# Capitalisation of environmental technologies in companies: economic schemes in a business perspective

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**Abstract:** Drawing from empirical cases of environmental sound technologies (ESTs) and economic theory, this paper discusses how such technologies can be brought into the marketplace in new and creative ways through creative public sector financial support and capitalisation. An example of capitalisation from the public sector in Denmark demonstrates new technologies being diffused through a successful program in existence for over 18 years. This approach might be useful in the commercialisation of environmental and energy technologies.

**Keywords:** Public– private partnership; capitalisation; environmentally sound technology.

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## 1 Introduction

The USA has seen its research and development (R&D) funding as a portion of real GDP decline over the last five years. Clark [1] recently examined this issue for the US as part of a study for the United Nations on *publicly-funded research and development on environmentally sound technologies*, with a special focus on how to transfer or diffuse

such technologies developed in the USA to developing nations. The results of the study were instructive and formed a part of a 10-nation Report for the UN.

In the USA, for example, R&D funding declined in comparison to other G-7 countries from 70.6% to 48.1% over a five year period (1993-1998). OECD countries saw a similar decline from 70.6% to 43% [2, p.4], despite coordinated efforts by the science community to maintain and restore at least current levels of funding. When examining the last five years for US R&D funding (1993-1998), the figures are even more disparate. While the US R&D percentage of GDP was 2.54% in 1994, so also was the United Kingdom and close behind were Germany at 2.33% and France at 2.38%. However, Japan exceeded the US R&D spending by 2.9% [2, p.4]. The trend among other industrialised countries for international investment in R&D continues and has significantly increased, thus challenging the US competitiveness in technology innovation and diffusion.

A prestigious consortium of US scientists led by Dr. Allan Bromley, former Science Adviser to President George Bush, submitted a statement to Congress in mid-October 1997 urging reconsideration of the federal R&D budget, in part so that the USA could maintain its competitive advantage in science. While these agreements for federal support of R&D are now supported by some objective studies (see [3]) and are compelling to support that line of reasoning, it is not certain that the current Congress will change its current 'political ideology'. For FY 98, Congress has changed R&D funding very little, only matching cost of living increases.

## 2 Business versus government economic models

Much of the current federal economic ideology and hence policy on R&D is based upon a particular neo-classical economic view of the world: government should have NO role in the private sector. Therefore, R&D activities especially are the domain of industry, not government. Who else, it is argued, knows what is the best R&D for the private sector, then the private sector itself? For government to provide R&D funds means, therefore, that it either knows best what research should be funded or worst, that government would influence industrial decisions.

In contrast, the liberal or pro-government ideological perspective is reflected in the 'push economic model' [4,5]. 'The Technology Pipeline' demonstrates how new ideas and research move from the concept stage logically into the marketplace as 'stars' or successful industries of tomorrow. All the researcher or inventor needs to do is follow the logical process outlined by business schools: business plan, venture capital, and industrial alliances. Basically, this approach argues that R&D needs to be pushed out from universities and laboratories into the private sector [6, p.3, 5].

On the other hand, the neo-classical economic model argues that the private sector itself (often described as the 'market') must see the demand and therefore needs for new technologies come first from the market or industry. In other words, the private sector must 'pull' technologies that it defines and sees as important from university and laboratory R&D. The market or industry, therefore, so goes the argument, must define where public R&D funds should be expended. The market defines the most significant research areas for publicly funded R&D.

Both the liberal or neo-classical economic models ignore the give-and-take in conducting everyday business activities. In short, business is interactive, iterative and not

static or even a linear process. As Table 1 illustrates, studies of R&D characterise the demands of industry as being short-term and often too narrow to satisfy markets and shareholder pressures. Whereas the universities are long-term oriented in their research programs, in part due to the time needed for graduate students to finish their dissertations (note the time frame is about five to eight years, often the time needed for students to conduct research, write the thesis and publish it). Laboratories have a two to five year time frame which places them closer to the commercialisation time frame of industry which is within months of the funding, and certainly not more than a year or two, before R&D must see products in the marketplace. These time frames are important because industry or the market rarely funds R&D that takes over two to three years before it is commercialised. Competition and certainly shareholders demand a far quicker return on the R&D investment than the more long-term laboratory and university R&D cycle.

