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The Role of Firms in Energy Transformation

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The Role of Firms in Energy Transformation

This paper looks at the role of firms in the transformation of fossil fuel based energy systems towards cleaner and greener energy systems. Firms are playing an important role in determining the speed and direction of technical change towards such energy systems. But systemic constraints and negative externalities tend to make such transformations constraint and difficult. To be able to understand how firms overcome these systemic constraints and bring about positive externalities it would be important to observe the strategic role played by firms. Firms are removing technological and economic constraints by engaging in strategic alliances with other firms and research organizations. Both small and large firms have positioned themselves strategically in the green energy market either through basic innovations or through innovations brought about by joint technological partnerships.

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I. Introduction

Systemic transitions are often slow but changes between the components of a system occur as a seamless web of change (Hughes, 1986). Transformation towards clean and green forms of energy will require considerable technological, organization and institutional changes. In fact all previous system transitions like the sailing ships to steamships (1840-1890 and horse-and-carriages to cars (1880-1920) required changes not only in the underlying technology, but in the practices, regulation, infrastructure and industrial networks (supply, production, distribution) (Geels, 2001). There are two ways in which transitions may occur: a transition might start with a single component change but which might gradually change the entire configuration of the system. Or changes in many components will accumulate to link up and reinforce other components in the system.

The latter transition delineates the transition to alternative systems. Energy security and climate change concerns are changing components within the energy system that are slowly reinforcing other components within the system. For example, public perceptions and environmental lobbies have helped push for institutional changes, like regulatory measures for CO2 reduction, which in turn are helping reduce technological and market uncertainties for firms, which typically attribute emerging and nascent technologies. These are assurances for firms particularly for returns from market and technological investments. Regulatory measures such as national targets setting in bringing renewable energy in the total energy mix do not guarantee success but act as an important catalyst as they encourage investors to commit, enable stable technological deployment and cost reductions, and encourage research (European Wind Energy Association, 2008). Although there are considerable changes still forthcoming in the energy system, both institutional and organizational, the role of firms in the transition process cannot be ignored. And it is this, which this paper will seek to show, and particularly more so because there are none or very few studies actively exploring the role of firms in the transition towards clean and green forms of energy.

II. Constraints in Energy Transformations

Technological systems are economic, social and technological constructs of a system and each of these components work together to create the system (Hughes, 1983). A technological system is defined as "…network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology…" (Carlsson and Stankiewicz, 1991, pg. 21). If an agent or a component of the system changes then all the other agents will need to shift and change in order to accommodate the new configuration. Not only are the actors inter-related, they are also markedly inter-dependent. Inter-dependencies and inter-relationships between the actors of a system make systemic transformations extremely difficult. Components and actors of energy systems include large established oil and gas firms, subsidies and incentives that sustain demand for cheap coal and gas, existing cheap and high performance technologies for electricity generation, existing distribution networks for automobiles, and existing internal combustion (IC) engines among many others. As energy forms the basis of almost all other sectors of the economy, the inter-relatedness, which characterizes the system, cannot go ignored. And because the different elements in a system are linked and aligned to each other, established technologies cannot easily be replaced by radically new technologies (Geels, 2001). This inter-linking feature between various components of the system characterizes the transition to clean and green energy technologies.

Three other features that typically characterize the energy sector are the hugeness of the energy system, difficulty in market formation and the existence of proponents of establishment (Jacobsson and Bergek, 2004). To be able to replace the entire energy system in the near future, the contribution of renewable energy will have to be astoundingly high. Renewables are contributing only 0.8% in electricity production in the OECD countries and excluding hydro. In addition, incumbent technologies are often subsidized, which not only include research and development subsidies but other forms of direct subsidies. Renewable energy technologies are new technologies with cost and performance disadvantages and competition with such incumbent subsidized technologies are not proving to be on a fair level playing field. And on the other hand, phasing out subsidies in fossil fuels is politically challenging particularly because it will hike up consumer prices, production costs, and increase investment risks for fuel dependent firms, and in some cases might even wipe out an entire industry.

According to Scheer (2007), to bring about a shift in energy sources, numerous practical hurdles will have to be overcome. These hurdles are those that reside alongside familiar sources of resistance (administrative, technological and economic) and thus forming a complex web of inter-relationships between the components of the system.

