biggest deals. The trend is shift away from purely hardware investments such as smart meters into optimization and analytic technologies. The movement away from capital intensive investments is likely responsible for the decrease in investment over last 5 years, but the interest in software enabled analytic technology has kept the smart grid sector active. The proliferation of enhanced communication capability allows real-time information to optimize and coordinate controls for intermittent distribution networks, brought on by increasing energy demands and renewable energy sources.

“The taxonomy is already starting to blur with product definitions are getting fuzzy and customers look for something that is broader”, says Eric from Silver Spring Network (McKinsey, 2010, p.59).

Recently Siemens had action in smart buildings. As it is known that smart grid provides a great opportunity for building owners, with advanced technology and integrated building systems, such as smart meters, a building can dynamically manage its own energy demand and generation, which enables cost effective electricity consumption. In order to assist all new smart solutions energy storage will be essential in smart grid concept. Energy storage systems will have a major role at a smart network with adoption of electric vehicles (EVs), plug-in hybrid vehicles and smarter buildings, due to its critical position to balance the supply and demand any given time.

Since 2010, ABB and Schneider Electric were the most active with six acquisitions each. GE and Siemens made five acquisitions each, followed by EnerNOC with four (Mercom Capital Group, 2010). GE's Grid IQ Insight platform is one of the core parts of the energy titan's plans to create an "industrial internet" or software that can link up everything from medical devices to jet engines (Greentech Media, 2013).

With energy management systems, users can improve and maintain energy efficiency and equipment performance, while maximizing operational savings and investment value. Regarding to technology layer leader companies are listed at figure 4 based on GTM Research forecast for 2015 market taxonomy in the United States.

The most prominent distributed generation firms are: A123 Sytems, Enphase Energy, SMA, Satcon, PV Powered, Balance Energy, Spara System and Direct Energy.

The leading grid optimization and distribution automation firms are: ABB, Siemens, Cisco, Telvent, GE, Schneider Electric, Current, S&C Electric Company, Cooper Power Systems, Echelon, GridSense and Areva.

The leading demand response firms are: Comverge, Honeywell, Cpower, ABB, Viridity Energy, SureGrid, World Enegy, EnerNOC, GridPoint and Ventyx.

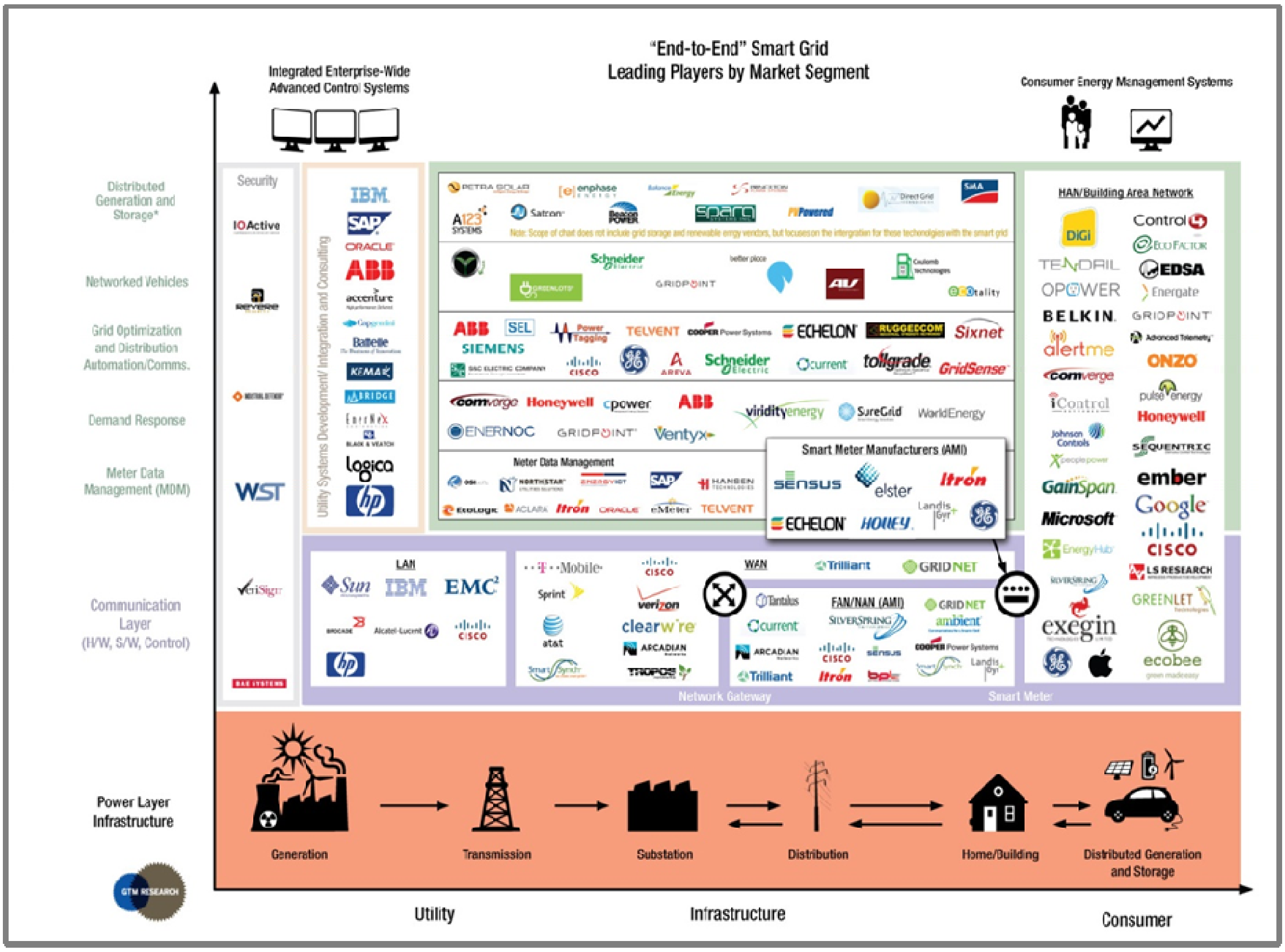
The most prominent meter data management firms are: OSIsoft, Ecologic, Aclara, Itron, Oracle, eMeter, Telvent, SAP, Northstar and Hensen Technologies.

The communication layer dividend into parts as: HAN/Building Area Network, wide area network (WAN), local area network (LAN) and advanced metering infrastructure (AMI). The leading firms at HAN/Building area network are: Belkin, Tendril, Alertme, Comverge, iControl, Ecofactor, Opower and Johson Controls. At wide area network the leading firms are: Trilliant and Gridnet. In addition to these firms leading local area network firms are: AT&T, Cisco, Verizon, SmartSynch and T-Mobile. At advanced metering infrastructure layer most important players are: Sensus, Elster, Itron, Echelon, Honey, Landis+Gyr and GE.

Next to these firms, security firms are also playing crucial role regarding the leading barriers of smart grid concept listed by International Energy Agency (IEA) studies. The leading security firms are: IBM, SAP, Oracle, ABB, Bridge, EnerNex, Logica, HP and Accenture.

The dataset, which will be provided in Chapter 4 includes the disruptive startups among these predicted firms, which presented at the taxonomy in the United States. Furthermore, the huge firm investments' are also included in the dataset, which is used for analyzing the relation between VCs and startups.

Figure 4: Smart Grid Taxonomy



Source: GTM Research

3.3. VENTURE CAPITAL OPPORTUNITIES IN SMART GRIDS

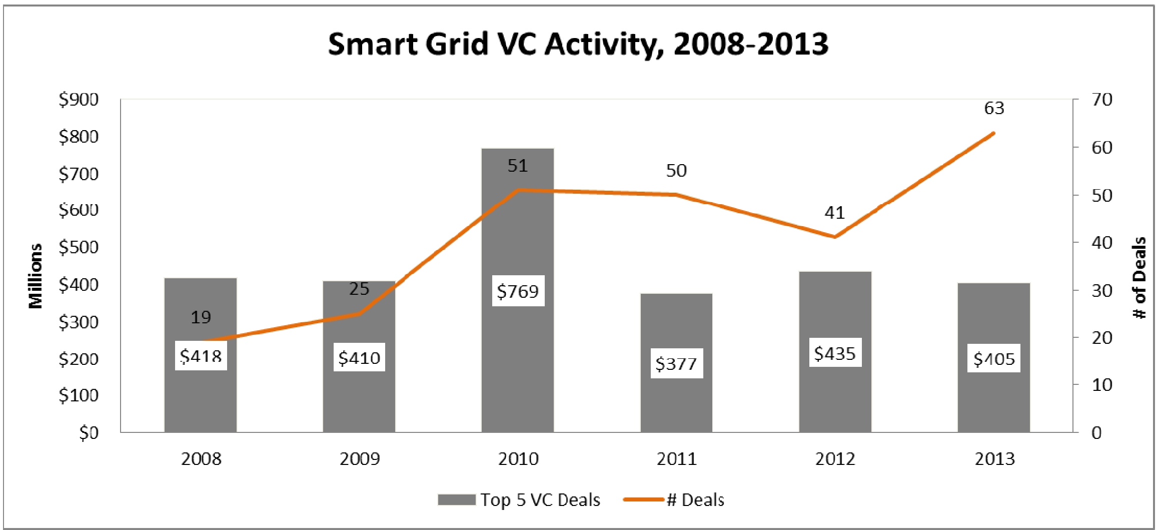
Many venture capital investment reports about smart grid market can be found on internet at such sources; GTM Research, Mercom Capital Group, I3 Cleantech Group, hence this part briefly explains the smart grid market evolution with graphs and provides some expectations gathered from released news and studies.

Regarding top 5 venture capital investments in the smart grid market had increased steadily from year 2005 to 2010 and in 2010, invested amount reached to $769 Million with 51 deals. Advanced metering infrastructure (AMI) has catalyzed new working relationships throughout the industry. Merger and acquisition (M&A) activity was also robust the sector with 40 transactions. Moreover, just four were disclosed for a total $1.3 Billion.

After 2010, total funding felt by half in 2011 even the venture capital (VC) transactions were about same as previous year, average deal size had major decrease and resulted to diminishment in investments $377 Million, as it is seen in the figure 5. As Mercom Capital points out, investors continued their interest on smart grid but with lower risk appetite. There were 30 acquisition transactions and without undisclosed transactions total amount reported as $4.6 Billion.

In 2012, after a slow start VC funding in smart grid market came to $435 Million in 41 deals, which is higher amount compared to in 2011, but number of deals decreased by 10. “Home automation companies have struggled mightily over the years to entice customers, but the convenience and savings created by the convergence of these technologies into one offering or platform might make it more appealing”, said Raj Prabhu, CEO and Co-Founder of Mercom Capital Group. A total 23 M&A transactions were executed in 2012 and amounting almost $17 Billion.

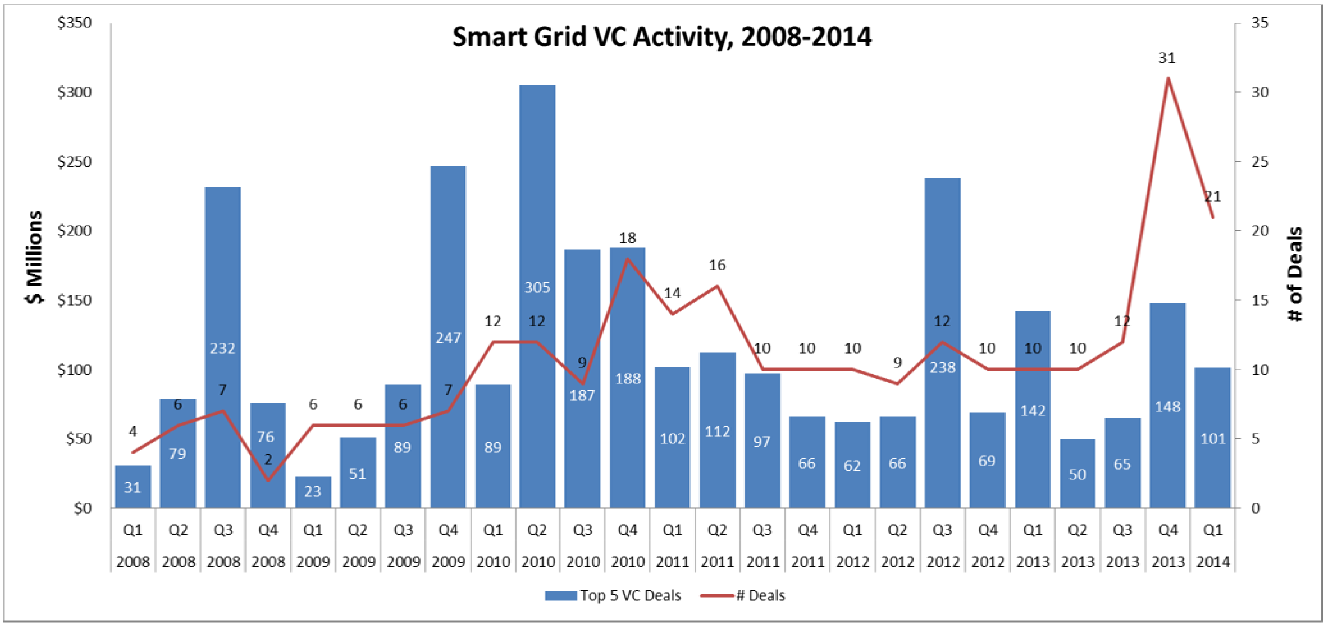
Figure 5: Smart Grid VC Activity



In 2013, venture capital funding recorded as $405 Million with 63 deals and slightly decreased compared to $434 Million in 40 deals in 2012. The dramatic decrease was due in part to a large equity investment from 2012, which acted as more of an outlier for the sector overall. “Deal activity picked up towards the end of the year, and after a long pause, IPOs have made a comeback”, said Raj Prabhu, CEO and Co-Founder of Mercom Capital Group. There were three IPOs in 2013 raising a combined $162.3 million. There were 16 M&A transactions that changed hands in 2013 and only five transactions had disclosed dollar amounts for $5.3 billion.

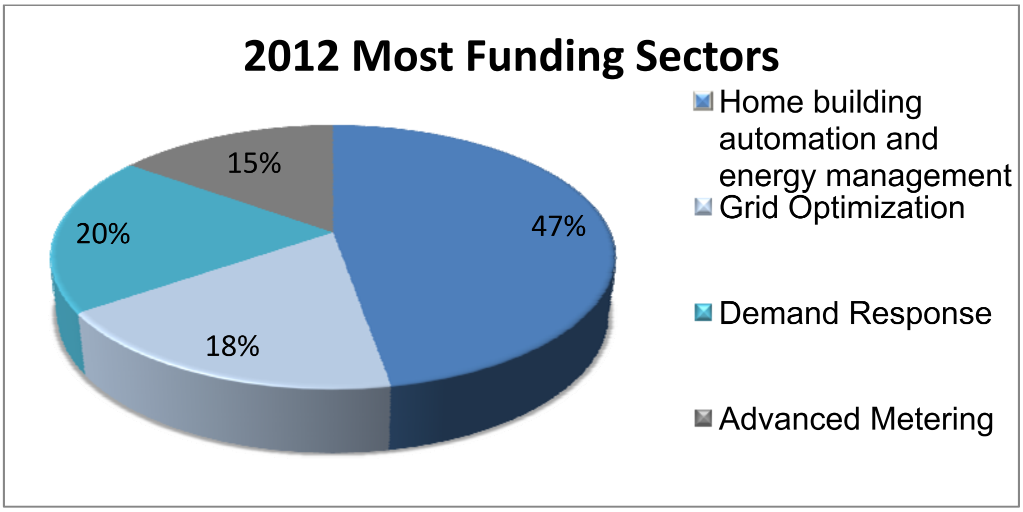
In 2014, “Funding into smart grid companies trending up the past of couple of quarters” said Raj Prabhu, CEO and Co-Founder of Mercom Capital Group. Moreover, 28 investors participated in funding rounds and $101 Million in 21 deals done next to 6 M&A transaction counted in total $3.35 Billion. In order to represent first quarter’s deal information quarterly VC activity is created, as seen in figure 6.

Figure 6: Smart Grid VC Activity(quarterly)



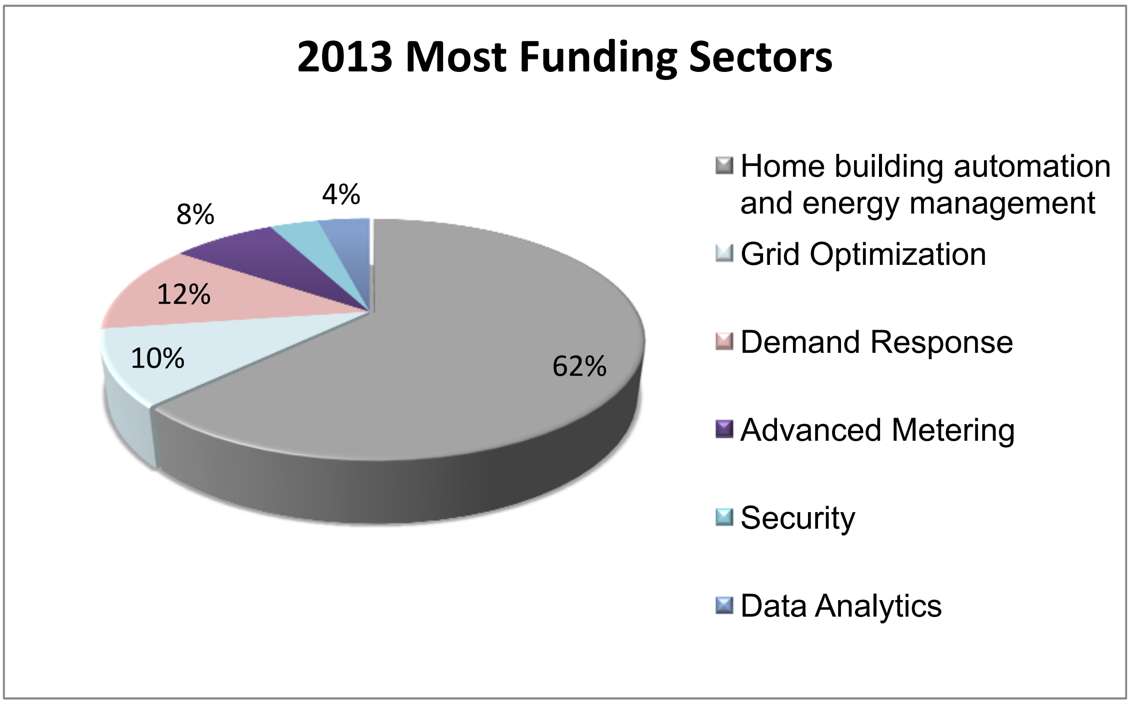
All the graphs are according to Mercom Capital Group's released report on funding and mergers and acquisition activity. In 2012, despite struggles, home and building automation companies continued to raise the majority of funding with $198 Million in nine deals. Demand response raised $82 Million in ten deals. Grid optimization brought $76 Million in nine deals, and followed by advanced metering infrastructure raised $63 Million in eight deals as presented by proportions in figure 7.

Figure 7: 2012 Most Funding Sectors



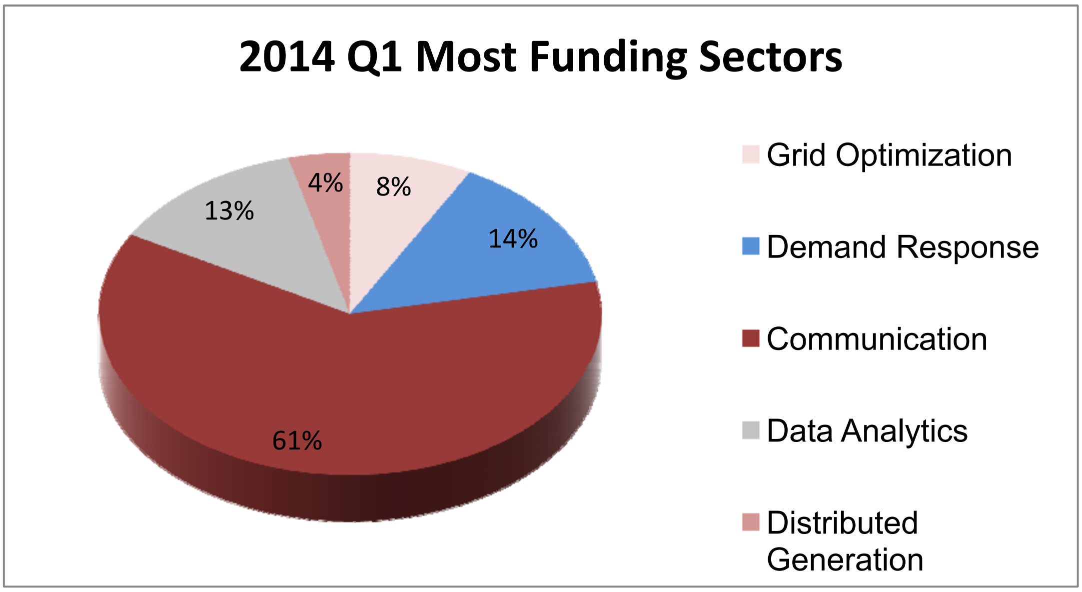
In 2013, home/building automation and energy management companies raised almost half of all VC funding with $190 Million in 24 deals. Grid optimization companies raised $51 Million in six deals, demand response companies raised $50 Million in eight deals, and AMI companies brought in $32 Million in eight deals. With about 50 million smart meters installed in the United States, there is a mountain of data for utilities to turn into useful applications, and Mercom saw three data analytics companies raising $16 Million in this area as shown their proportion in figure 8.