**Table 1** IØ performance by country

| | *Population* | *Per GNP* | *Number of Projects* | *Performance Levels* |
|---|---|---|---|---|
| | | (US$) | | |
| Poland | 40 million | $1,966 | 45 w/43 (only 2 losses) | Doing well |
| Czech Republic | 8 million | $2,440 | 20 | All doing well |
| Hungary | 10 million | $3,010 | 6 | All doing well |

Much of the long term R&D in the USA therefore must be publicly funded. Depending on how one counts R&D budgets, and aside from the US Department of Energy with its 11+ laboratories (see Table 1 for locations) and $16 billion budget for their operation. There are almost 720 other public laboratories in other federal departments and agencies with another $50 billion of funding.

The current US Congressional economic ideology sees government environmental policy turned into research programs through environmental R&D. In other words, environmentally sound technologies (ESTs) need to be funded by the private sector to meet the environmental policy demands of government, or environmental policies and regulations should not be implemented in the first place, since they put an undue hardship on industry. This is the essence of the US debate over the global Kyoto guidelines. Government regulations or guidelines interfere with the free market (sic) and will hinder economic development.

ESTs, in this political context, differ from other forms of research in that they are often viewed as 'applied' to and meeting public policy decisions. Thus while the government can create the regulatory demand for ESTs, it places the R&D burden on the private sector or more recently on state, regional and local authorities. Hence, states and regions must increase their role in both the regulatory and funding arenas for ESTs. As in other ideological economic policies, the neo-classical perspective abrogates the role of the federal government to state or regional levels, causing a difficult transition for states along with economic and enforcement hardship.

The economic policies of the last two decades have increasingly relied on concepts such as 'competitive advantage' [7,8]. In the last decade of the 20th Century, neo-classical economists used popular analogies from US sports to apply business- economic models as 'level playing fields', 'team play' or quantitative economics with 'game

theory'. Terms like 'team player', 'winner' and 'loser' all are designed to demonstrate that business is a 'game' in which only one side won in the end. Of course, such an analogy assumes that the rules of the game were similar for all players. Reich [9, pp.34-80] presents an historical argument on how the USA economic supremacy after W.W.II mistakenly allowed US corporations to smugly assume their global economic dominance. But, as US core corporations learned throughout the 1980s, other companies throughout the world played a different 'economic game', with different rules.

Business and economics is not a game where competitive advantage becomes 'sideline' or 'Monday morning quarterbacking'. For example, the best case of this narrow economic thinking and its mistaken impact on US economic policy can be seen in the constant US assertion that Japan and the USA need to be on 'level playing fields' in order to compete. The argument is that the Japanese are not playing fairly and therefore US businesses are at a disadvantage. Tyson [10], former Chairperson of President Clinton's Economic Advisers, made a similar point, but did not make the case of the underlying need to change economic theory and, therefore policy.

A non-linear 'interactive push-pull economic model' provides the key non-ideological philosophical perspective (see forthcoming [11]) needed behind the creation of a new public policy toward R&D in ESTs. Economic schemes exist within this non-linear model that can commercialise and diffuse R&D for ESTs. Below we consider a model developed in Denmark which diffuses technologies through a creative and successful public - private interactive economic program (scheme) in existence for 18 years.

Clearly, no other industrial country defines the free market the same way as the USA. Therefore to have a level playing field for the US citizens is really 'tilting' business and economic policy toward the US economic system and hence giving US firms strong advantages. In other words, 'competitive advantage' means 'US competitive advantage'; purely an ethnocentric term that is limited to US connotations only. What we see in the Danish economic scheme is an economic model centred more in cooperative business relationships with government. Other collaborative economic models are also found in the 'business network theory' among others [12-14].

In the 21st Century, US businesses face a world radically different than the one of the past century. Conventional economic history and theory (defined especially as the neo-classical and liberal-Keynesian) do not answer the pragmatic problems facing global businesses. Reich [9,15] argues that US businesses operated after W.W.II under a close relationship between core corporations and big labour unions. This form of 'free market' capitalism allowed the core corporations to be 'high volume producers' and flood the world markets with US goods and services. Reich calls this a "national economy" and others might label it an 'industrial policy', especially geared heavily toward the defence and military industries [16,17].