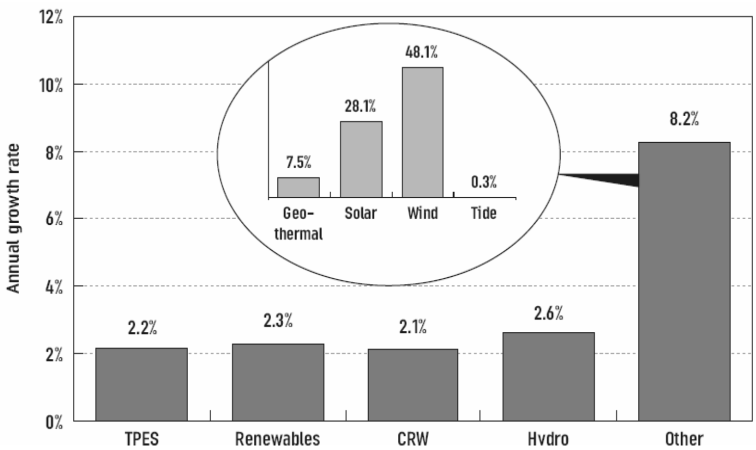

Fig1: Between 1970 and 2004, total renewable energy supply experienced an annual growth rate of 2.3% over the last 33 years. The 'other' in the category signify new renewables (solar, wind, geothermal etc.) recorded a 8.2% annual growth, mostly speeding up in the late 1990s and early 2000s. (CRW= Combustible Renewable and Waste and TPES= Total Primary Energy Supply) *Source: IEA, 2007*

Soete and Kemp (1992) has shown that network externalities[1], the selection environment and dynamic learning and scale effects will determine the extent to which a system can be transformed into a new and clean energy system. Both positive and negative externalities grow as each technological system develops over time. Congestion caused by canals in the 18th – 19th centuries and horses as a means of transport at the end of the 19th century were negative congestion externalities which eventually limited the growth of these means of transport. Pollution network externalities are caused by tanneries, chemical and paper factories dumping toxic materials into a river that destroys fisheries and thus the eventual means of sustainable livelihood for fishermen. Thus negative externalities tend to limit the growth of technological trajectories and might lead to another or an alternative mode of production or transportation that may or may not be sustainable. On the other hand, positive externalities exist if the benefits are an increasing function of the number of other users or components. This means that positive externalities can only be developed over a period of time and this feature poses a barrier for the entry of new and cost disadvantaged technologies.

The selection environment broadly includes institutions and the mechanisms behind the selection of a technology. If the selection environment is locked into a certain mode of transportation or method of production or process it will inhibit the smooth transition to another system. Dynamic scale and learning effects need to be encouraged by institutional changes. Institutional changes will change the mechanisms that will gradually bring forth dynamic scale and learning effects. Dynamic scale and learning effects result in price reductions and product improvements over the long run. Economies of scale help to lower costs of production while learning leads to lowering production costs and improving technological performances through learning-by-using, learning-by-interacting and learning-by-doing. However, dynamic scale and learning effects can only be achieved over time and only once the smooth transition from fossil-based systems towards clean and green systems had begun.

III. Firms in Energy Transformation

Policies and regulations that typically constitute the selection environment select certain innovations and drop certain others. A selection environment also has an ability to break path dependencies. Alexander (2001), for example, in his study of political institutions, finds that path dependence occurs because change means significant costs at least in the short run, and that discounting effectively means that only exogenous shocks can pull an organisation from a path once it has been established. Therefore it is the implementation of regulations and policy measures that have pulled organizations out of the path of fossil-based activities towards cleaner and greener forms of energy. So what the selection environment does is give firms opportunities to develop cleaner and greener forms of energy through various tax, production

[1] Is a cost or benefit arising from an economic transaction that falls on a third party and that is not taken into account by those who undertake the transaction (Gibson, 1996)

and investment incentives and take firms along another technical trajectory, breaking the assumed path of technological development.

Firms are removing certain systemic constraints and helping in the transformation towards new and clean energy systems. By engaging in strategic alliances and joint ventures for the development of a renewable energy technology, firms are overcoming network externalities and gradually achieving dynamic scale and learning effects to make the eventual transition to a green energy system.

III.A Firms Strategies

Firms like all organizations are the main vehicles for technical change. The definition for organizations follow Edquist et al (1997), "Organizations are technical universities, research institutes, R&D department of firms..." We will only focus on the firm as an organization that brings about technical change. The importance of firm in impacting technical change is viewed here: "Although the primary objective of capitalist firms is not innovation, innovation is often an important precondition for making profit and therefore a large portion of the innovation processes in a capitalist market economy takes place within firms" (Edquist et al, pg. 58, 1997).