Figure 8: 2013 Most Funding Sectors



According to Mercom Capital report, in 2014 smart grid communication technology companies received the most VC funding raising $62 Million in 11 deals. Demand response companies raised $14 Million in three deals. Data analytics companies raised $13 Million in three deals. Grid optimization companies brought in $8.1 Million in one deal, and distributed generation companies raised $4 Million in three deals. Notably, AMI did not see any VC funding in Q1 2014. The proportion of technologies represented at the figure 9.

Figure 9: 2014 Most Funding Sectors (Q1)



After representing VC activities and most funding sectors, the study provides top 5 deals between 2010 to Q1 2014, some flashy acquisitions and IPOs at a glance. The table 6, 7, 8 was created by combining Mercom Capital, TechCrunch, Greentech Media and Crunchbase sources, and indicates top 5 deals between 2010 to 2014, acquisitions and IPOs.

Table 4: Top 5 Deals

TOP 5 VC Deals between 2010-2014 (Q1)						
NO	Company	Country	Funding Type	Amount ($M)	Investors	Year
1	Landis+Gyr	Switzerland	Growth Equity	$165	BAYARD CAPITAL PARTNERS, DLJ MERCHANT BANKING PARTNERS	2010
2	Trilliant	USA	Series B	$106	INVESTOR GROWTH CAPITAL, GE, ABB, VANTAGEPOINT CAPITAL, ZOUK CAPITAL, MISSIONPOINT CAPITAL PARTNERS	2010
3	OpenPeak	USA	Series C	$52	MILLENNIUM TECHNOLOGY VALUE PARTNERS, INTEL CAPITAL	2010
4	Brightsource Energy	USA	Series D	$150	DFJ GROWTH, VANTAGEPOINT CAPITAL,DRAPER FISHER JURVETSON,MORGAN STANLEY	2010
5	Solyndra	USA	Series F	$286	Undisclosed	2010
6	iControl Networks	USA	Series D	$51.60	INTEL CAPITAL,COMCAST VENTURES, IFUND, CHARLES RIVER VENTURES, TYCO INTERNATIONAL, ROGERS COMMUNICATION, CISCO	2011
7	SmartSynch	USA	Undisclosed	$25.70	Undisclosed	2011
8	Silver Spring Networks	USA	Undisclosed	$24	GSV CAPITAL, EMC	2011
9	GridPoint	USA	Private Equity	$23.60	Undisclosed	2011
10	Joulex	USA	Series B	$17	TARGET PARTNERS, TECHOPERATORS, FLYBRIDGE CAPITAL PARTNERS, INTEL CAPITAL, SIGMA PARTNERS	2011
11	Alarm.com	USA	Undisclosed	$136.00	ABS CAPITAL PARTNERS, EQUIS CAPITAL PARTNERS, NJTC VENTURE FUND,TECHNOLOGY CROSSOVER VENTURES	2012
12	Silver Spring Networks	USA	Undisclosed	$30	HITACHI	2012
13	Tendril	USA	Undisclosed	$25	VANTAGEPOINT CAPITAL, GOOD ENERGIES, RRE VENTURES, GE, SIEMENS	2012
14	GridPoint	USA	Undisclosed	$25.30	Undisclosed	2012
15	Comverge	USA	Undisclosed	$16	TRIANGLE CAPITAL CORPORATION	2012
16	Nest	USA	Series C	$80	GOOGLE VENTURES, VENROCK	2013
17	Utilidata	USA	Series B	$20.50	BRAEMAR ENERGY VENTURES,AMERICAN ELECTRIC POWER, FORMATION8,SAUDI ARAMCO ENERGY VENTURES	2013
18	Space-time Insight	USA	Series C	$20	ZOUK CAPITAL,OPUS CAPITAL,ENERTECH CAPITAL,NOVU SENERGY PARTNERS	2013
19	Enlighted	USA	Series C	$20	ROCKPORT CAPITAL, KLEINER PERKINS CAUFIELD AND BYERS,DRAPER FISHER JURVETSON,DRAPER NEXUS VENTURES, INTEL CAPITAL	2013
20	GreenWAVE	USA	Series B	$19	THE WESTLY GROUP, CRATON EQUITY PARTNERS	2013
21	Sigfox	France	Series B	$20.60	FSNPME,ID INVEST PARTERS, INTEL CAPITAL, ELAIA PARTNERS, PARTECH VENTURES	2014
22	Enverv	USA	Series C	$15.40	WALDENINTERNATIONAL, CISCO, UMC CAPITAL, CASSIOPEIA CAPITAL,BENCHMARK, NEWENTERPRISEASSOCIATES,	2014
23	SWG	USA	Series B	$13.40	RIVERVEST VENTURE PARTNERS	2014
24	AutoGrid	USA	Series C	$12.80	EON, FOUNDATION CAPITAL, VOYAGER CAPITAL	2014
25	Grid20/20	USA	Undisclosed	$8.10	Undisclosed	2014
Source: Mercom Capital and Crunchbase						

Table 5: Acquisitions

Company name	Investors	Amount	Date
VENTYX	ABB	$1,000,000,000	2010
ARCHROCK	CISCO	$100,000,000	2010
EKASYSTEMS	COOPER INDUSTRIES	$266,000,000	2010
CPOWER	CONSTELLATION ENERGY	$78,000,000	2010
EMETER	SIEMENS	$220,000,000	2011
TELVENT	SCHNEIDER ELECTRIC	$2,000,000,000	2011
SUMMITENERGY	SCHNEIDER ELECTRIC	$269,000,000	2011
ENERGYCONNECT	JOHNSON CONTROLS	$32,300,000	2011
COMVERGE	HIGCAPITAL	$49,000,000	2012
SMARTSYNCH	ITRON	$100,000,000	2012
LANDISGYR	TOSHIBA	$2,300,000,000	2012
EMBER	SILICONLABS	$72,000,000	2012
VIVINT	BLACKSTONE GROUP	$2,000,000,000	2012
POWERONE	ABB	$1,000,000,000	2013
NESTLABS	GOOGLE	$3,200,000,000	2013
CONSERT	TOSHIBA	$11,000,000	2013
JOULEX	CISCO	$107,000,000	2013
ACLARATECHNOLOGIES	SUN CAPITAL PARTNERS	$135,000,000	2014

“Acquisitions are increasing and will continue to shape the landscape in the coming years. Large, established, global companies are expanding product portfolios to stretch across smart grid categories with the goal of providing end-to-end solutions to utilities and other large customers” (Cleantech Group, 2010, p. 3).

Table 6: IPOs

Company name	Year
A123SYSTEMS	IPO 2009
TESLA MOTORS	IPO 2010
BRIGHTSOURCE ENERGY	IPO 2011
ENPHASE	IPO 2012
SOLARCITY	IPO 2012
SILVER SPRING NETWORKS	IPO 2013
CONTROL4	IPO 2013
OPOWER	IPO 2014

TechCrunch media’s news, declares VC funding for startups at the highest point in more than a decade, according to both studies by MoneyTree and DFJ Venture Source, capital raised from venture capitalists by growing, private companies is at its highest point since 2001. It is not determined, which group has it more right, however, “huge dollar amounts are on hand at the moment, as investors look to pour capital into companies of all stages while the NASDAQ is high, the IPO window is open, and cash-rich industry giants are more than willing to buy talent and products alike” (Wilhelm, 2014). Within the two studies scope, the future for startups and investors is supposed to be more active in smart grid market as well.

4. SMART GRID ANALYSIS OF VENTURE CAPITAL INVESTMENT WITH A NETWORK APPROACH

A venture capital firm invests its shareholder’s money in startups or early stage companies that risky but potentially very profitable ventures. The venture capital fund earns money by owning equity in the companies it invests in, which usually in high technology industries, such as biotechnology, IT and software. During the fund transactions it gains money from fund operating services, however the biggest revenue comes from company exists, but also bears the highest risk potential, when implementing a strategy. Thus, in order to provide precious insight for venture capital firms, a data set is created to analyze smart grid market in terms of company exists and mobility, and to predict potential exits.

4.1. DATA COLLECTION

The data set combines 5 different sources, and all provides list of disruptive and most innovative companies leading in smart grid sector, which backed by venture capital firms or acquired by giant companies after venture capital funding. Since venture capital firms attempt to sell their portfolio companies’ equities to big powers, adding data of energy companies that acquire startup will be beneficial to see the interaction between venture capital firms and energy companies among investments. Hence, investors include giant energy companies next to venture capital firms. While doing data research, it is observed that U.S based venture capital firms and smart grid market exits at U.S market are highly available to reach so that the data set includes U.S firms at most.

Data sources with brief definitions are; Greentech Media (GTM), which produces industry-leading news, research, and conferences in the business-to-business greentech market, GTM Research, the research arm of the company, produces competitive intelligence reports, data subscriptions, and strategic consulting, ERB Institute, who is committed to creating a socially and environmentally sustainable society through the power of business, Mercom Capital who is a thought leader and highly respected for its in-depth knowledge in cleantech and healthcare information technology marketplaces and Gigaom, who provide deep insight on disruptive companies, people and trends. Indeed, data sources are used to create the list of smart grid technology related companies.

Firstly, the Greentech Media's report on smart grid industry called "Grid Edge 20" list is used where a selection of twenty technology vendors that have significant existing market traction and are well positioned for the imminent technology and industry transformation. Secondly, the innovative companies are taken from Greentech Media's news on March 27, 2013 about Greentech Media Research (GTM) Innovation Award 2013 study "The Networked Grid 150 : The end to end smart grid vendor ecosystem report and rankings 2013". Thirdly, Mercom Capital Smart Grid reports on top 5 VC deals from 2010-2014 Quarter 1 are used. Fourthly, Giagom's list that prepared at 2010 on smart grid market acquisitions is examined and venture capital backed companies are taken. Lastly, ERB Institute, University of Michigan MBA/MS 2012 study on smart grid paper "Where we are today and what the future holds" analyzed and venture capital backed key companies are taken into the data set.

After listing the company names, some venture capital databases primarily CrunchBase, CB Insights, and company press releases are exploited to find investors and to have deeper knowledge about the investments. Furthermore, latest technology news and information online sources such as, TechCrunch, Business Wire, Cleantech Investor, VCCircle, Link Silicon Valley are used to reach a complete dataset.

4.2. DATA ANALYSIS

In total the dataset consist of 95 firms and 343 investors with investment type of acquisitions, grants, private equities, growth equities, tax equities, post initial public (IPO) equities and venture funding at the years between 2002 and 2014 first quarter. Each firm is categorized as follows,

- Category 1: Home/building automation and energy management
- Category 2: Grid optimization and distribution automation/communication
- Category 3: Demand response
- Category 4: Advanced metering
- Category 5: Security
- Category 6: Communication
- Category 7: Data analytics
- Category 8: Distributed generation and storage
- Category 9: Electric vehicles
- Category 10: Category 1, 3
- Category 11: Category 2, 4

Among 95 firms, 8 firms went to IPO and only 18 firms were acquired. Due to 7 of acquired firms has no depth information such that 5 of them has no venture funding info and 2 of them has 1 investor, which is not related with other investors, it is not possible to explain firms centrality effect on their acquisition possibility with a graph theory and network analysis. However, the study tries to figure out the movements and relations between firms and investors.

Table 9 represents the number of transactions per year from 2002 to 2014(Q1)[1] based on the dataset, which includes almost all striking investments. Respect to table 9, it is observed that after year 2004 transactions increased and the maximum level reached at year 2010 with a total of 110 transactions. Although there is a quite decline in year 2012, in 2013 number of transactions increased. Furthermore, 49 transactions in the first quarter of 2014 indicate slightly declining investment trend in smart grid technology firms that presented by Mercom Capital's funding and M&A report, which is provided at Chapter 3.1.

Table 7: Transactions per Year

Year	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
# of transaction	6	3	21	45	50	66	70	104	110	89	107	49

On the other hand, to understand which categories are funded at most, table 10 is created and respect to it home/building automation holds the most investors after distributed generation. It is not surprise that distributed generation is the leader among others due to governmental supports such as incentives and granted programs, interaction with electricity generator companies. End user related technologies basically home/building automation and energy management demand response are combined by most of the firms who has enough purchasing power. Unless a firm has enough power to purchase or develop other related technology which is required in order to demonstrate its product benefits to end user, then partnership programs are used between firms very commonly. Therefore, categorization domain needs to be considered carefully to make an accurate

[1] First quarter

judgment, because a firm may include more than one technology or enable other technologies as well.

Table 8: Number of Investors per Category

Category	1	2	3	4	5	6	7	8	9	10	11
# of investors	97	30	22	7	7	91	36	148	21	36	4

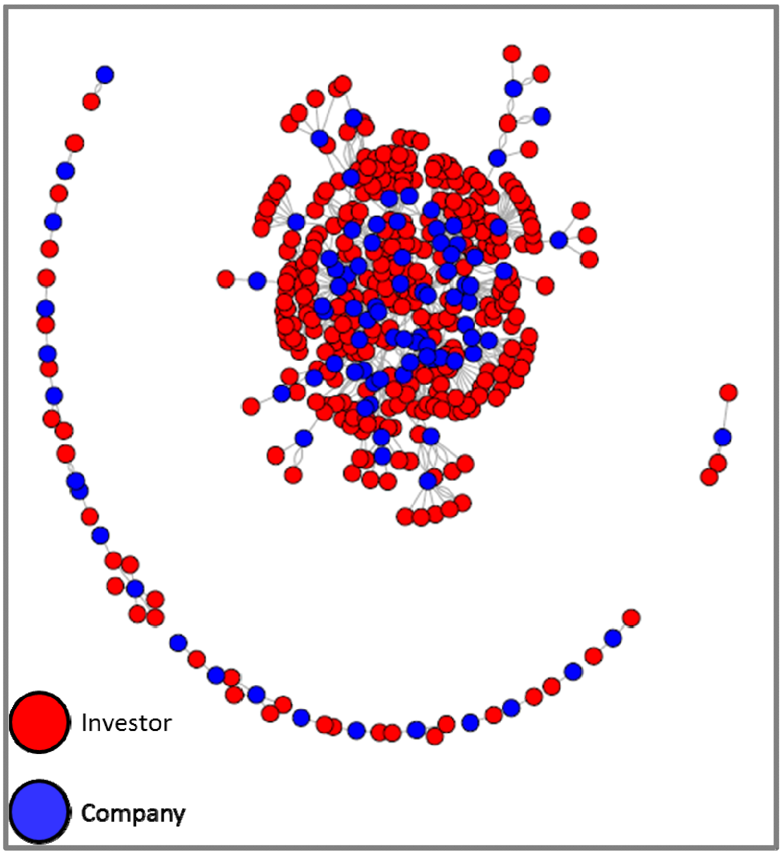
4.3. BUSINESS NETWORK

This section is the key component of the study in determining mobility of smart grid technology market. Networks are created by using RStudio, which provides open source and enterprise-ready professional software for the R statistical computing environment. It is believed that network analysis is a reasonable solution to make powerful predictions instead of implementing statistical verification owing to insufficient company exits.

4.3.1. ENTIRE NETWORK

At first, while drawing network all the transactions are taken at the years started 2002 until 2014’s first quarter. However, it is not possible to interpret the generated bipartite graph shown at figure 10 due to recurring investments by same investors to same firms. Therefore, networks are plotted year by year in order to reduce complexity of graph, and then relationship between firms and investors for each year are examined. Next to that firm-firm and investor-investor networks are created to catch better cluster patterns.

Figure 10: Bipartite Graph of Investors and Firms 2002-2014 (Q1)



While plotting networks, vertices are colored in order to gain information on market intelligence of smart grid technologies. That's why, for color standardization figure 11 is created, it uses same category definitions, which are set at previous Chapter 4.2. In total the dataset includes; 20 home/building automation and energy management 13 grid optimization, 7 demand response, 3 advanced metering, 2 security, 13 communication, 8 data analytics, 20 distributed generation and 1 electric vehicle firms with 6 combination of home/building and energy management and demand response solution providers, 2 combination of grid optimization and advanced metering solution providers, as it is illustrated at table 11.

Figure 11: Category Representation with Colors

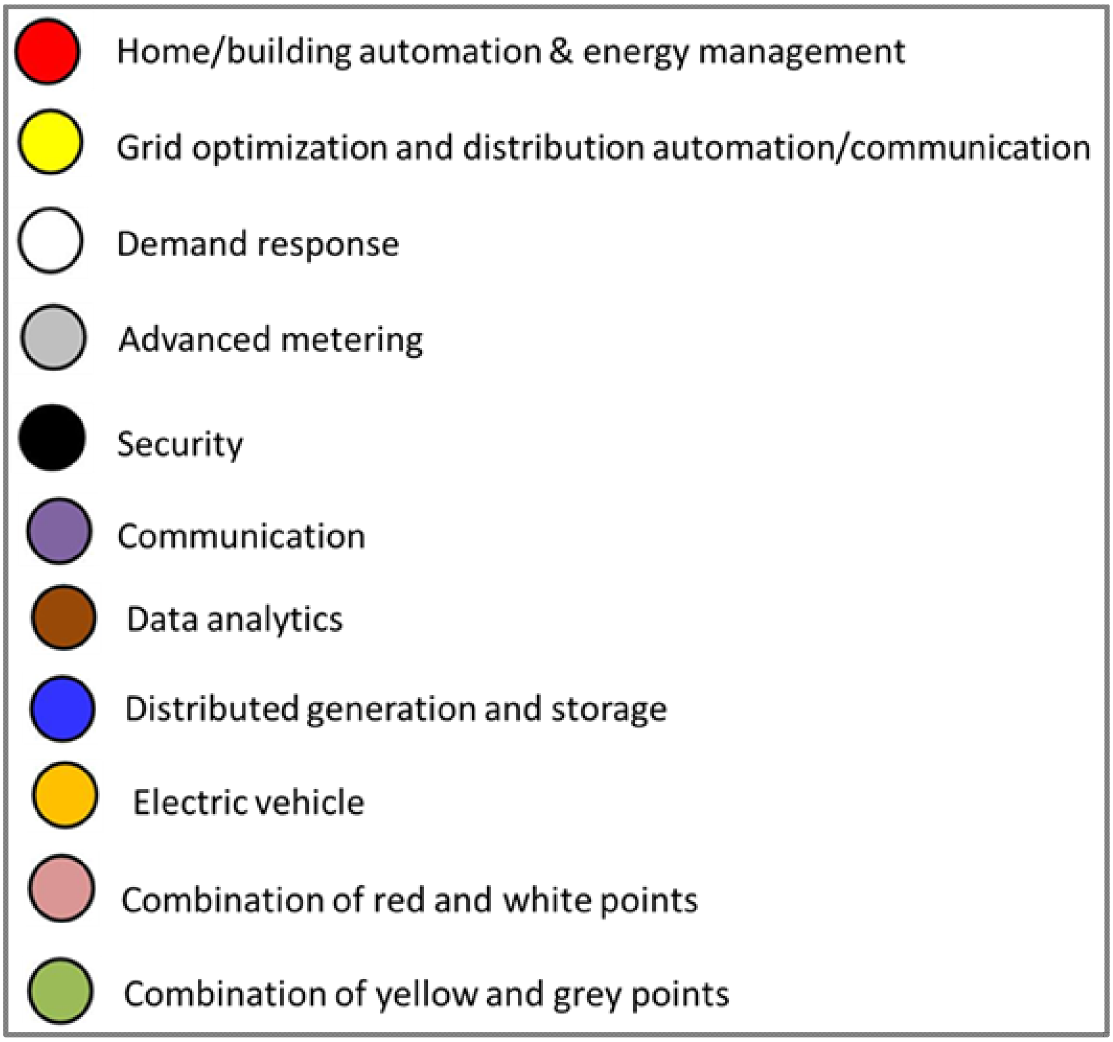


Table 9: Number of Firms per Category

Category	1	2	3	4	5	6	7	8	9	10	11
# of firms	20	13	7	3	2	13	8	20	1	6	2
color	Red	Yellow	White	Grey	Black	Purple	Brown	Blue	Orange	Pink	Green

On the below figure 12, firm network is shown and created by using all firms in the dataset from year 2002 to 2014. The colorful vertices represent firms and edges represent common investors that linked firms each other. It includes lots of clusters in the center area except outer vertices, which shows amount of disconnected firms with 21 firms out of 95. Actually, the firms at the center show how investors are correlated by creating connections between firms despite having numerous investors in the market. In detail, from 2002 to 2014 communication, home/building automation and energy management, and distributed generation firms are close to each other, which indicate existence of common investors between these categories.