By the early 1980s, the global marketplace had changed, but not the US business community. US core corporations were failing to penetrate or even maintain their markets. Reich presents a compelling case that US core corporations shifted in the late 1980s to 'high value' production in order to compete globally. The result now in the 1990s for US businesses is trying to create 'worldwide demand for their (US) skills and insights' [9, p.77]. In other words, US manufacturing might go elsewhere in the world, but US 'know how' was still valuable and therefore able to form the basis for core corporation to conduct business (see [18]). No longer are global corporations nationalistic since they may have operations in many countries depending on the optimal conditions

for making a profit (e.g. a US company might have operations for manufacturing in Singapore, accounting in the Philippines, customer serving in Holland, and marketing in the UK).

Drucker [19] presents a compelling case for the emergence of a new 'Post-Capitalist Society' in the USA. Without reviewing all of his arguments, he essentially states that the US economic system after W.W.II has now ended. The USA is now on the path to a truly new capitalist society that will lead to success through financial resources vested in 'pension funds.' [19, pp.55-69]. The vast concentration of capital in these funds and the managers of them are today's true capitalists. 'Pension fund capitalism is capitalism without capitalists' [19, p.70].

Passive capital, in the form of venture, seed, mezzanine, and investment capital is the source for new funds in US business development, especially the high tech industry. The statistics from the mid-1990s confirm this observation when venture capitalists doubled their investments into 1997 from the lows of the early 1990s [20,21]. The *SF Business Times* [22] noted, for example, that 1996 marked an all-time high in the issuance of Initial Public Offerings (IPOs) generated primarily by venture capitalists.

These analyses miss two important points. First, although Drucker acknowledges it, the basis for the economic systems themselves are the nation-state or country itself. And second, the development of the post-capitalists society of pension and venture capital funds in the US economy, is rooted in historical US economic pragmatic policy. The US economic system has changed from a 'capitalist' one to a 'pension and venture fund' system, which Drucker argues is in need of a new 'economic theory' to explain it.

A variety of economic theories and models today identify the deployment of innovations in the firm. The conventional liberal approach developed by Michael Porter at Harvard University uses a structural analysis of the firm in order to understand its competitive advantages and plot strategies against other firms (see [7,8]). In order to accomplish the analysis of the firm, Porter created what he calls the 'five-forces' framework: entry barriers, substitutes, buyers' and suppliers' bargaining power, and intra-industrial rivalry. Each force needs to be adequately understood in order that the firm becomes competitive. However, as Mowery *et al.* [23] note:

> "The primary determinants of success thus are external to the firm, resting on characteristics of industry structure, rather than on the firm's internal managerial, technical, marketing, and other resources." [23,p.2]

Instead, Mowery argues that a "resource-based framework" must be employed to analyse the firm, its behaviour, and competitive strategy [23, p.1]. Relying on the competitive advantage paradigm further limits the ability for the "firm's ability to enter new markets or lines of business" [23, p.2]. In other words, the conventional paradigm ignores innovation, research or other significant resources internal to the firm. One of those resources, that is considered here, is capital formation. Another is corporate management in the context of risks, incentives, and rewards.

The resource-based business model, in contrast to the conventional paradigm, argues that "a business enterprise is best viewed as a collection of sticky and difficult-to-imitate resources and capabilities" [23, p.3]. The presentation of the corporate financial managers' survey data [24] supports the resource-based framework. This paradigm focuses upon limited resources that are internal structures and functions of any firm. The assumption is that the resources are static in time and fixed (as in an accounting context) to a particular firm, organisation or sub-set of a firm. On the other hand, the

interactionists' paradigm [11] is clearly superior to the conventional paradigm. However for the sake of convenience and expediency, the resource-based framework is used as the basis of the subsequent discussion.

The resource-based approach argues that the firm must understand and analyse itself as having capabilities. In most cases, these capabilities cover a wide range of areas, but for the sake of this study, the concern is only upon technology and innovation. Teece *et al* [25] note that in the short run, firms have to live within their current capacities:

- Business development is viewed as an extremely complex process. Quite simply, firms lack the organisational capacity to develop new competencies quickly.

- Some assets are not readily tradable, for example, tacit know-how and reputation. Thus resource endowments cannot equilibrate through factor input prices.

- Even when an asset can be purchased, firms may stand to gain little by doing so [25, p.10].

The resource-based framework concerns issues like management knowledge, process and design manufacturing, among others. The focus here is on innovation through research and development through interfirm cooperation and alliances. This is significant particularly in the context of financial considerations such as investment and capitalisation.