To understand the role of firms in generating technical change, one must study how firms acquire existing knowledge needed to innovate or spread knowledge to other innovators (Thomson, 1993). One of the main factors hindering firms from making the transition to clean and new energy system is risk and uncertainty. Risk and uncertainty facing firms are affected by two selection mechanisms: the anticipation of higher regulation supporting new technologies and the type of market in which the firm operates. Regulations tend to reduce risks while markets may reduce or even increase risks and uncertainties, depending on the signals received by regulations. Because of the notion of risk and uncertainty associated with new technologies "firms do not know beforehand the feasibility, cost, or results of technical change, the theory must give a place for the choice of strategies by firms" (Thomson, pg.1, 1993).

Firms engage in strategies like research alliances, or form partnerships to jointly develop products, or acquire new technology or knowledge by buying another firm. All market engagements of this kind that induces new knowledge acquisition or innovation or increased technological performance of firms will tend to reduce the degree of risk and uncertainty surrounding the new technology, thereby making the transition to a new technology easier and smoother.

Strategy according to Johnson and Scholes (2006) is the direction and scope of an organization over the long run that achieve advantages for the organization through a configuration of its resources within a challenging environment, to meet the needs of the market. And following Metcalfe & Boden (pg. 50, 1992), the definition of strategic processes are, "...the ways in which a firm identifies and selects between a range of technological options; the ways in which these (strategic) activities…are inter-related with, the firm's technological choices…" Further, they have identified strategy, in (pg. 51), "with the generation over time of selective advantages for firms, advantages which are based on the accumulation of specific knowledge capital."

These strategies are indeed forms of learning that lead to an improved understanding of a new technology by firms, new knowledge acquisition, and technology innovation. So a firm bets on a new technology or decides to develop a new technology through strategies. There are different types of firm strategies but innovation strategy is specific to the search process. In the organisational context, innovation is linked to performance and growth of a firm through improvements in efficiency, productivity, quality, competitive positioning, market share and reductions in costs among others. Strategies like innovation strategies are those that lead to innovative outcomes like efficiency improvements, growth and cost reductions among others. These strategies are through behaviours like internal R&D; venture funding, licensing, joint research collaborations with other organizations or universities and acquisition of other firms among others.

III.b Large and Small Firms in Energy Transition

Because large incumbent firms are part of the already established conventional energy market, large firms are in fact barriers to the transition towards new and emerging renewable energy markets. Incumbents are part of the (negative) network externality that resulted over the years since the industrial revolution and include large electricity suppliers and large oil and gas firms. But because of regulations and policies promoting renewable energy technologies in few countries, electricity generators like E.ON (Germany) and Iberdoal (Spain) are turning themselves into partial renewable energy firms and so are oil and gas firms like Royal Dutch Shell and British Petroleum. So despite technological uncertainty, anticipatory climate change and renewable energy policies are forcing incumbents to re-strategize. And if the oil firms' (or an incumbent's) transition to renewable energy companies involves the right strategies, these firms can profitably re-deploy their skills and assets (A. Lovins et al., 2007) and be involved in the advancement of these technologies.

But only once a technology is recognized to have attained market potential that large firms will begin to explore or invest in them. These incumbents are sourcing energy particularly from wind energy, as it achieved reached grid parity or dynamic scale and learning over the years of technological development. But large incumbents are still reluctant to deploy large-scale solar PV unless the technological uncertainties are shared with other firms, or there are incentive programs given by the firm's country. The latter is the case for solar PV firms from Japan, initially large semiconductor firms that received incentives from the Sunshine Project that began in 1974. According to Mytelka (2003), strategies of knowledge generation and appropriation that privilege larger firms are playing a significant role in new wave technologies than in earlier mechanical technologies. Size is an important element in the appropriation of knowledge that that has enabled established firms to remain dominant particularly in new and emerging technology markets. Large firms that are manufacturing solar photovoltaics and crowding the marketplace are Sharp, Solar World (Shell), Sanyo Photovoltaics, Mitsubishi Solar and Kyocera Solar and large wind turbine manufacturers are Vestas, Nordic, Siemens and GE Energy.