Figure 12: Firm Network Between 2002 – 2014 (Q1)

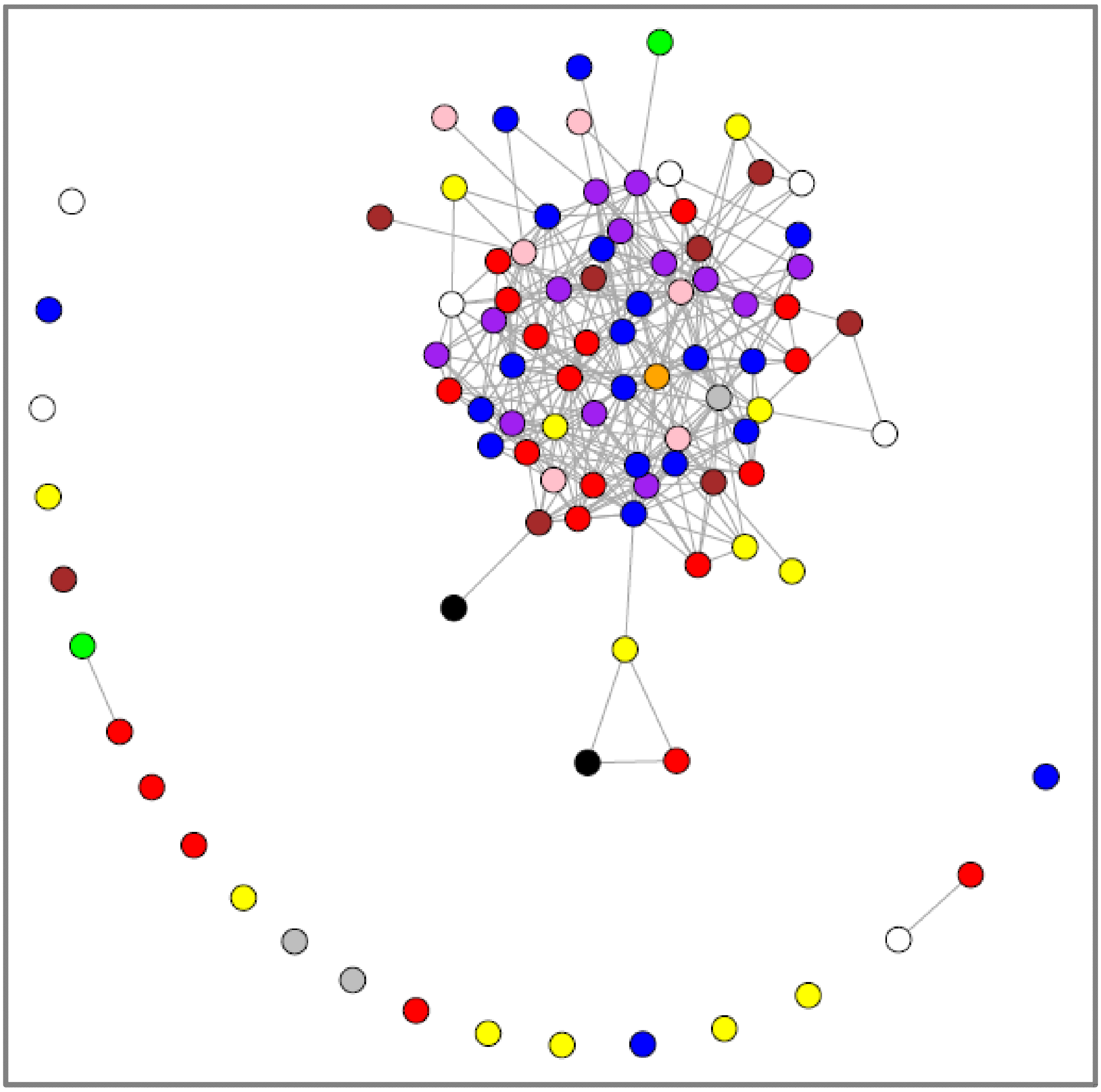
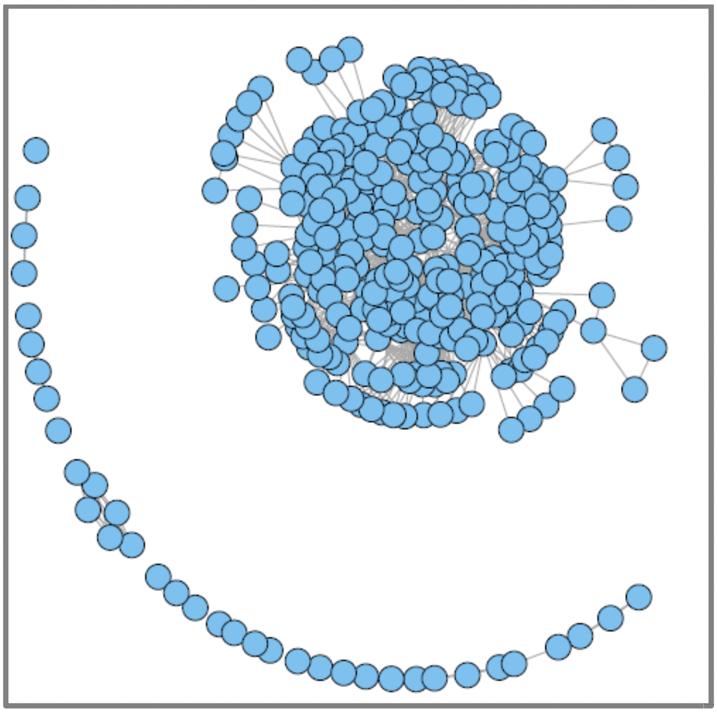


Figure 13 represents the investor network in the whole dataset from 2002 to 2014(Q1). It is seen that 36 investors are outer side of the network among 343 investors. However, due to overlapped years, density of network is so high, it is not sufficient to make analysis. As a further step a detailed observation required in order to come up with more points for a better comprehension. Thus, yearly network analysis is done and can be founded as follows.

Figure 13: Investor Network Between 2002 – 2014 (Q1)



4.3.2. YEARLY NETWORK

The study provides yearly networks from 2005 to 2013 to give a comprehensive output. Since the year 2014 has not ended, only first quarter of the 2014 can be reachable, and it cannot be used for interpreting the whole year with the limited data for this reason the network of 2014 is not represented. Also year 2002 and 2004 are not displayed in the network analysis, due to insufficient data with having 9 transactions in total with 3 firms and few investors who do not demonstrate any relation.

The bipartite graph of 2005 (Figure 14) indicates that none of the investors invested in multiple projects (See Appendix 1). Hence, there is no relation between firms as figure 15 demonstrates. There are 5 firms; two communication firms, one distributed generation, home/building automation and energy management, and an electric vehicle in the firm network. In total, number of investors are 21 and average investor per project is 4.2 in 2005. Communication firm SmartSynch was the leading startup with the ten investors followed and by home/building automation firm Control4 with four investors.

Figure 14: Bipartite Network 2005

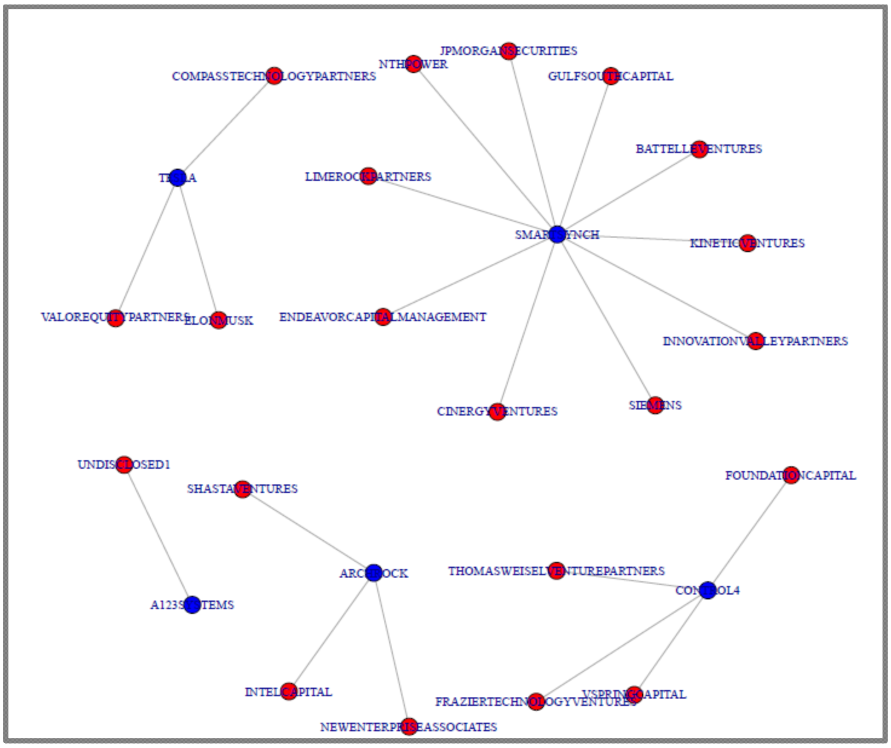


Figure 15: Firm Network 2005

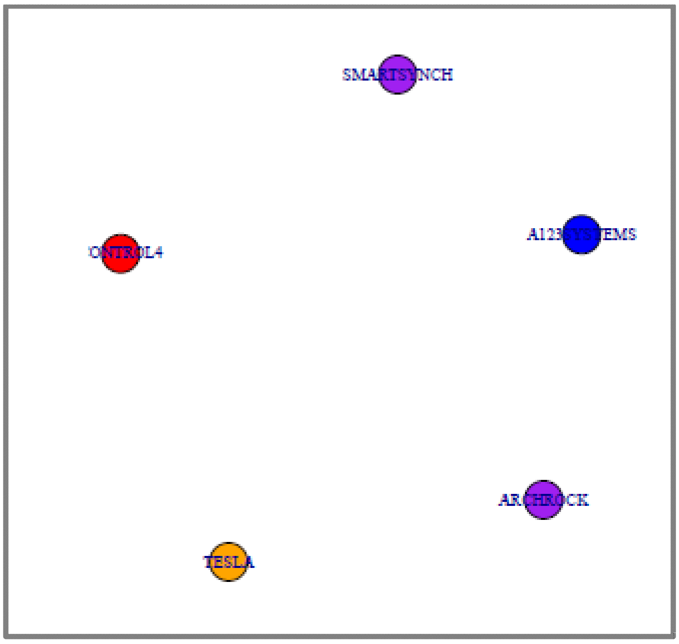
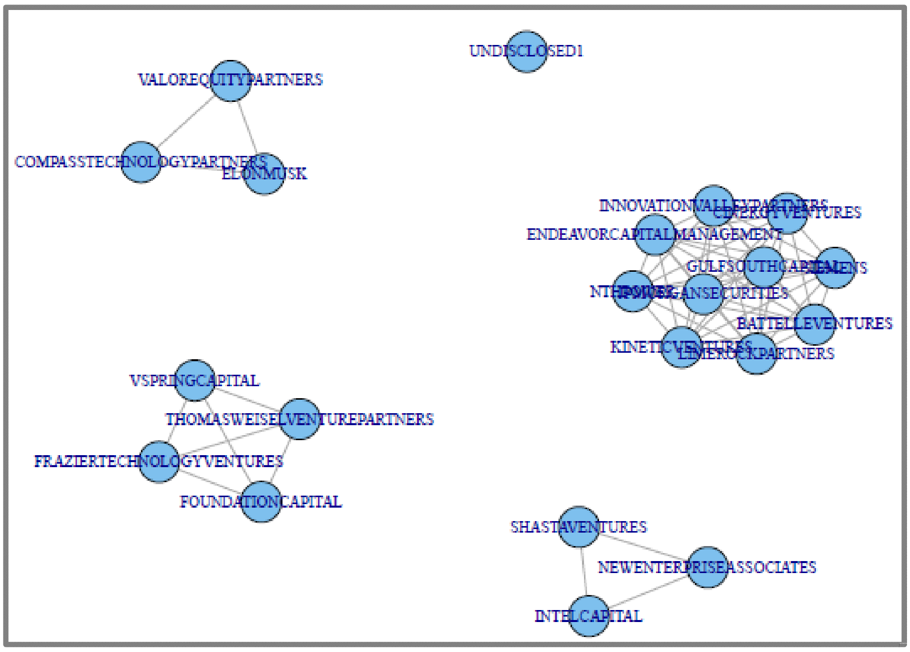


Figure 16: Investor Network 2005



In 2006, first clustering started as it is seen on figure 17. 4 investors created clusters around founded firms, which were created via 4 investors funding at 2 different firms (See Appendix 2). The invested firms are creating subgraph in figure 18, these are SolarCity, Ember, Tesla Motors, BrightSource Energy and OpenPeak. Numbers of firms increased from 5 to 11, with the addition of SolarCity, Ember, OpeanPeak, Tendril, iControl, GridPoint, Sentilla, SynapSense and BrightSource Energy. However, Archrock, Smartsynch and Control4 did not receive any funding respect to previous year. According to figure 18, home/building automation and energy management, demand response and distributed generation were active in the market. And Tesla was key firm that located in the middle and linked other firms.

Figure 17: Bipartite Graph 2006

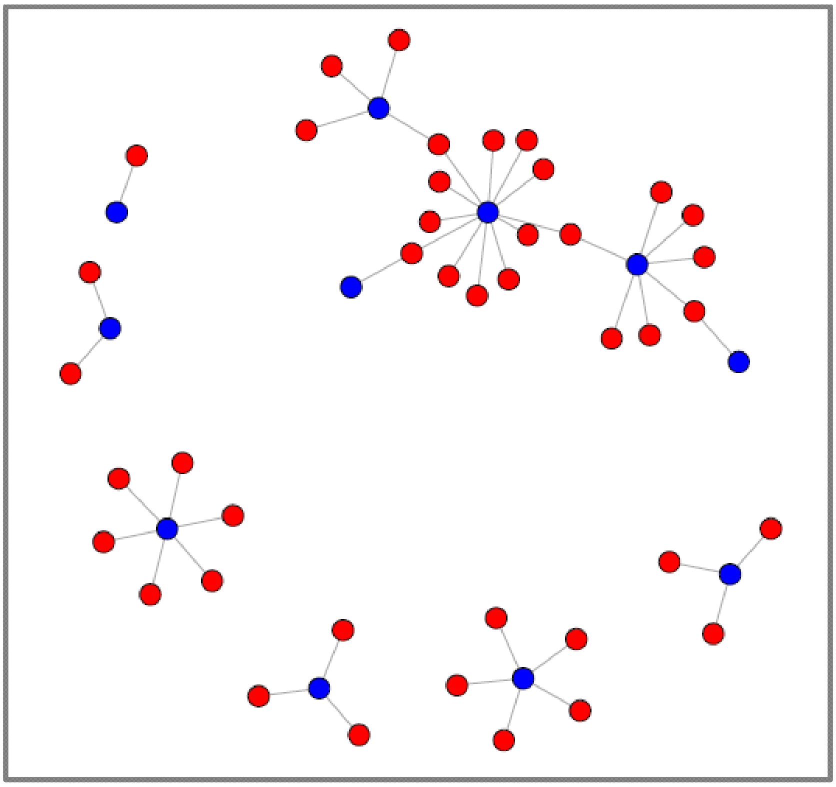


Figure 18: Firm Network 2006

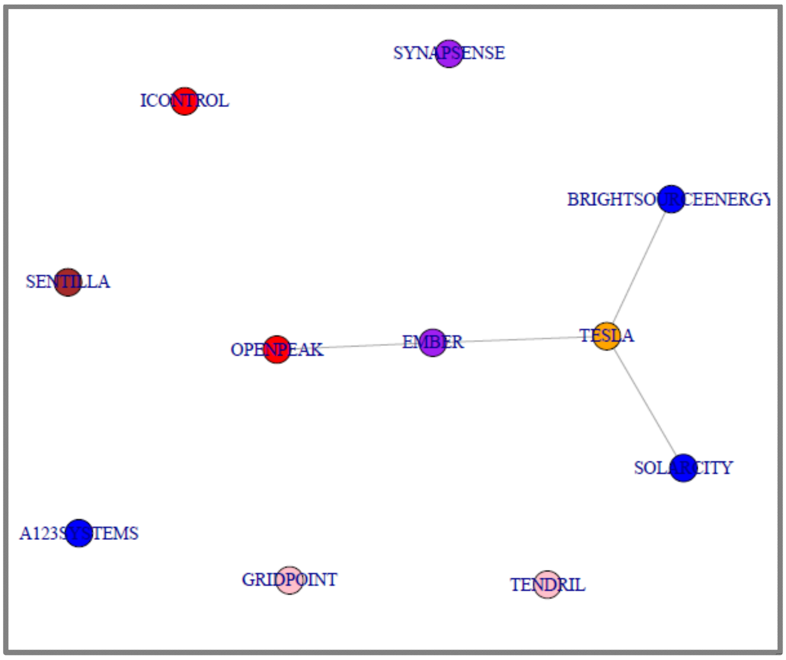
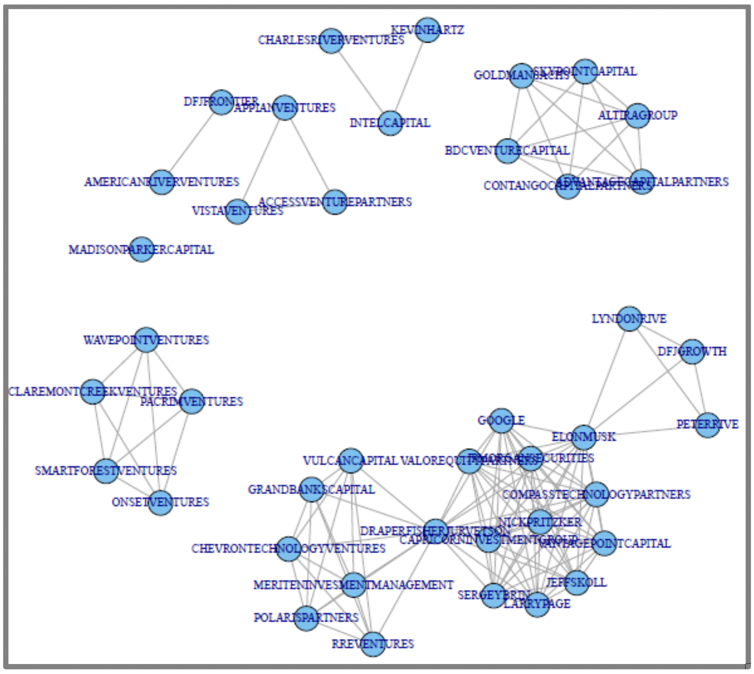


Figure 19: Investor Network 2006



In 2006 investor clusters escalated and investor numbers increased from 21 to 41. Also length of the subgraph is extended, as illustrated in figure 19. Average investor per project is 3.72.

The bipartite graph of 2007 shows a similar pattern compared to 2006 (See Appendix 3) and number of investors and projects slightly increased respect to 2006. The number of subgraph increased to 2 and all firms in the subgraph changed based on previous year, as seen at figure 21. Ice Energy, GridPoint and Arch Rock came together and at the same year Control4 and eMeter was supported by common investor. Distributed generation firms were active with Xtreme Power, Ice Energy and Sungevity. Also, demand response firms occurred with Ventyx and CPower, in addition to advanced metering firm eMeter.