The conventional paradigm, as represented by Porter's work emphasises competition to the determinant of collaboration and alliances. As Mowery and Oxley [26] argue, there has been a "dramatic growth" in the founding of international joint ventures and strategic alliances over the last 15 years. These new ventures involve everything from manufacture of goods for global markets to joint develop new products for domestic markets [27].

Mowery *et al*. [26] note how Herbert and Morris studied over 800 interfirm alliance agreements in the 1980s noting that the preponderance were in the high-tech industries: 24% in automobiles, 19% in aerospace, 17% in telecommunications, 14% in computers and 13% in other electric industries. More recent data collected by Hagedoorn and Schakenraad, [27,28] in the early 1990s support this trend for interfirm alliances with the addition of biotechnology, new materials and information technology.

Volumes have been written about the national economies of the various G-7 countries. We will not go through an exhaustive discussion here about these various forms of 'free market economies'. A critical distinction is the differences in capital formation across different G-7 countries. In Germany, for instance, business economics for a free market works in an entirely different manner than the pragmatic US system. The role of the major banks is fundamental in German businesses, especially for the development and advancement of its core or basic corporations. Bank representatives sit on most of the corporate boards and can participate directly in business decisions.

For the Japanese, the free market works differently again than the other G-7 members. Major trading companies (or *keiretsu*) hold equity shares in companies and cross-board membership of all kinds, including banks, manufacturing, real estate, and service companies. The Italians have developed yet another kind of free market economy, whereby major core corporations remain primarily in the hands of the founding families, but have strong government support. The French have evolved their own particular

economic system centred around government ownership and support of major industries. The list goes on, differentiating free markets among the G-7 countries.

In basic economic terms, the federal government approach is supply side 'technology push' which for business applications, is unsatisfactory. Economists will talk about the demand side 'technology pull' approach which is 'market' dominated. This implies that the customer knows what it wants better than the laboratory scientists. A new model of 'technology interaction' whereby the research scientist within the laboratory must be in constant interaction with the private sector in order to create new technologies for a three to five year time frame.

The policy question is clear: Is the cost of commercialising technology worth the governmental investment? Without engaging in the political debate over the role in government, the basic issue often focuses upon the justification of federal or state funds for research, development and technology commercialisation in terms of 'job creation'. Aside from the political popularity of job creation, further analysis reveals that this is not the best, and certainly not the sole, metric for success.

Some policy makers and scholars argue that job creation is the basic metric for justifying government funding. The essential problems are in defining the types of jobs (public or private sector) and determining the long term impact. Studies have found that job creation for the public sector are often unproductive (that is, public sector temporary positions) and often generate low tax revenues. Creating high paying and sustainable jobs requires a different set of metrics to measure the successful outcome of government plans, policies, and funds.

## 3 Advanced energy and environmentally sound technologies in the firm

For Graedel and Allenby [29], the globe is a closed system operating as if it is a biological 'life cycle'. The concept 'industrial' linked with 'ecology', adds a specific focus on manufacturing, business and economics in general. "Manufacturing and other industrial activity (must be viewed) as part of a larger ecological whole" [29,p.24].

Sustainable development and industrial ecology are evolving concepts with theories and models being created. While Graedel and Allenby note that this 'nascent field' is changing rapidly, there are a number of apparent "fundamental principles" [29, p.24]. The UN Report on ESTs [1] further outlines an overall approach to understanding how governments and environmental policy(s) can assist in the transfer or diffusion of ESTs. The UN issued two reports in the mid-1990s addressing this issue including such solutions as: tax measures, incentives and disincentives along with international carbon taxes, information clearing-houses and technology transfer agencies, environmental regulations, trade-related measures including tariff measures and export restrictions on environmentally hazardous technologies, tradable emission permits; transfer of patent rights, and environmental offset investment programs [30,31].

Without repeating Allenby's (or others') definitions and reviews of sustainable development and industrial ecology, the purpose here is to focus only upon the capitalisation of advanced energy and environmental technologies for firms. In that context, the literature in industrial sustainability and ecology is limited and indeed 'nascent', if not woefully inadequate. It does not consider either the economic systems within countries or across national boundaries.