Rank	Firm	Original Industry
1	Sharp	Electronics
2	Q-Cells	Start-up (1999)
3	Suntech	Start-up (2001)
4	Kyocera	Ceramics
5	Sanyo	Electronics
6	Motech	Measuring Instruments
7	Deutsche Solar	Subsidiary of Solar World (Shell) /Oil & Gas
8	First Solar	Start-up (1999)
9	Mitsubishi	Electronics
10	Sun Power	Startup (1985)

Table 1: The top 10 firms in solar PV production are a mix of large diversified incumbents and small start-ups. Source: Adapted from Prometheus Institute, "Asian Cell Producers Swamping the Boat: A Look at the First Half of 2007, PV News, vol. 26, no. 9 (September 2007), pg. 6-8

Often small firms through their entrepreneurial activities undertake the challenges that arise from the business opportunities of new and emerging technologies. These small firms are spin-offs or small start-ups that have found market applicability of their basic research and are ready to test them in the market. But these small firms or start ups have limited resources and often struggle to access complementary assets which are needed to get their ideas to the market. And therefore smaller firms, often with the radical technology that has a good commercial potential, tend to reach for both research and market capital by engaging in technological alliance with other firms, both suppliers and customers.

A small US start-up, Nanosolar Inc., made entry into the solar energy market in 2002 through private angel funding. It explored copper-based CIGS, a thin-film technology rather than the dominant monocrystalline technology. Solar PV technology is at the growing stage of the technology life-cycle, with two main existing variants of the technology: thin film and monocrystalline. Monocrsytalline is the older and dominant technology with 90% of the market share but has costs and production limitations because of the high cost of silicon. More recent and cost-effective technologies are thin-film technologies that use little or no silicon[2]. Nanosolar acquired the basic CIGS technology through licensing from a private individual and

[2] The process of crystalline silicon fabrication of using a rod of pure silicon and sawing it into wafers is expensive. Thin-films are usually deposited and not sawed, and use only a fraction of the material used in crystalline process fims. The growth rate of thin-films like Cadmium Telluride (CdTe) and Cadmium Indium Gallium Diselenide (CIGS) has risen tremendously. And now next generation organic and nanotech thin-films promise even greater cost declines. Chris Knight, 2008, Breakthrough Institute, available at http://www.thebreakthrough.org/

from Unisun Corporation, a pioneer firm in CIGS printing. Later in the year 2006, Nanosolar started a joint venture alliance with Coenergy, a European manufacturer of solar PV components and systems, to co-develop large scale photovoltaic systems. The same year, the research team at Nanosolar produced cells with a world-record efficiency of 14.6%. By 2008 and since its inception, through various strategic alliances including accumulating knowledge from technological licensing and internal R&D, Nanosolar obtained 17 patents in solar PV technology, advancing the performance and cost of solar PV technology manifold. According to a report by Nanosolar, their PV panel costs are $.99/watt. A recent patch of panels they shipped to Germany reportedly had an installed cost of $3/watt, which is nearly 1/3 that of the US average.

Another start-up, this time in the hydrogen-fuel cell industry, Ballard Power Systems, has had 23 partnerships since its inception in 1979, and through various partnerships it managed to successfully commercialize fuel cell technology. Ballard developed a low-cost proton membrane exchange (PEM) fuel cell under a contract for the Canadian National Defense. In 1993, Ballard and Daimler-Chrystler agreed to a joint venture to further automotive fuel cell technology. Later Ford collaborated to jointly develop hydrogen fuel cells for next generation fuel cell cars. The fuel cell alliance focused on research, development and manufacturing of fuel cell stacks (devices that convert hydrogen into electricity), fuel cell systems (that control hydrogen going into the stack and the power) and electric drives (devices that convert electricity into power). Ford and Daimler-Chrystler has 18.5% and 22.8% share respectively in Ballard, and through their sheer size and investment capabilities, the large firms through this alliance tried to create a leadership position in the PEM fuel cell industry. Ballard also supplied its propriety fuel cells to Honda, Nissan, Volkswagen, Yamaha, Cinergy, Coleman Powermate, Plug Power and Matsushita Electric Works, among others. In 2001 Ballard acquired XCELLSIS and Ecostar from DaimlerCrysler and Ford. This acquisition brought in 650 additional patents issued and pending for Ballard totalling to over 1,200 patents (Fuel Cell Today, 2001). In 2002, Ballard and Millenium Cell signed a joint technological development, and obtained a licensing option for the hydrogen on demand fuel system.