Figure 20: Bipartite Graph 2007

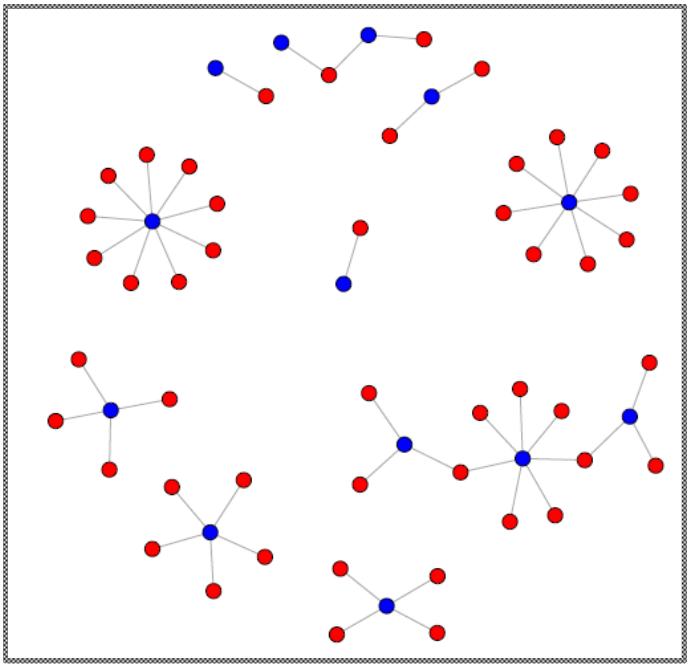
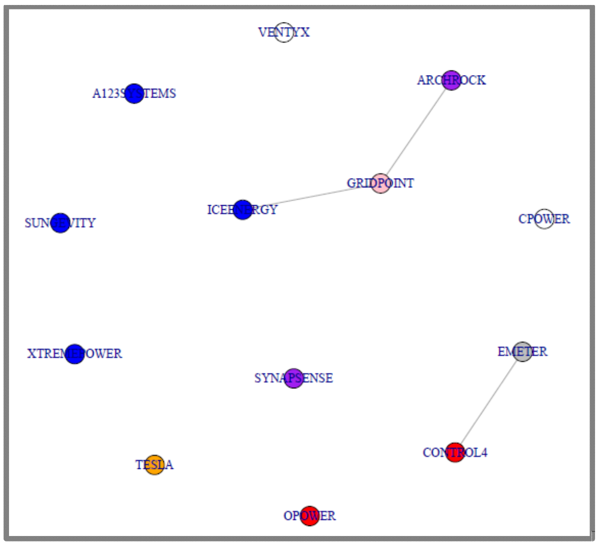
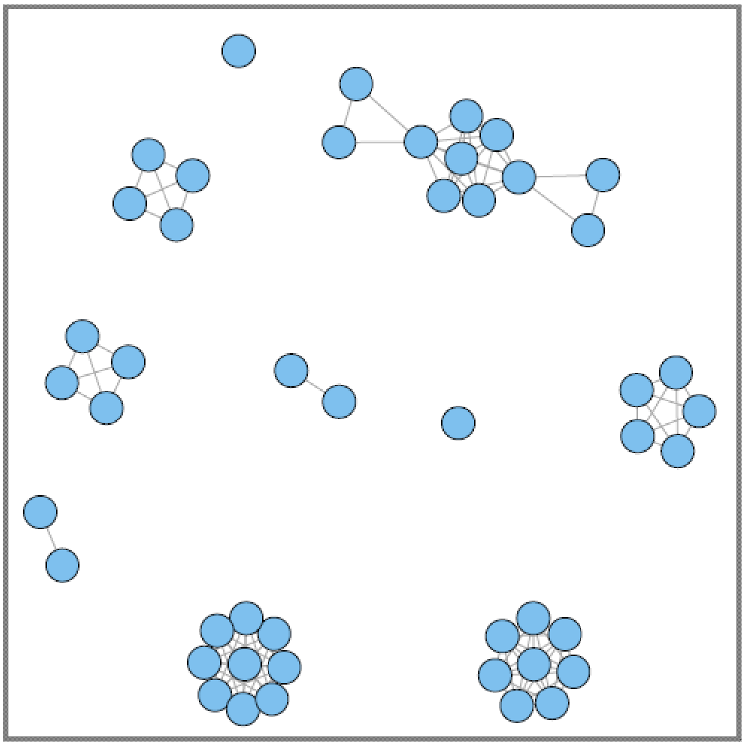


Figure 21: Firm Network 2007



When figure 22 is analyzed, it is seen that most of the firms were funded by more than one investor, and the observation proven with average investor per project 3.61 data.

Figure 22: Investor Network 2007



In 2008, the number of subgraphs increased, as it is represented in figure 23. 3 subgraphs are observed and all occurred in different way (See Appendix 4). For the first time, an investor funded 3 firms at the same year, and for the first time a firm connects two subgraphs. There are 2 investors who founded 3 firms and created a long subgraph. The other special case is that the double edges between firm and investor indicates multiple funding activities in a year.

Figure 23: Bipartite Graph 2008

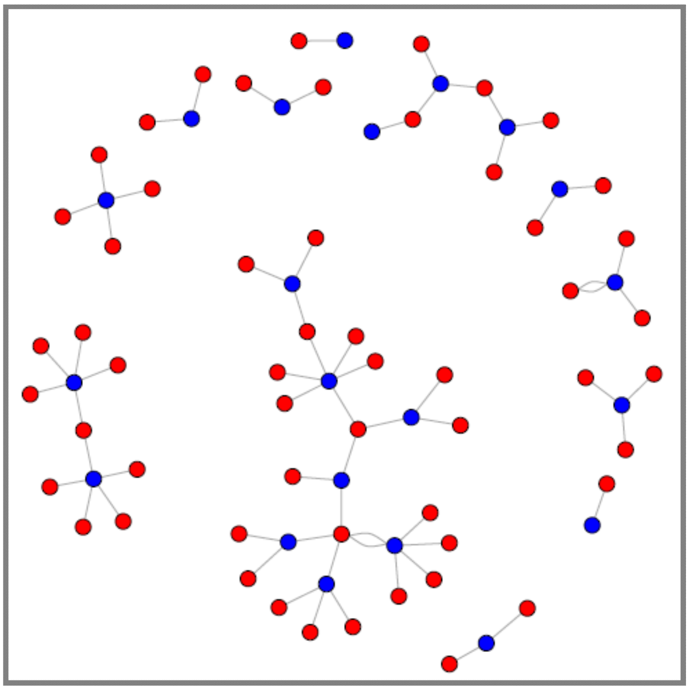


Figure 24: Firm Network 2008

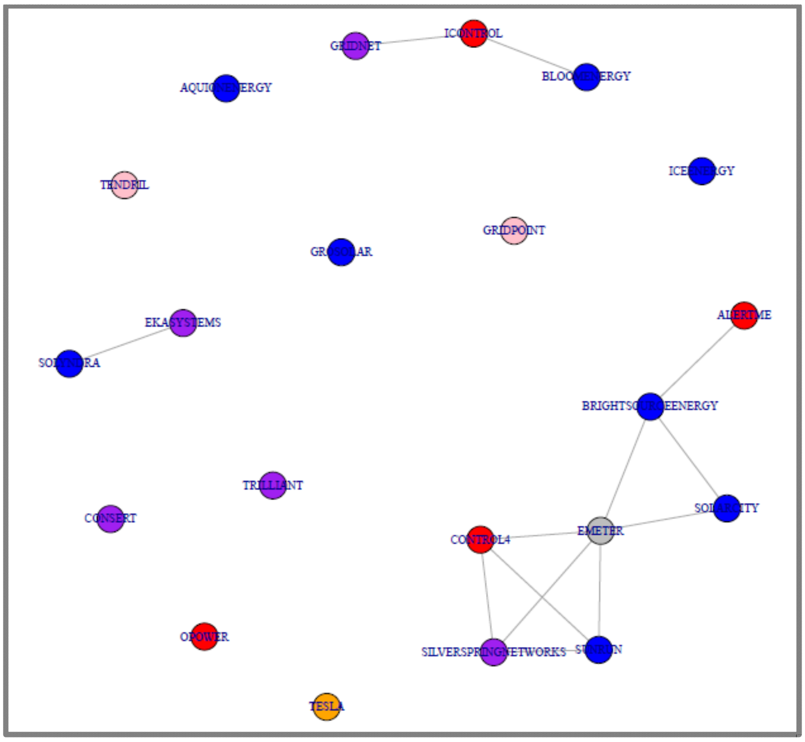


Figure 24 demonstrates the relations between firms in 2008. It is seen that Bloom Energy, iControl and Grid Net connected with common investors. On the other hand

Alert Me, BrightSource Energy, SolarCity, eMeter, SunRun and Silver Spring Networks created the other subgraph. Furthermore, this graph indicates improvement of the past connected firms, such that BrightSource Energy, SolarCity and eMeter, Control4 became components of the same subgraph. Figure 25 represents many clusters among investors. Only two investors did not connect with any other investors. Average investor per project is 2.61.

Figure 25: Investor Network 2008

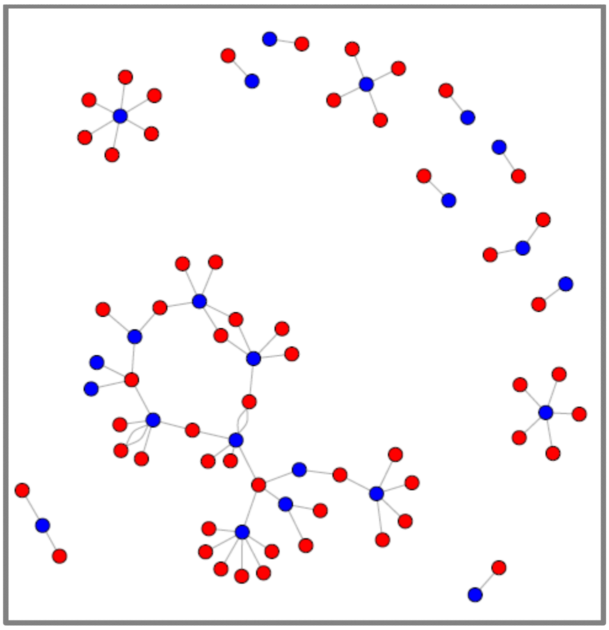
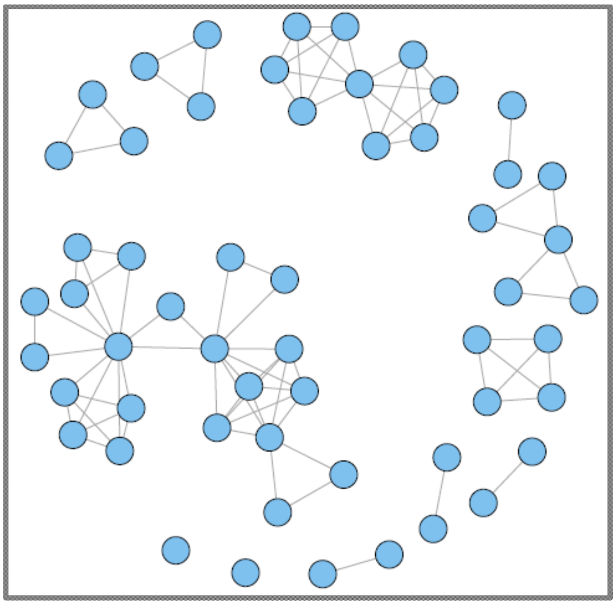


Figure 26: Bipartite Graph 2009



The first time that a subgraph has a cycle was in 2009, shown in figure 26. In the cycle, some points are connected via firms, and some via investors (See Appendix 5). Distributed generation firms represent the majority with 7 deals, in figure 27. Previously connected Grid Net and Icontrol linked to Silver Spring Networks and A123 Systems, which established the subgraph. A123 Systems went public in this year. Figure 28 indicates the investor network showing, many clusters appearing. Since the number of investor and firms slightly changed, the average investor per project is close to the number for 2008, with 2.43 investors.

Figure 27:Firm Network 2009

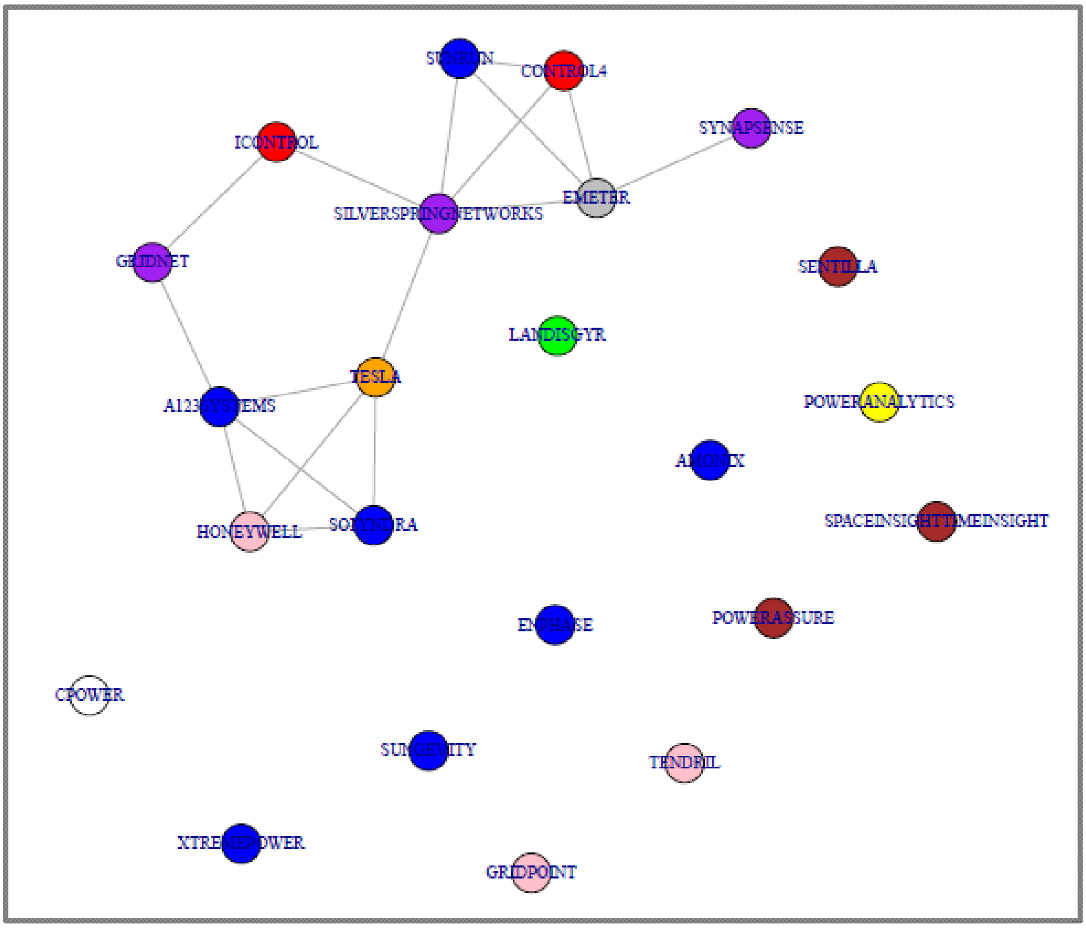
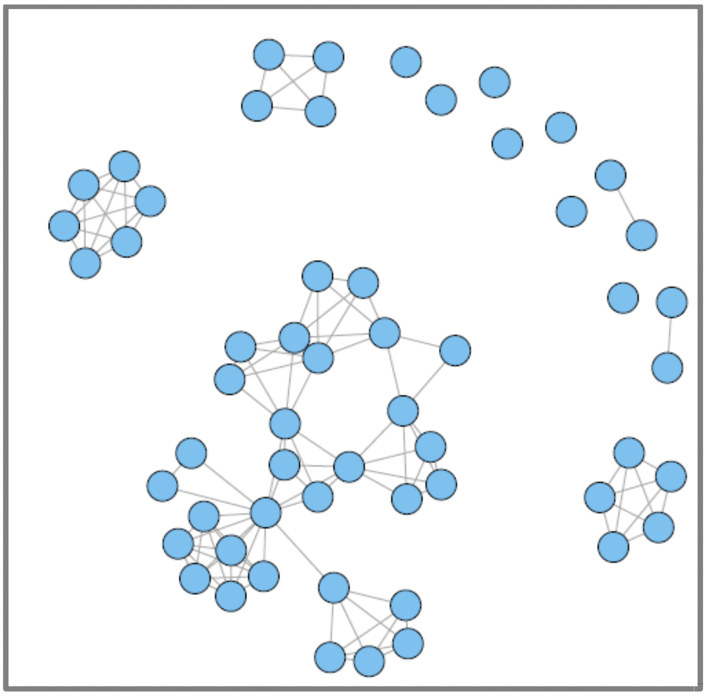


Figure 28: Investor Network 2009



In 2010, bipartite graph is presented in figure 29. A cycle is located at the center of bipartite graph (See Appendix 6). Likewise, year 2009 distributed generation firms hold the majority among other firms, with 10 deals, followed by communication firms. In figure 30, it is observed that a long subgraph is reached with 15 components, which are mostly recently integrated into the market. Utility enterprise software producer Ventyx was acquired by ABB. Wireless network products for data centers and buildings Arch Rock was acquired by Cisco. Wireless network provider Eka Systems was acquired by Cooper Industries. And demand response and energy management provider CPower was acquired by Constellation Energy. Next, these acquisitions Tesla went public in 2010. Average investor per firm is 2.37, which is less than 2009, due to boom increase in project number.

Figure 29: Bipartite Graph 2010

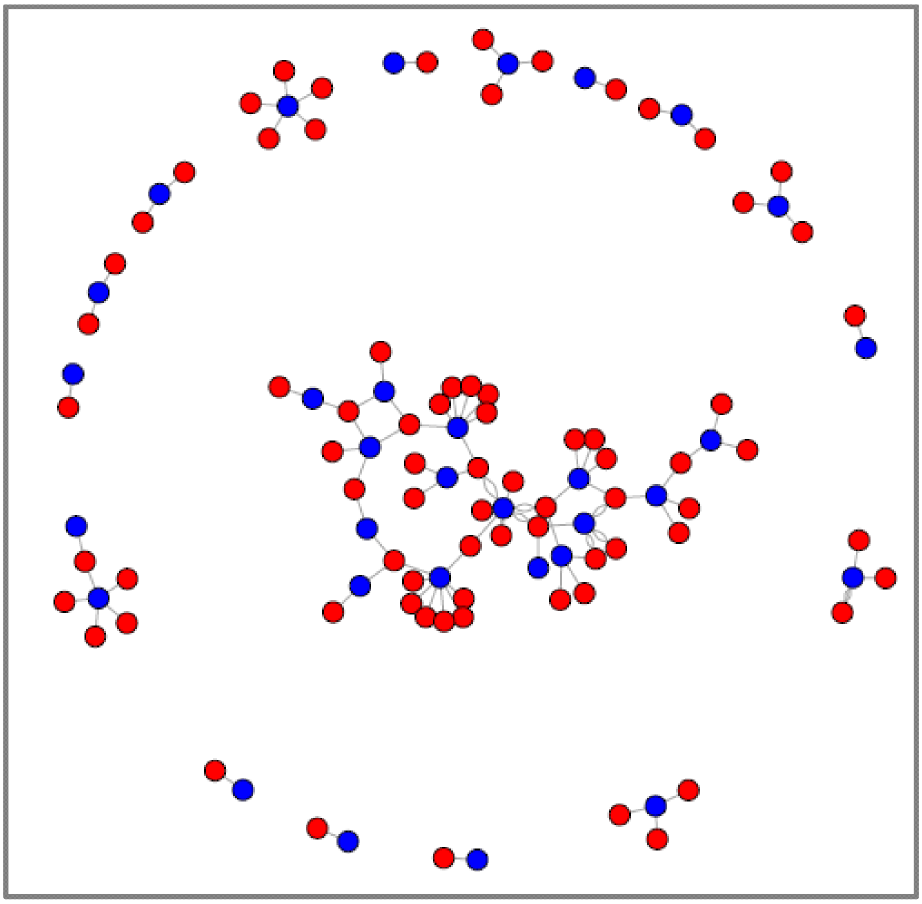


Figure 30: Fİrm Network 2010

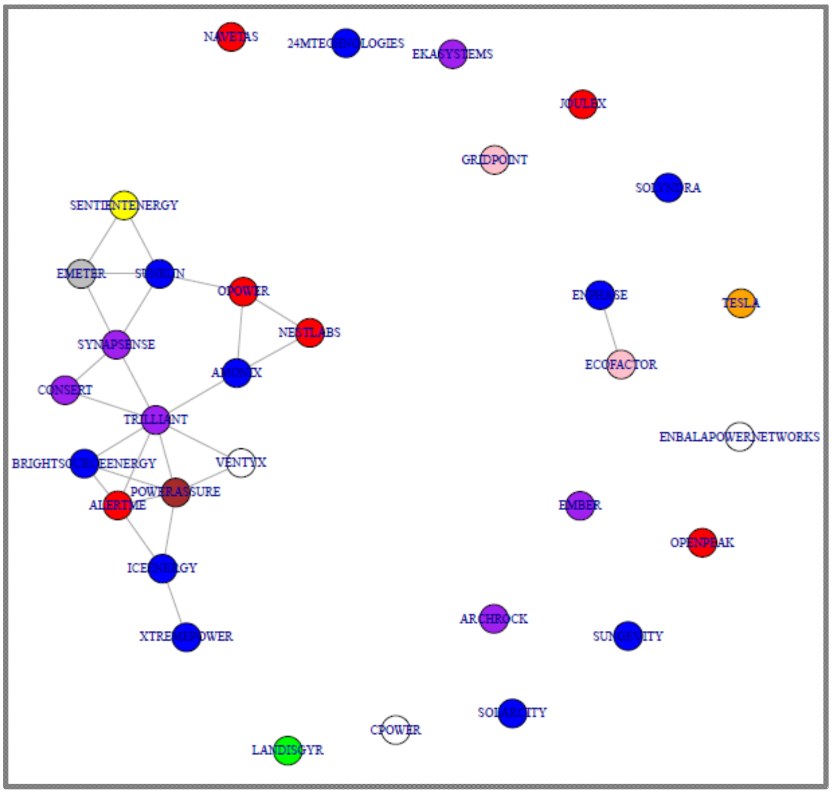
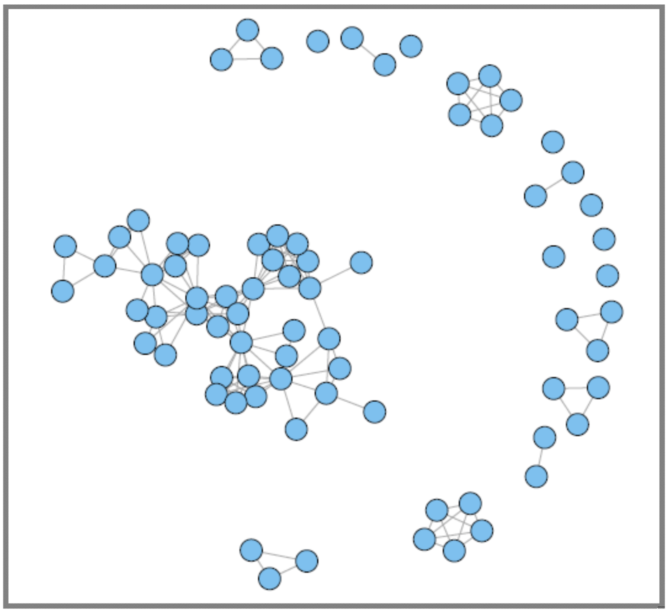


Figure 31: Investor Network 2010



In 2011, bipartite graph demonstrates the branches in the network. The highly populated subgraph originated from an investor (See Appendix 7). Home/building automation and energy management funds increased, with 11 deals, and it is followed by distributed generation, with 7 deals. As figure 34 demonstrates, firm network enlarged and reached its record level between the periods 2002-2013, with 18 components. Advanced metering firm eMeter was acquired by Siemens, meanwhile communication firm Telvent and home/building automation firm Summit Energy was acquired by Schneider Electric. Demand response firm EnergyConnect was acquired by Johson Controls. Hence, huge giant companies were active in the smart grid market in 2011. Distributed generation layer firm BrightSource Energy went public in this year. On the other hand, average investor per project increased to 2.5 compared to 2010, due to the boom in investor numbers. Figure 35 represents the investor network in 2011 with a total of 90.

Figure 32: Bipartite Graph 2011

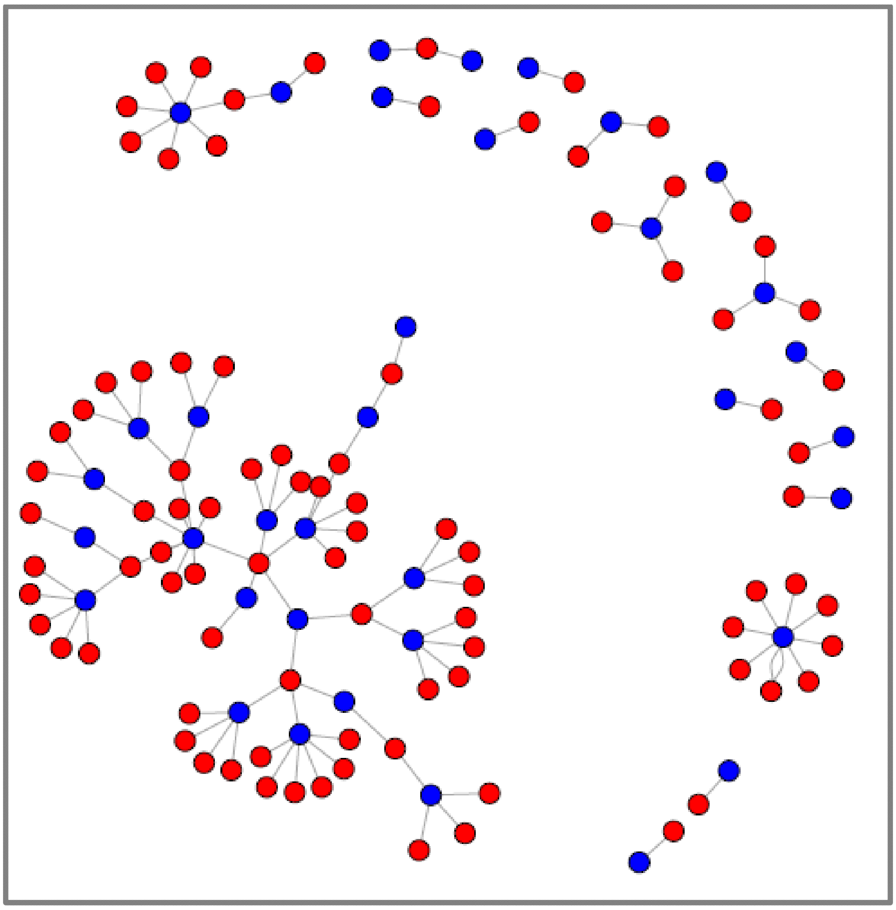


Figure 33: Firm Network 2011

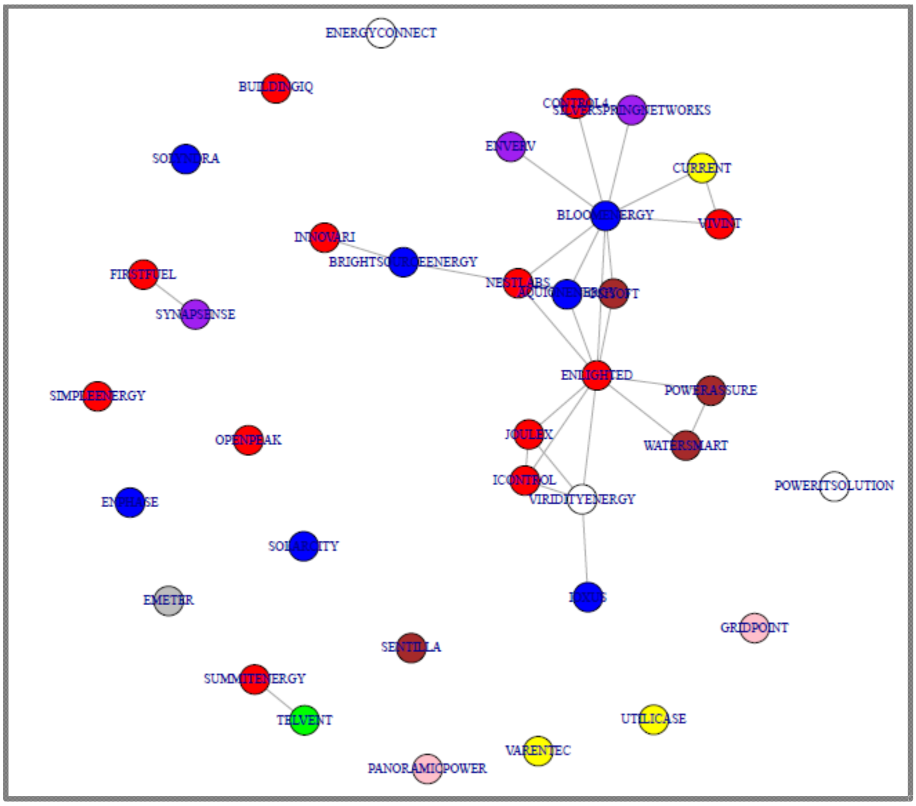
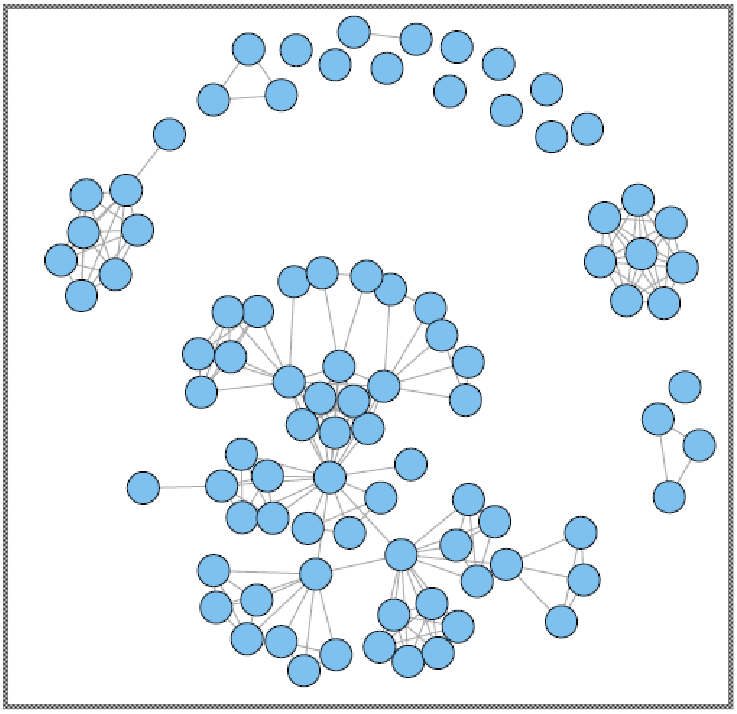


Figure 34: Investor Network 2011



In 2012, many firms were funded by only one investor, hence length of the subgraph is decreased and most of the investors funded one project rather than investing in multiple projects (See Appendix 8). Demand response firm Comverge was acquired by HIG Capital. Itron was acquired communication firm Smartsynch and enlarge its activities in advanced metering. Toshiba acquired Landis+Gyr and focused at advanced metering. Communication firm Ember was acquired by Silicon Labs. Leading home/building automation firm Vivint was acquired by the Blackstone Group. During this year, both distributed generation firms: SolarCity and and Enphase, went public. Also, the average number of investors per project reached the lowest level since 2005, with 2.10. Distributed generation firms appearing with 9 deals and hold the majority. 3 subgraphs are raised, as shown in figure 36. On the other hand, many investor clusters came out with distinct transactions, presented in figure 38.

Figure 35: Bipartite Graph 2012

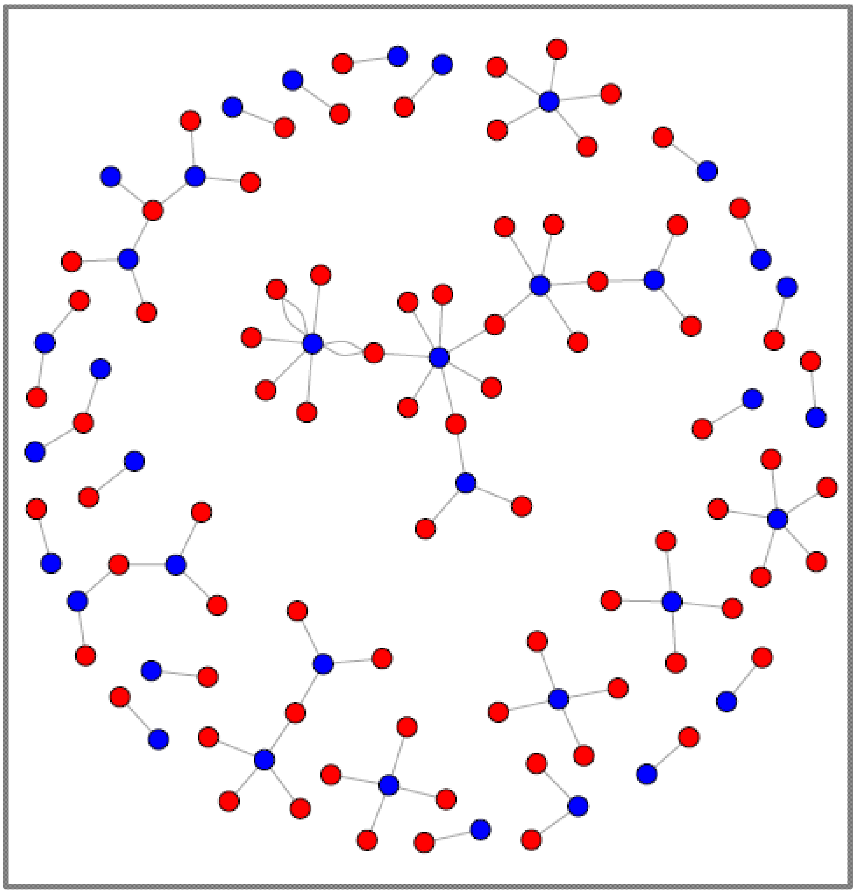


Figure 36: Firm Network 2012

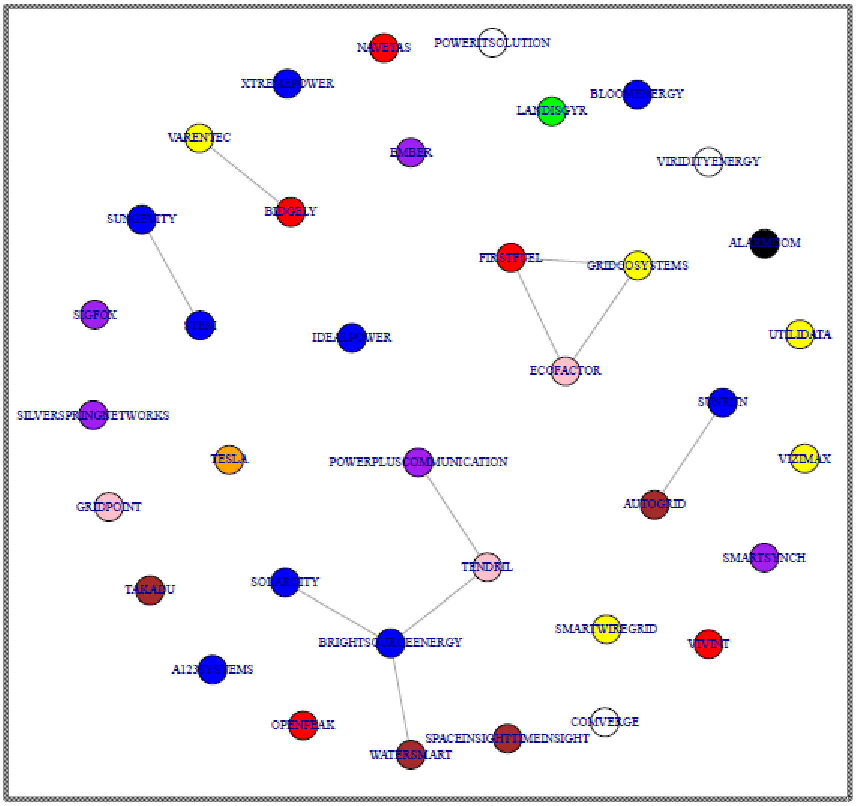
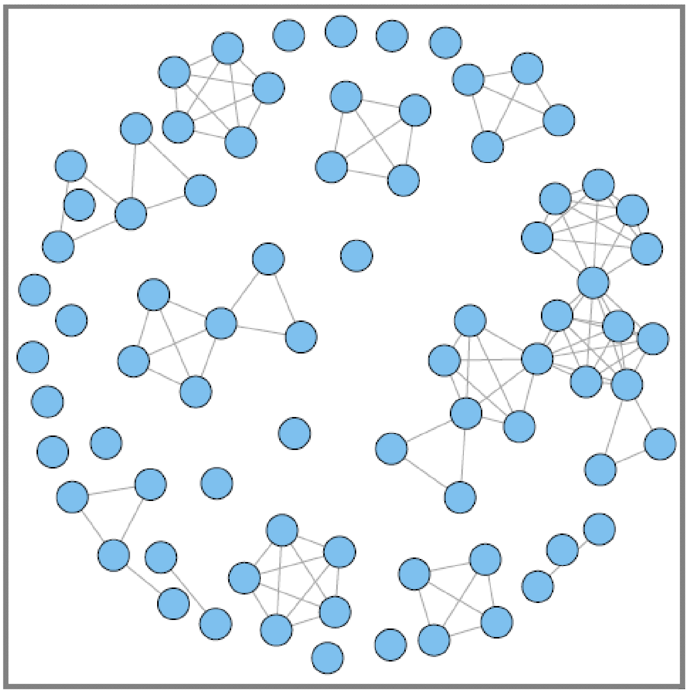


Figure 37: Investor Network 2012



Lastly, in 2013 number of investors reached 90 again, the same level as 2011. Moreover, number of firms increased to 41, which is the highest level in the period of 2005 to 2013. Grid optimization firms passed distributed generation and home/building automation. 4 acquisitions were made, 2 of them in home/building and automation technology, Joulex was acquired by Cisco, Nest Labs was acquired by Google, in grid optimization layer, Power-One was acquired by ABB and at communication layer, Consert was acquired by Toshiba. The highest deal was made by Google, with $3.2 billion for Nest Labs acquisition. Two subgraphs occurred as seen in figure 38 (See Appendix 9). Communication firm Silver Spring Networks and home/building automation firm Control4 went public this year. The average investor per project increased slightly to 2.19 compared to 2012.