Table 1: Few examples of the extent of large and small firms' participation in the development of renewable energy technologies through alliances that help firms reduce technological risks and market uncertainties.

Firm	Technology	Size	Total Alliances
Energy Conversion Devices Inc	HFC	Small	32
Fuelcell Energy Inc	HFC	Small	9
Ford Motor Co	HFC	Large	183
Plug Power Inc	HFC	Small	13
UTC Fuel Cells	HFC	Small	2
Shell Hydrogen	HFC	Large	6
Millennium Cell Inc	HFC	Small	5

General Motors Corp	HFC	Large	234
SolarWorld AG	Solar PV	Small	4
Evergreen Solar	Solar PV	Small	2
Mitsubishi Corp	Solar PV	Large	465
Gaz de France	Solar PV	Large	29
TOTAL	Solar PV	Large	39
Fuji	Solar PV	Large	42
Solec International Inc	Solar PV	Small	1

The total alliances in the above table imply strategic alliances for joint technological development, licensing and strategic sharing of technological resources like skills and other knowledge. Ford Motors, GM and Mitsubishi Corporation, showing the largest number of alliances in the given technology in the table, a re all incumbent large firms that due to their sheer size and investment abilities, have managed to build on their capabilities in the area of renewable energy through strategic alliances with other major firms around the world. Oil and gas firms like Gaz de France and TOTAL, have been slow in their attempt to enter the renewable energy market, other than a few examples of active buying and selling of renewable energy assets. For example, BP attempted in the past to develop solar PV panels, but later sold it. Solar World AG, with a relatively high number of alliances, was previously part of Arco Solar and Siemens Solar. In fact in 2006, Shell Solar sold its thin film manufacturing's assets to Solar World AG. Fuji Electric Corporation and Mitsubishi are both large firms that have been in the semiconductors business since their inception. But because of the inter-relatedness of new wave technologies (Mytelka, 2004), these firms have a technological lead in terms of production and design of solar PV technologies.

CONCLUSION

The role of firms in the energy transition is an important one. Firms are removing systemic constraints and other systemic barriers and helping the move towards greener and renewable energy systems. Selection mechanisms are ensuring the investment ground on which the firms play. However, the move towards a green or renewable energy system from a fossil fuel-based system is a slow and cumbersome one, with still great many economic, technological and social hurdles. The transition requires tough regulatory measures that promote renewable energy technologies as a reliable energy source, and efforts that make them technologically and commercially viable. Already supported and pushed by regulatory measures in some countries, firms are innovating in renewable energy technologies, thereby improving efficiencies and lowering production costs.

Firms have responded to the regulatory triggers set by governments around the world and prompted by the world future market needs and potential, they have begun to make strategic decisions towards technological innovation. In fact, we have seen that through technological alliances firms are being able to reduce technological risks and market uncertainties, commonly associated with performance and cost-disadvantaged technologies. Large firms are reluctant, at least in the beginning, to enter the new and emerging market. But not wanting to lose out on the future market potential coupled with a desire to become a first-mover, large firms are betting on new technologies and sharing the technological risks by collaborating with smaller firms with the technological edge or engaging in joint ventures with other firms or through the creation of consortiums.

Large firms, as compared to small firms, engage in many more alliances than smaller firms, on the average. Their capital and investment capabilities help them search for the required technology to a wider extent than smaller firms. Although not always the ones with the new innovation or technology, large firms overcome technological barriers often through alliances that are exploratory in nature. Small firms on the other hand, seek out large firms to help them access markets and supply chains and/or give them capital to do further technological research. Therefore, governments seeking to help make the energy transition must ensure that policies and tax incentive help small and large firms innovate in renewable energy technologies and profit. Small firms, particular in an early and new technology like HFC, need extensive support for entrepreneurial skills and incentives like technological incubation and funding opportunities. Large and incumbent firms that have made a technological alliance with another firm, new or in the area of the technology for some years should be given research tax incentives, and other policies conducive to research and innovation.

Thus, we have seen above that firms are helping remove the usual barriers to entry in new and emerging technologies by engaging in alliances with other firms. These alliances are helping remove systemic constraints and other systemic bottlenecks that typify such systemic transitions. The role of firms in the green and clean energy market is an important one, which should evolve together with green energy policies, and the two should co-evolve to make the transition smooth and possible.

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