Figure 38: Bipartite Graph 2013

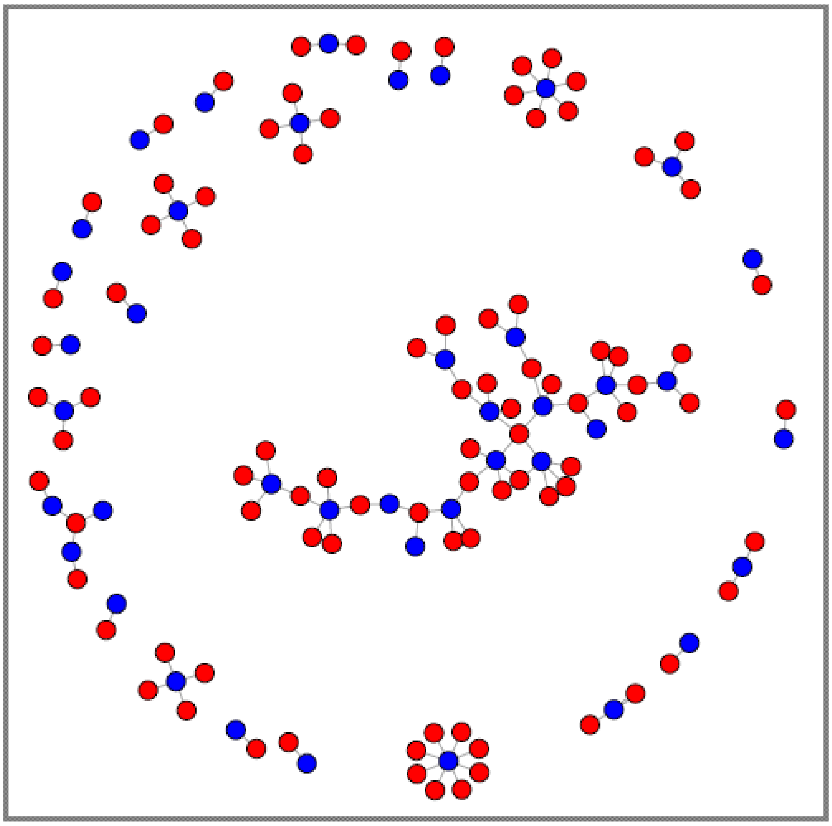


Figure 39: Firm Network 2013

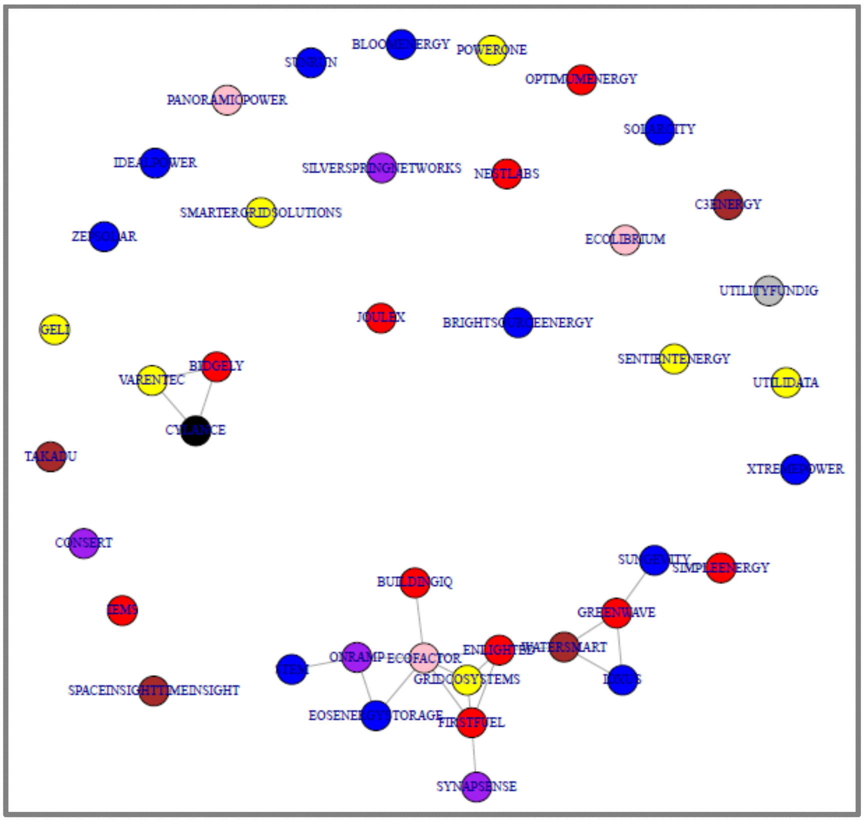
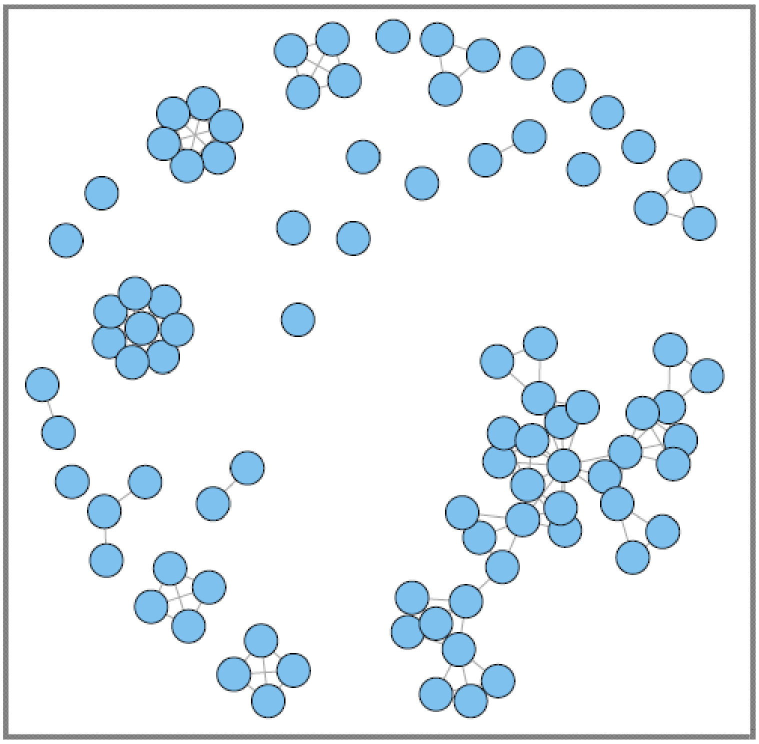


Figure 40: Investor Network 2013



In assessing the investor landscape in the smart grid market, it is seen that the market is populated not only by venture capital, but by public, and private companies. Regarding the investment activities between 2005-2013, it is observed that acquisitions and consolidation are increased, and will continue to shape the landscape in coming years. According to the graphs, except 2005, following years' bipartite graph includes subgraph that occurred with a connector vertex or vertices, connector could be a common firm or a common investor in the network, which also extends the length of the subgraph with additional branches at the network diagram. When all graphs were plotted, subgraphs were examined and connectors were analyzed in order to understand the relation between vertices of the subgraph. Meanwhile, some investors emerged as major participants in the smart grid market with their success and high growth of funds. Furthermore, these remarkable investors or their portfolio companies, coincidence with connectors at subgraphs, which is highly important for the outcome of the study. Therefore, assessing these venture capital firms' activities will be useful for understanding their cooperation effect on the success of the firms. Here are the flashing investors in the network: RockPort Capital, Foundation Capital, VantagePoint Capital Partners, Kleiner Perkins Caufield and Byers (KPCB), DBL Investors and Draper Fisher Jurvetson Venture (DFJ Venture). These six venture capitals play crucial role in the success of the firms when they become the investment partner, and this situation is determined via network approach analysis. Therefore, each investor of this venture capital group will be presented in detail in order to gain the best insight of the venture capital activities in the smart grid market.

RockPort Capital is a multi-stage venture capital firm that invests in the areas of alternative and traditional energy, mobility, and sustainability (Rockport Capital, n.d). The venture capital firm began to enter the smart grid market in 2008 in the communication layer, and invested in Eka Systems which provides wireless smart networks, smart grid networking and AMI solutions for the energy management and utility operations areas. In 2010 Eka Systems, was successfully acquired by Cooper Industries. Meanwhile, the investor tended to distributed generation layer, and funded first, a California based solar company with Solyndra and afterwards Rockport, which is focused on home/building automation and demand response combined solution provider, Eco Factor. The company continued to support the distributed generation layer and invested in Enphase. The Enphase Microinverter System increases the performance and reliability of the solar energy system, while also improving aesthetics and enabling flexibility in design (Enphase, n.d). With a powerful strategy Enphase went public in 2012. With these accomplishments, RockPort canalized home/building automation and energy management companies FirstFuel and Enlighted next to grid optimization company Gridco Systems. At Gridco Systems and at Enlighted fundings RockPort became investment partner with the other rising venture capital firm Kleiner Perkins Caufield and Byers. In addition to that, RockPort continued to enlarge its portfolio companies in smart grid market with adding Eco Factor, which provides a platform including demand response program, HVAC performance monitoring and proactive energy efficiency solutions. After RockPort and, another venture capital firm Aster Capital became an investment partner in Eco Factor funding, Eco Factor's success possibility escalated due to Aster Capital's giant sponsors Alstom, Schneider Electric, Solvay and European Investment Fund, which will enable Eco Factor solutions to be tested and enhanced with the collaboration of Aster Capital's sponsors, and this could enable it to be acquired by another company as happened at Aster Capital's previous investment in CPower.

Foundation Capital is a venture capital firm located in Silicon Valley. The firm was founded in 1995, with a single purpose: to build successful companies (Foundation Capital, n.d). Foundation Capital began by supporting the advanced metering firm eMeter and home/building automation and energy management firm Control4.

Actually, both technology categories related to each other directly, which enabled utilities to provide full service for commercial, industrial and residential consumers in terms of learning instant energy consumption data. In both its portfolio companies, Foundation Capital achieved success, with thriving exit due to $220 million acquisition of eMeter by Siemens, and assistance in Control4 on the way to its initial public offering (IPO) in 2013. Since then, Control4 has expanded into international markets and became one of the three leading companies in the smart home business, with distributors in Turkey as well. The outstanding data transmission technology fostered company's popularity, and this facilitated finding strong technology partners. By creating strong partnerships, Control4 enlarged their business with integrating automation system to hotels and yachts, in addition to buildings. Meanwhile, Foundation Capital tended to distributed generation segment and invested in a United States based residential solar provider called SunRun. It is expected that SunRun will encounter the same opportunities as eMeter with

Foundation Capital's previous investor partner, Sequoia Capital at eMeter investment. In addition to these startups, Foundation Capital took an important step forward with Silver Spring Network investment and became investment partner with GSV Capital, like Control4 funding. Silver Spring Networks delivers a powerful and comprehensive suite of smart grid networking solutions, and the company have launched and operated Silver Spring Smart Energy Platform for utilities large and small, investor-owned and public power, in the United States and abroad (Silver Spring Networks, n.d). Silver Spring Network took other successful venture capital firms' attention as well; DFJ Growth and Kleiner Perkins Caufield and Byers (KPCB) with Foundation Capital and brought them together in its funding phase. Today, Silver Spring Networks has earned a reputation as a leading smart grid networking infrastructure player and has developed its interest in the smart city concept, and is cooperating with a lighting firm on advanced streetlight and traffic signal project (Lesser A., 2013). Furthermore, Foundation Capital's latest portfolio company Aquion Energy, which manufactures sodium ion batteries and energy storage systems, is expected to be successful in coming years with the supporting of other leading venture capital firm KPCB.

Regarding the Foundation Capital's investments, it is seen that venture capital's investment partnership continued at other startup funding after a successful accomplishment. For instance Foundation Capital was an investor partner with KPCB, GSV Capital and Sequoia Capital at multiple finance projects. Also, Foundation Capital followed a wise and logical roadmap on investing smart grid market, starting with advanced metering and then focused on home/building automation and energy management firms. Advanced metering firms were very critical in boosting smart grid concept, hence when Foundation Capital witness eMeter's acquisition, they exploited home/building automation systems, which is a complementary technology of advanced metering, and their investment activities followed by supporting communication technology in order to reach a fulfill service between utilities to end users. Afterwards, the company invested on distributed generation layer in order to increase renewable energy sourced electricity generation to be utilized more by home users. Bottom line, Foundation Capital is one of the premise company among smart grid investors with a perfect smart grid vision, and attempting to implement smart grid concept consciously, which has brought company successful returns from its investments.

VantagePoint Capital Partners is a venture capital firm with investments in the cleantech, information technology and healthcare sectors and has more than $4.5 billion in capital under management (Crunchbase, n.d). In 2006 the company started with distribution generation layer firms and invested on BrightSource Energy who designs, develops and deploys concentrating solar thermal technology to produce high-value steam for electric power, petroleum and industrial-process markets worldwide (BrightSource Energy, n.d). During this investment, VantagePoint Capital became an investment partner with flashy venture capital firms DBL Investors, DFJ, DFJ Growth and some oil companies Chevron Technology Venture, BP and Statoil next to leading global investment banking firm Goldman Sachs. In the same year, VantagePoint Capital invested in electric car producer, Tesla Motors, and came together with the same co-investors: DFJ and DFJ Growth from BrightSource Energy funding rounds. Both portfolio companies BrightSource (2011) and Tesla Motors (2010) went public and satisfied VantagePoint Capital's expectation on profitability. After that, venture capital firm focused on home/building automation and energy management startups. Even though the company is United States based, they invested in U.K based venture firm AlertMe, which enables people to manage and control their homes from their mobile phones and the web, their previous investment partner. BP also invested in AlertMe. Later on VantagePoint Capital-backed Tendril, whose technology facilitates a dialog between consumers and suppliers through an energy ecosystem that connects in-home devices (like thermostats) to the utility back office. Afterwards, the company tended to focus on the communication layer and invested Trilliant who is the leader in delivering intelligent networks that power the Smart Grid. At both funding projects VantagePoint Capital became investment partner with energy giants GE, ABB and Siemens. Lastly, the venture capital firm again focused on home/building automation and energy management company, but this time U.S based Innovari, which is developing a framework to enable utilities and energy consumers to work together in ensuring an ever-more reliable and cost effective energy value chain going forward (VantagePoint Capital, n.d).

According to VantagePoint Capital's investment activities, it is determined that with most of their investments, they associated with powerful and well-known companies, which indicates their accurate decisions on selecting profitable projects. Furthermore, these projects were remarkable that most of them were invested in by more than 5 different investors. The company mainly focused on communication platforms that benefits both utilities and end users in terms of assistance in energy consumption reduction with energy management programs and providing cost effective solutions with increasing renewable energy sources by deploying distributed energy resources and supporting electric vehicle manufacturer. In this sense, the company's targets are to realize smart grid concept through 2-way communication applications, enhance network utilization and create awareness among consumers on efficient energy consumption. Within this scope, VantagePoint endeavor to revolutionize services and apply advanced technology to solve challenging problems, and in accordance with their aim they are not afraid of ambitious visions and significant commitments.

Kleiner Perkins Caufield and Byers (KPCB) is a well-known Silicon Valley venture capital firm, due in large part to their past success. They were early investors in many significant companies, including Amazon, AOL, Compaq, Electronic Arts, Google, Intuit, Macromedia, Netscape, Segway, and Sun Microsystems (Crunchbase, n.d). KPCB started smart grid investments in 2008, with home/building automation layer and funded home management and monitoring solutions provider iControl. Its user-friendly home solutions enable people to stay connected in real-time to what matters most: their property, home and business, anytime over email, mobile, web and other access points (KPCB, n.d). KPCB co-invested with Cisco and Intel Capital on iControl and it is expected to go public or be acquired by another company in the next years. Meanwhile, KPCB invested in communication layer's premise firm Silver Spring Networks and Bloom Energy, which offers on-site power generation systems that can use a wide variety of inputs to generate electricity (Crunchbase, n.d). KPCB funded Bloom Energy with $450 million, which is the highest amount in one round, also in total KPCB funded $750 million to Bloom Energy and this demonstrates KPCB's great expectations from Bloom Energy, whose aim is to lower energy costs, reduce carbon footprints, improve energy security, and provide a better future. During this investment, KPCB became investor partner with Goldman Sachs and GSV Capital. Afterwards, in 2010 KPCB again focused on home/building automation category and invested in Nest Labs, which designs and manufactures sensor-driven, Wi-Fi-enabled, self-learning, programmable thermostats and smoke detectors (Crunchbase, n.d). KPCB was investment partner with Google in this investment project and in first quarter of 2014, Nest Labs was bought by Google with $3.2 billion and expected to enlarge their sale points at international market in coming days. Nest Lab's first product, introduced in late 2011, was a hockey-puck-shaped thermostat that programs itself based on how a user changes the temperature. It can also detect, using sensors, when there is no one in the home to lower energy use (Winker R. and Wakabayashi D., 2014). Next to Nest Labs, KPCB continued to make investment on home/building automation layer and funded Opower, which is software as a service company that helps utilities meet their efficiency goals through effective customer engagement. Like, Silver Spring Networks, Opower went initial public offering in 2014. In 2010 the venture capital firm invested in a solar power system developer named Amonix which manufactures concentrated photovoltaic commercial solar power systems for tropical climates. Before the Bloom Energy investment project, KPCB worked with Goldman Sachs for the first time at Amonix funding. In 2011, KPCB invested in three different categories: data analytics, distributed generation, and home/building automation and energy management, and brief information about these firms will be presented as follows. OSIsoft is the data analytics firm and offers collaborative tools that make mission-critical information visible across the enterprise and value chain, now, and over time (Osisoft, n.d). Aquion Energy is a Pittsburgh based company that manufactures sodium ion batteries and energy storage systems. Its patented Aqueous Hybrid Ion (AHI) technology provides high performance, safe, sustainable, and cost-effective energy storage (Aquion Energy, n.d). As mentioned above, in this investment KPCB was partner with Foundation Capital next to Bill Gates. Enlighted is a home automation firm and provides a next-generation approach to managing energy use, beginning with significant reductions in lighting energy consumption. Comprised of Enlighted Smart Sensors, the Enlighted Gateway, and the Enlighted Energy Manager, the Enlighted system operates in a robust, fault-tolerant architecture (Enlighted, n.d). KPCB was investment partner with other flashy venture capital firms Rockport Capital, DFJ and previous partner Intel Capital. Lastly, KPCB tended to grid optimization layer and invested in Gridco Systems with co-investor Rockport Capital. Gridco Systems is a leader in active grid infrastructure solutions, enabling utilities to more effectively integrate renewable and distributed generation, increase energy efficiency, manage peak capacity, and improve system reliability (Gridco Systems, n.d).

The outcome of KPCB's investments demonstrate that the home/building and energy management layer will enlarge with different products and concepts, as figured at when iControl, Nest Labs, Opower and Enlighted is analyzed. In addition to that, the venture capital bolstered Aquion and Amonix, which have the potential to boom and became leaders in distributed generation layer, given that holding group of investors' power. Furthermore, KPCB did not only invest common technology categories regarding previously mentioned flashy venture capital firms, they also invested in data analytics firm OSIsoft, which implicitly assisted implementation of other solution providers. Next to these startups, with additional Silver Spring Networks and Bloom Energy investments, KPCB became leader investor among other flashy venture capital firms with making investment in ten startups between 2002 and first quarter of 2014. Considering its disruptive portfolio companies, KPCB's aim: helping entrepreneurs build successful products and services, has already been reached and has been proven with portfolio companies' success as well. KPCB's perfect perception and imagination in evolvement of smart grid industry enables them to stand one step ahead in smart grid investments, and become role models in smart grid market.

DBL Investors is a venture capital firm created from the spin-out of the Bay Area Equity Fund I from J.P. Morgan in January of 2008. DBL Investors uses venture capital to accelerate innovation in a way that positively affects an organization's social impact as well as its financial success (DBL Investors, n.d). DBL invests in and helps nurture outstanding entrepreneurs and companies in cleantech, information technology, health care and sustainable products and services. Their Cleantech segment's portfolio company list includes eMeter, Tesla Motors, BrightSource and SolarCity. DBL Investors started to make investment on smart grid market companies in 2008 and all startups; advanced metering, distributed generation, electric vehicle firms are invested. eMeter's software provides utilities with detailed dynamic electricity usage information, which can be used to identify unaccountable energy use and losses, as well as to support innovative programs that reduce the need to build power plants used for peak demand days only (DBL Investors, n.d). Hence, the solution provided by eMeter has a positive impact on electricity distribution and control in terms of outage management for utilities. In addition to DBL Investors, investors include Foundation Capital and Sequoia Capital. With a solid investment plan eMeter was supported was acquired by Siemens in December of 2011. Meanwhile, DBL Investors invested BrightSource Energy with $155 million, which is record level of investment for the venture capital firm. The company's energy generation approach is based on solar-thermal created steam supplemented with gas, providing more stable and more profitable power generation for utilities when compared to other types of renewable energy such as wind, hydro and photovoltaic. Next to DBL Investors, the other investors are VantagePoint Capital, Draper Fisher Jurvetson and Morgan Stanley. BrightSource Energy went public in 2011 so that DBL Investors received a recompense for its investment. On the other hand, DBL Investors funded SolarCity and became investor partner with other flashy venture capital firm DFJ. SolarCity is the leading provider of solar energy systems that deliver reliable power to homes and businesses. Now SolarCity is pushing into a new frontier, energy-storage-backed solar (cooperation with Tesla Motors), in which it takes on challenging economics and utility pushback against the potential market disruption that its battery-solar systems represent (GTM Editors, 2014). In addition to DBL Investors, investors include Elon Musk, DFJ, Generation and Mayfield. In 2012 SolarCity went public, and after that its stocks value rose surprisingly and it is expected that SolarCity will continue its rapid growth (Houim T., 2014). DBL Investors also invested in Tesla Motors with some same investor partners, Elon Musk, DFJ and VantagePoint Capital next to Google. In 2010 Tesla Motors went public.

Based on DBL Investors investments, their three portfolio companies went IPO and one of them was acquired by energy giant Siemens which indicates adorable success of the venture capital firm on smart grid market investments. DBL Investors' solid background, which is originated from leading financial services firm J.P Morgan, has an absolute share on this level of achievements. Although DBL Investors invested in just four projects, other enterprising investors expect top-tier venture capital returns from DBL Investor's funded startups as well hence DBL Investors became investment partners with three other flashy venture capital firms: Foundation Capital, VantagePoint and DFJ. It is wondered a lot if DBL Investors will keep going with same success rate at new projects in coming years.

Draper Fisher Jurvetson (DFJ) is a global venture capital firm based in Silicon Valley which invests growth stage technology companies that are scaling rapidly, and poised for market leadership. DFJ Growth is the later stage investing practice of Draper Fisher Jurvetson (DFJ) (Crunchbase, n.d). Within clean energy technologies, it invests in energy generation, transmission, utilization and storage, water purification, grid optimization, industrial sensing and monitoring, and advanced materials and catalysts. The firm seeks to invest in the United States with a focus on East Coast, Mid Coast, West Coast, California, and Texas. It also invests in China, India, South Korea, Vietnam, Europe, and Greece (Bloomberg BusinessWeek, n.d). It seeks to be the lead investor in its companies' first round of financing, and holds board seat in its portfolio companies. The venture capital firm started to invest in 2006 in the Ember at communication layer. Ember is a Zigbee systems developer which is the only standards-based wireless technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks in just about any market. This technology could be used in smart homes, building automation, advanced remote control, home energy savings, IP-based home energy management and led lighting control (Zigbee, n.d). Chevron Technology Ventures also invested to Ember and in 2012 the startup was acquired by Silicon Labs for $72 million. In the same year DFJ invested in Tesla Motors and SolarCity companies as well. In both investments DFJ co-invested with CEO of Tesla Motors and at the same time chairman of SolarCity, Elon Musk and both startups did a good job and made profitable return. In 2008 DFJ invested in BrightSource together with VantagePoint Capital, DFJ, DBL Investors, Morgan Stanley and Goldman Sachs next to petroleum companies BP, Chevron Technology Ventures, Statoil. BrightSource Energy designs and builds utility-scale solar power plants to help companies lessen their dependency on fossil fuels. After a year, DFJ invested in communication layer again, but this time to Silver Spring Networks, which supported by Foundation Capital, KPCB and GSV Capital next to Google and the company went public in 2013. In the same year 2009, DFJ invested in a data analytics firm called Power Assure, and this was the first investment that was done in data analytics layer and this trend was followed by other flashy investor KPCB, with the investment in OSIsoft. Power Assure is a leading innovator of data center infrastructure and energy management software for large enterprises, government agencies, and managed service providers (Power Assure, n.d).

Power Assure's solutions facilities managers balance load, capacity, service levels, and power consumption within and across data centers. Power Assure is the first ever two-category winner at the Cleantech Open, winning the "smart power" and "sustainability" categories in 2008, also it is an AlwaysOn Going Green Silicon Valley 2010 winner and Cleantech Open Alumni of the Year for 2011. Next to DJF, ABB invested in Power Assure too. In 2011, DFJ invested in WaterSmart Software in its seed phase with $950,000 dollars. The software helps water utilities make it easier for their customers to save water and save money. WaterSmart was a winner of Imagine H2O’s inaugural water efficiency prize in March 2010 (WaterSmart Software, n.d). And lastly, DFJ invested in Enlighted at home/building automation and energy management layer 2013, and became investment partner with other flashy venture capital firms: RockPort Capital, KPCB next to Intel Capital.

In summary of DFJ investments, its nine portfolio companies indicates, it has helped entrepreneurs trailblaze new markets and build iconic companies. Except four portfolio companies: WaterSmart, Enlighted, SynapSense and Power Assure, all backed companies went public or were acquired. Without dispute, DFJ have courage to back entrepreneurs with broad visions that disrupt entire industries and DFJ think big about trends before they become mainstream, as appeared from historic success like Skype, Hotmail, next to recent breakout stars like Twitter and Tumblr. Hence, portfolio companies are selected in a compelling mechanism in order to create a new trend. In addition to the company itself, DFJ created a partner network of independent VC firms across the globe that adopted DFJ branding. It was the closest thing to VC franchising at the time. To date, there have been 16 outside funds who have joined the network, 11 of which are outside the U.S. These include DFJ Mercury, DFJ Athena Korea, DFJ Frontier, DFJ Esprit, among others (Techcrunch, 2013). Among these VC firms, DFJ Frontier invested in one of the disruptive firm in smart grid market, SynapSense with $1.5 million at 2006. The SynapSense wireless monitoring and cooling control Solution is the leading energy efficient Data Center Infrastructure Management (DCIM) solution, enabling the world's data centers to achieve unprecedented energy savings with enhanced reliability. Next to DFJ Frontier, the company is supported by leading investors worldwide including BOSCH, Emerald Technology Ventures, GE Energy Financial Services, Nth Power, and Sequoia Capital.

Beside the venture capital firms, large, established, global companies are also active in the smart grid market. They are seeking to expand their product portfolios to stretch across smart grid categories with the goal of providing end-to-end solutions to utilities and other large customers. Regarding the venture capital investment partnerships mentioned below, some of the giant energy companies, such as GE, Alstom, Schneider Electric, Siemens and ABB emerged next to petroleum industry companies BP, Chevron and Statoil, which are active in the smart grid market. Across multiple smart grid segments, there is a tension developing between vendors of broad solution suites and those with best of breed products and applications. Vendors like GE and ABB in the distribution grid management space have product sets spanning hardware, communications, and software that can be implemented as a single solution (Cleantech, 2010, p.11).

5. CONCLUSION

The study begins with presenting smart grid concept and tries to provide a clear insight on smart grid vision. Hence, all the benefits, causes and necessities of adopting a more modern infrastructure are mentioned at the beginning of the study. Afterwards, on-going or successful smart grid projects and regional market overview are presented. In conclusion, the study highlights VC activities in order to supply information about the trending technologies in smart grid industry regarding the relation between disruptive startups with their investors. The crucial points from the research are collected and presented as follows.

Based on the U.S Department of Energy Smart Grid reports increasing energy efficiency, renewable energy and distributed generation would save about $36 billion annually, by 2025. Smart grid integrated distribution system would decrease carbon emissions by up to 25%. High dependence on foreign net oil imports could be replaced by Plug-In Hybrid Electric Vehicles (PHEV's) and reduce carbon emissions by more than 27% with the adoption of smart grids. Furthermore, power outages and interruptions cost Americans at least $150 billion annually, about $500 for every person. A modernized energy infrastructure with a smart grid concept will help equip energy providers and utilities around the world with better visibility, control and flexibility to handle modern energy challenges and deliver the benefits of better efficiency, reliability and a more balanced system between energy supply and energy demand (Trilliant, n.d). Considering smart grid's general interest, initially countries and then companies are in pursuit of deploying smart grid technologies to the current network. In this sense, early stage companies are backed by stimulus funding and a new market evolution has begun, and some newer companies have risen to market leadership.

Although most of the firms in the dataset originated from U.S market, it does not mean that smart grid market is only active in North America. As mentioned in Chapter 3, smart grid applications are ongoing all around the world, and the pace of implementation and pilot project demonstration is going according to country's situation in terms of energy strategy and politics, economics and electricity infrastructure. Hence, the scope of the markets should be enlarged to create wider investment opportunities. For instance, China and European countries are also active in the smart grid market, as presented in Chapter 3. The increased number of IPO in 2013 was good news for the smart grid sector in general, boosting investors' confidence and setting precedence for successful exits in the sector. After the expensive roll out of smart meters, there is a huge desire from utilities to get a better insight and management of their energy assets. Hence, smart meters provide a huge opportunity for utilities leveraging the capability to provide actionable insights from the collected big data. This significantly outpaces other investment categories such as distribution automation, transmission enhancement, wide area control systems, and makes improvements focused on facilitating integration of renewable and electric vehicles. Next to that, successful startups proved to be hopeful for more potential opportunities in the sector in coming years (i3 Cleantech, 2013, p.3).

In order to gain a deep insight on this emergent sector, the study aims to research the venture capital firms' mobility in the smart grid market, and tries to figure out how the smart grid VC firm ecosystem is evolving as a living and breathing organism. However, due to the lack of adequate acquisition of startups, a significant relation between startups and investors could not be found with scientific data analysis. Thus, in order to address this question, a network model based on industry connections was used to gather the data from announced partnerships, press releases, public collaborations and financial news. These were used to analyze the relationship between investors and venture firms, and their relationship was visualized via network mapping tool R-studio. In this sense, in Chapter 4, the network between investors and firms are illustrated.

This study assesses the market at the macro, systems level. However, smart grid market consists of various investors, private, public. During the research, most of the news about smart grid market are scanned and remarkable startups and firms are taken into dataset in order to focus on the overall market view of venture capital ecosystem, rather than a more granular analysis of each venture capital firms. The output of the study tries to demonstrate how firms and investors interacted with each other from 2005 to 2013. It is seen that components of the network are not randomly linked each other. The successes of firms are highly related with their network attributes. The study ends with the observation of huge VCs and their portfolio companies related with smart grid sector. It is seen that, a group of venture capital: RockPort Capital, Foundation Capital, VantagePoint Capital, Kleiner Perkins Caufield and Byers, DBL Investors and Draper Fisher Jurvetson, cluster in varied projects, and when multiples of them fund same startup, the success rate of the startup exponentially increases, and the startup goes public or is acquired by another company. Among these flashy venture capital firms: Kleiner Perkins

Caufield & Byers and Draper Fisher Jurvetson have been already placed in the top VC ranking list prepared by CB Insights.

For the coming years, number of acquisition will increase, since startups passed their early stage and middle stage era with support of VC firms, thus most of them reached their last stage, and are ready to become the dominant power in the prosperous energy market. In fact, some startups have already become IPO, such as; Control4, A123 Systems, Enphase and Opower and some of the startups became key element of the market and created their own brand such as Trilliant, C3 Energy, Tendril and iControl. Among 95 startups, 18 were acquired and 8 of them went IPO, which yields 27% of the investments were accomplished with lucrative returns. Although the percentage is currently not high, fortunately respect to firm's technology category market conditions can vary and could become smoother. Since the energy sector consists of many high level players, they enable startups to grow under their dominance by merger and acquisition transactions. On the other hand, some companies which have already become successful in their sector and became worldwide well-known brand, have taken action in their related smart grid categories, such as information and communication, cyber security and data analytics. Since these technologies are being used in other sectors as well, those huge companies can easily adopt their know-how and market experiences to the electricity market, which could convert conditions into more challenging for startups at the market integration point.

While deployments of smart grid technologies are accelerating, some firms went bankrupt especially in the solar power related businesses and battery manufacturers. Thus, even though smart grid market has extensive potentials, market opportunities regarding policies and sectorial regularity needs to be considered in order to make successful investments.

Lastly, I would like to share my expectations from the startups which have high potential exit or IPO in the next years. When the IPO or acquired firms are observed in detail, it is seen that these firms have about 10 investors on average. Even though the nature of venture capital firm is to combine with other venture capitals to eliminate the risks, it also demonstrates growing loyalty, support and trust for a firm. Hence the more investors mean the higher possibility a firm can boom in the future. Particularly, defining a number can make sense to make a better prediction on upcoming exits or IPOs. Based on this calculation, the firms with 9 investor are revealed as SunRun, Simple Energy, iControl, GridPoint, Bloom Energy, Aquion Energy and Amonix, therefore, these firms have high potential for a profitable returns.

As a future work, the dataset should be enriched by adding the following years' data and calculation can be made to prove the centrality effect on the success of firms, or to obtain further results.

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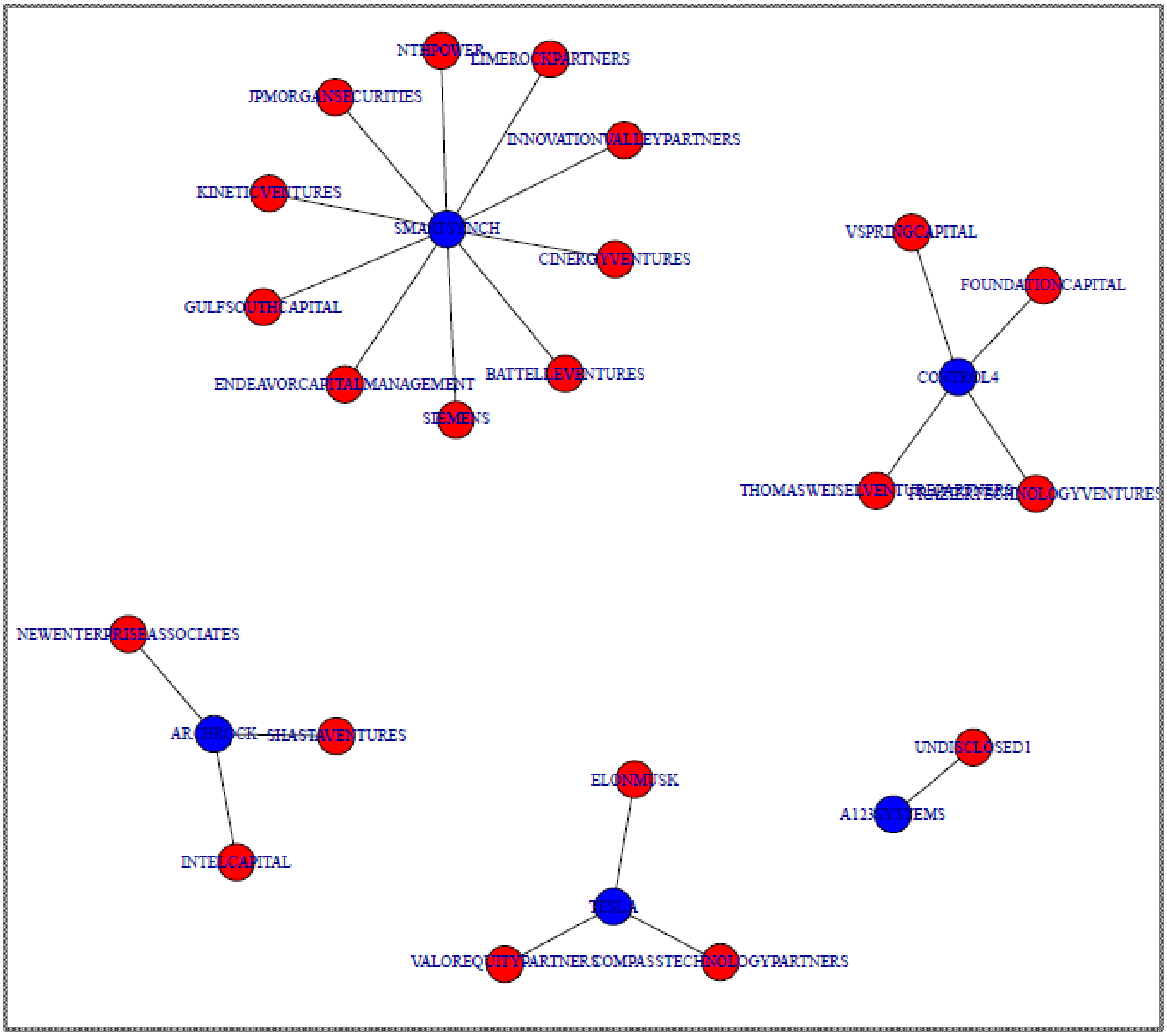
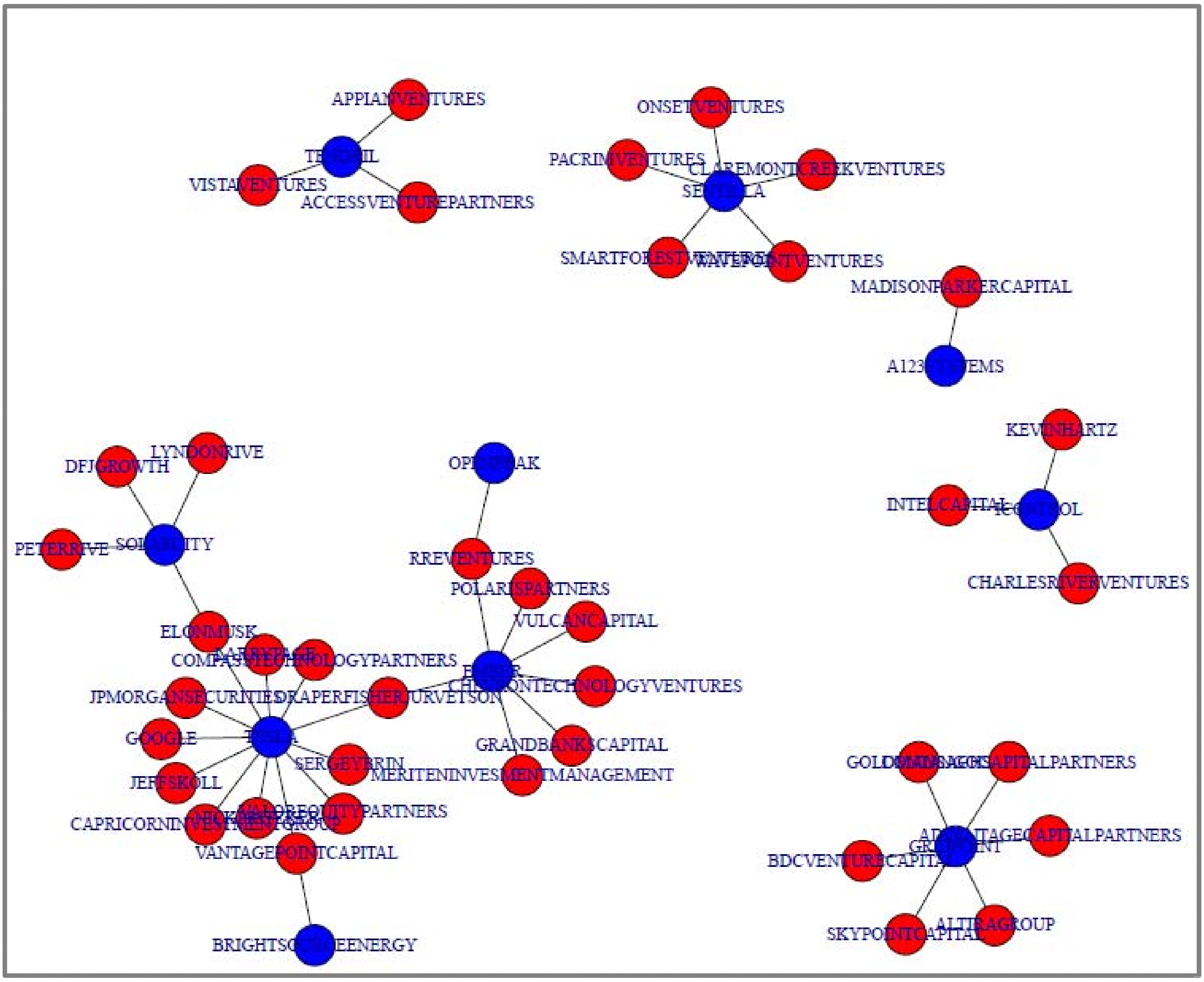
7. APPENDICES

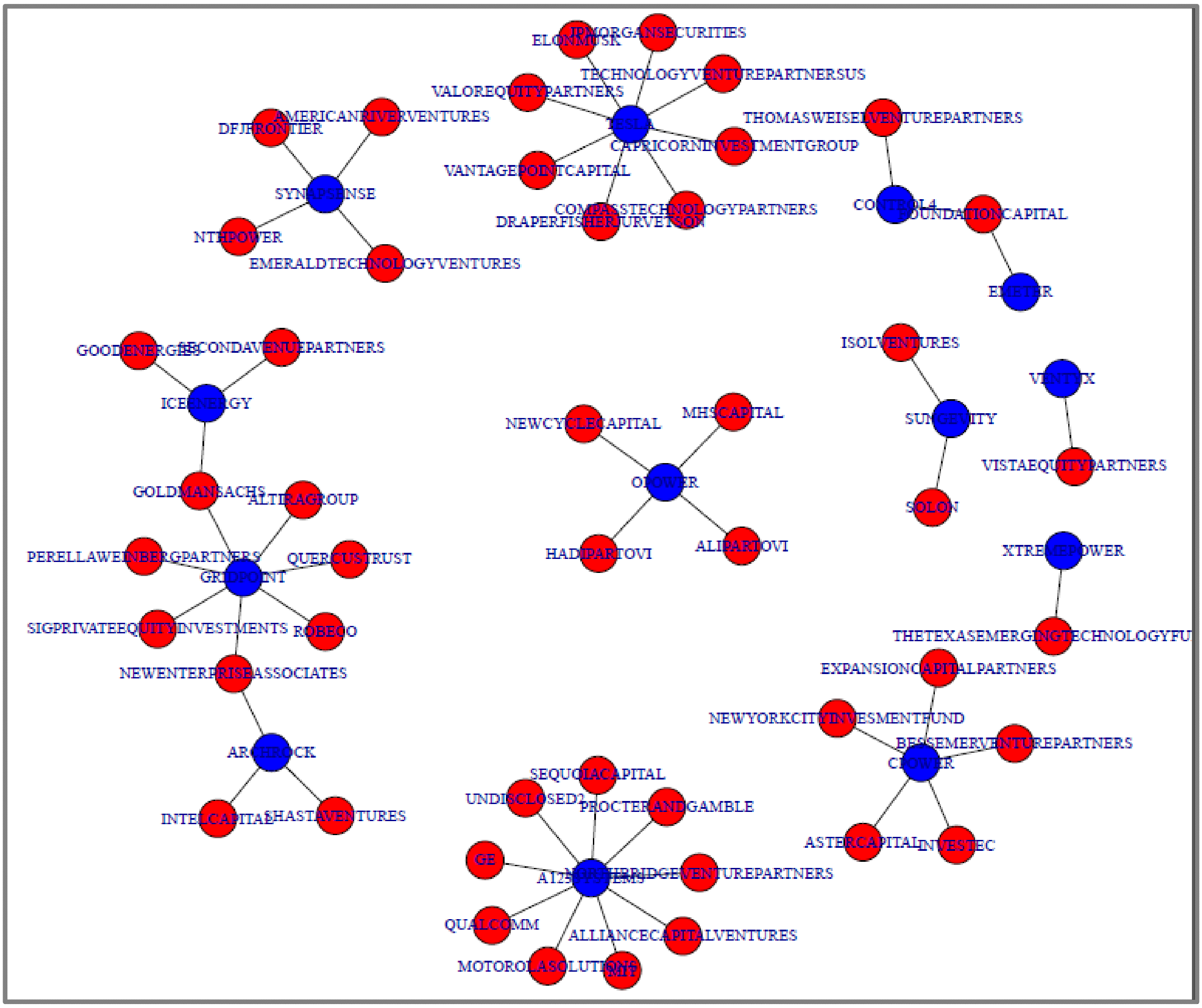
APPENDIX-1. Bipartite Graph of 2005



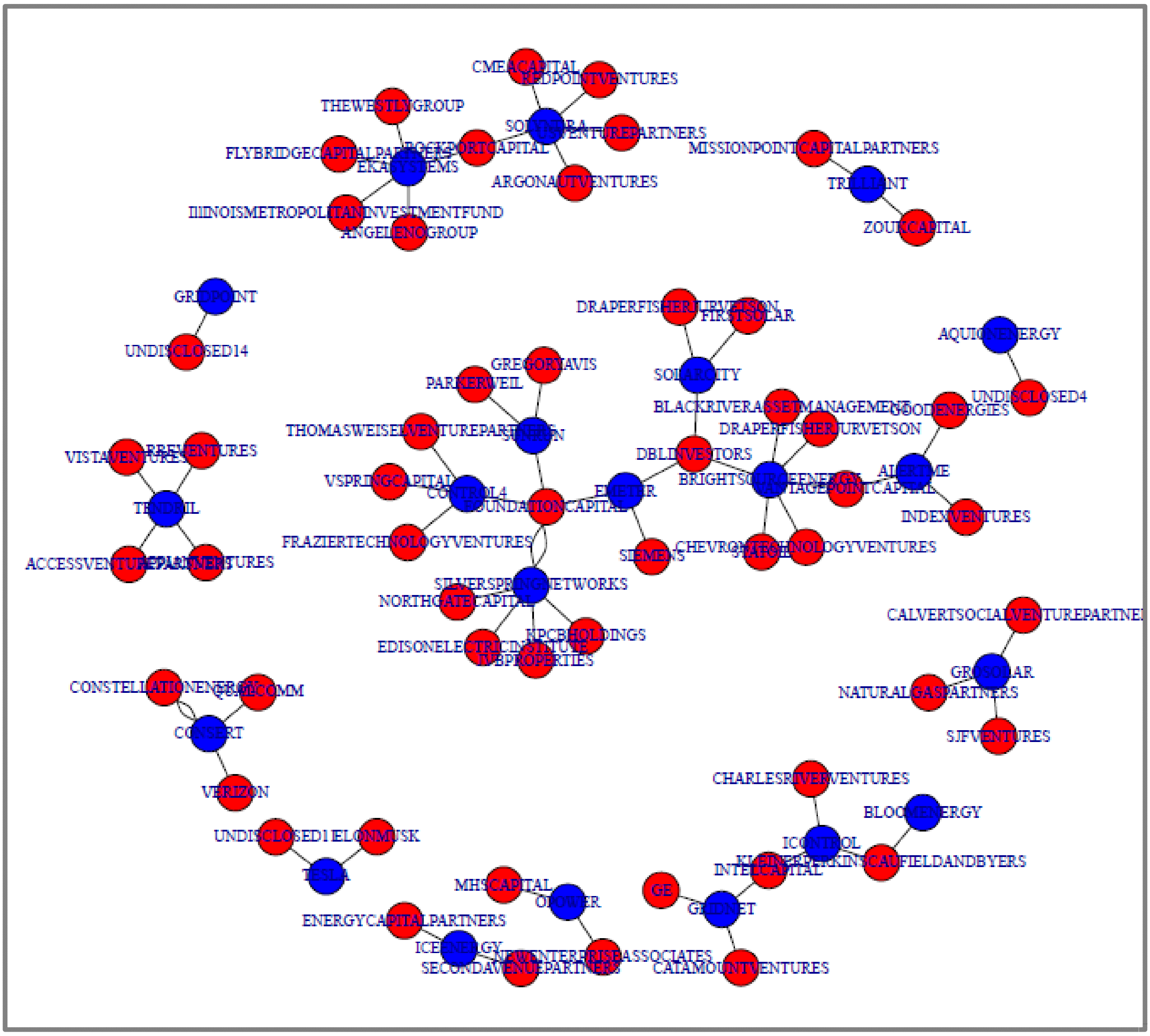
APPENDIX-2. Bipartite Graph of 2006



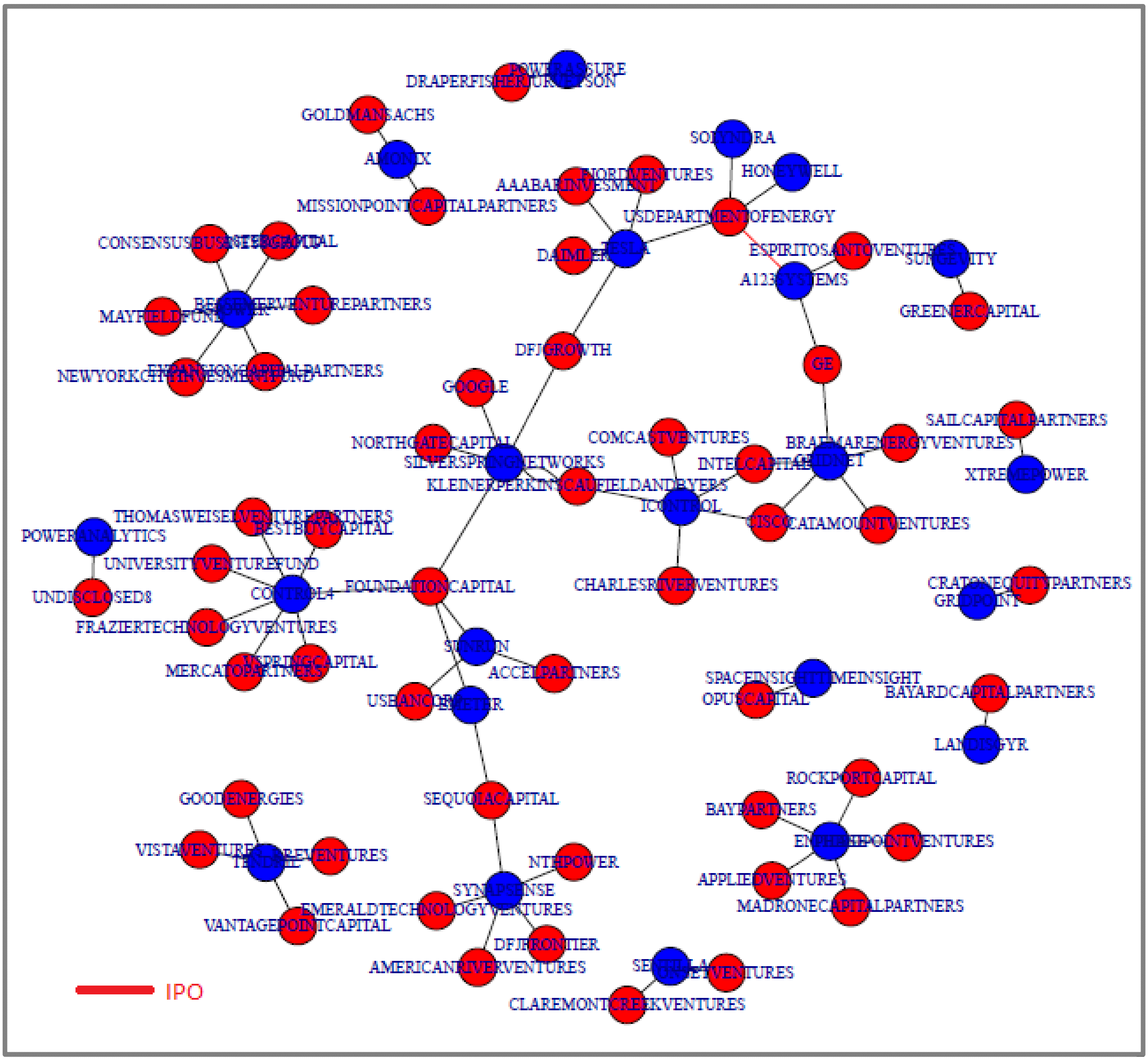
APPENDIX-3. Bipartite Graph of 2007



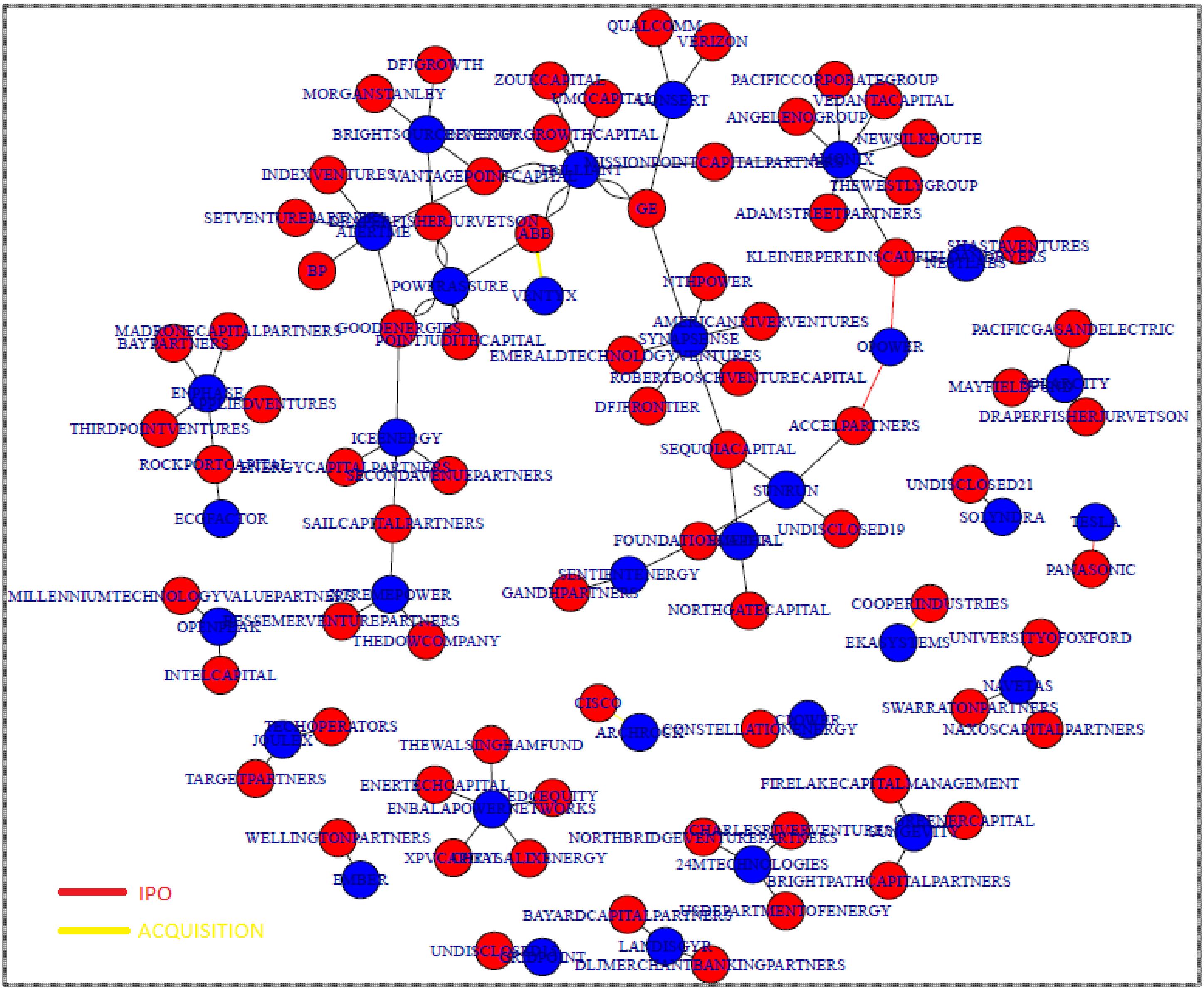
APPENDIX-4 Bipartite Graph of 2008



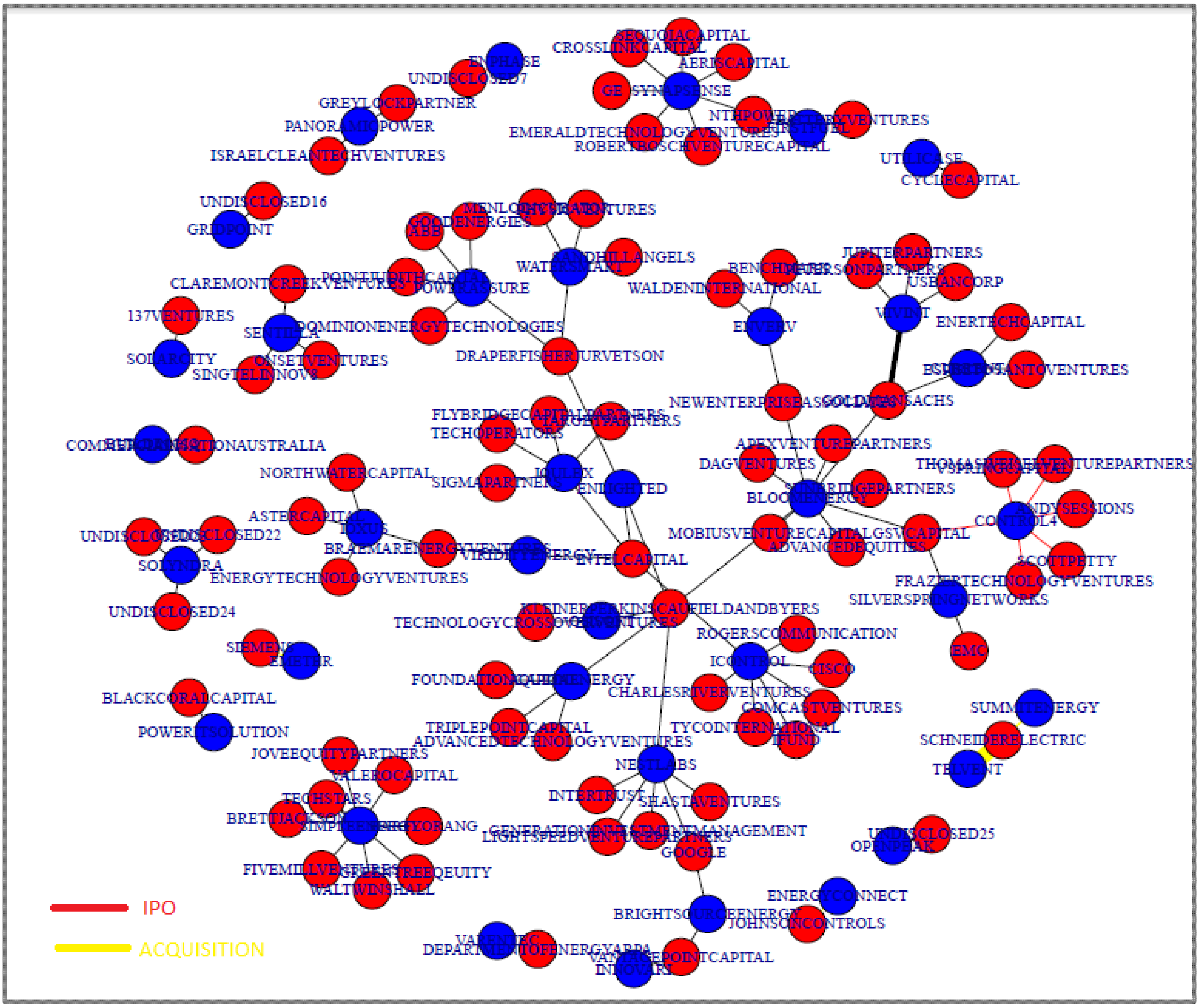
APPENDIX-5 Bipartite Graph of 2009



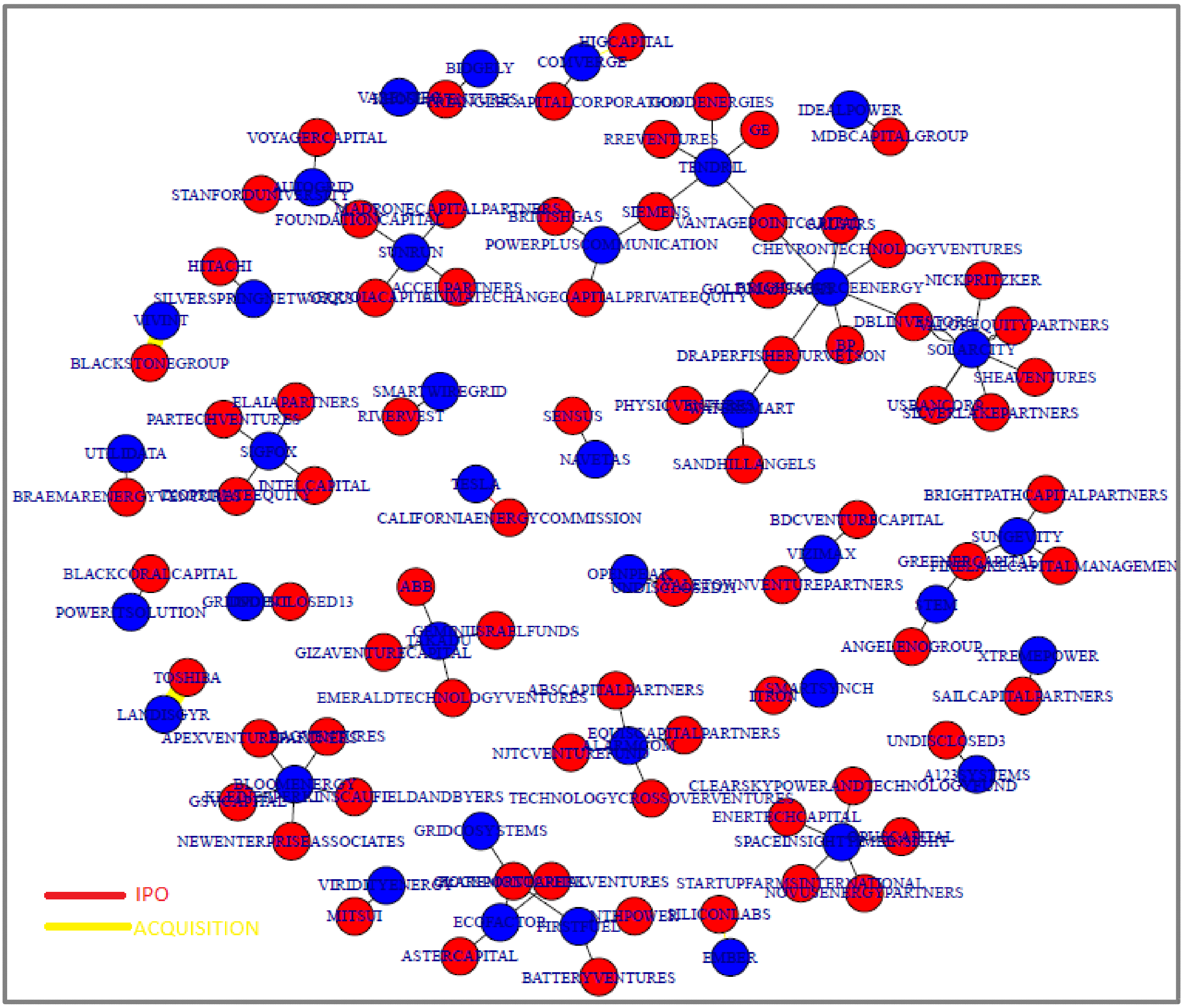
APPENDIX-6 Bipartite Graph of 2010



APPENDIX-7 Bipartite Graph of 2011



APPENDIX-8 Bipartite Graph of 2012



APPENDIX-9 Bipartite Graph of 2013