For example, Romm [32] argues that better management within companies can produce more environmentally sensitive, if not clean, industrial operations. 'Every company can increase its profits and productivity dramatically by reducing pollution' [32,p.3]. For business operations, profits are well-worth advocating as part of an industrial ecology approach to solving global environment problems. There are many other economic analysts who make the same point in reference to general business practices (see Drucker [19] or Deming [33]).

Romm's basic point is nevertheless significant: changes in the management of companies can be both profitable and environmentally sound. Most corporate Boards of Directors regularly debate this issue today. Yet management within industry does not appear to be enough to assure 'responsible corporate' decision making about the environment. As Porter and van der Linde [8] argue from a case in Holland, in order to have environmentally responsible companies, there needs to be some form of governmental regulation or guidelines or participation. In short, as the neo-classists would argue, an '*environmental* invisible hand' should be left to the corporations or market. Such an argument is suspect. However, the liberal economic Keynesian argument, that governmental intervention in the form of financial and regulatory support is the answer, is also suspect.

Allenby places the economics of industrial ecology directly on the shoulders of businesses, "especially product and process design" [29, p.26]. In other words, if companies consider what they produce, manufacture and distribute, then they will make environmentally 'friendly' goods and services. Again while this perspective is important, it does not cover the basic concern for how businesses introduce new technologies that are environmentally friendly and improve global ecological conditions.

New environmental technologies (e.g. [5,34]) developed in US national laboratories can provide technological solutions to environmental issues, in part legislated by governmental regulations, while creating new business opportunities and economic systems.

Intense and constant interaction must take place between the market pull sectors – such as manufactures, energy, and power companies – and the technology push providers – such as research institutions like universities and national laboratories – in order to commercialise new technologies. Such close collaboration supersedes industrial competitive issues and problems in an interactive non-linear economic system [11]. In other words, the typical economic analysis that presents demand versus supply fails, because the business process is really one that is a constant interactive process.

## 4 Innovative government economic programs for business development

The world in the 21st Century is different. Nations exist, and therefore companies within their borders, while global in perspective, have to operate within certain political constraints. Regional economies are important, but constitute only a small part of economic and business activity. More significantly, new, sustained, and mature business activity must be long term and global in nature [9]. Otherwise, local and regional competition for businesses becomes divisive and destructive.

Other industrialised nations have evolved their own particular form of free markets [17,35]. Not all nations define the 'free market' the same way as the USA or other western democracies. Sorensen [13] examines the issue of government and business

relationships, thereby concluding that most industrialised nations have a strong relationship (he uses the term, "partnership") between government and business. This relationship critical to global economic competitiveness [14].

The US government does not have a strong relationship with its business community. Instead, the US government and its business community are often advisoral over trade, regulatory, and business practice issues. However, the USA can develop a new form and definition of a free market economy derived from the experiences of other nations that hold similar basic economic values and beliefs: Denmark, Taiwan, Switzerland, Japan, and Holland among others. This new economic outlook should focus specifically at:

> "small firms, (that) appear to have many advantages, particularly within an industry cluster. The economies of sharing present a wide range of possibilities if the experience of Italy, Denmark and other countries is adaptable to the United States." [36, p.72]

What can the new US economy learn from other nations?

## 5 Role of national governments with corporations: as equity partners in research & development

Given the above approach to economics, US policy makers need to 'borrow' or learn from the experiences of other nations. Any economy depends 'pragmatically' in part on what can be learned from others. Consider the commercialisation of new environmental technologies for companies in a small industrialised country, Denmark. The issues of macro economics (defined only as fiscal and monetary policies) are the concern of other scholars. In terms of a national political economy, Denmark is an industrialised country with excellent environmental and economic record from which the USA could learn much. It has 5.6 million people, of which the largest city and capital of Copenhagen with 1.4 million.

Denmark over the last five years ranked either 2nd or 3rd in all United Nations economic indicators for world competitiveness [37]. The country weathered the worldwide recession fairly well (in terms of maintaining standard of living and increasing productivity; however the country also balanced its budget over the last six years and increased its balance of payments as exports soared) despite an unemployment rate of about 10% through 1994. Similar to the US Clinton Administration, the current Danish government is a coalition of economic conservatives and social liberals, replacing (since 1992) the ruling and once majority party (Christian Democrats for 10 years) in Parliament.

The basic assumption in Denmark about its system of a free market economy is that any government in power must have businesses as its partner. If societal goals (free universal education, national health care, strong social services, and high standard of living) are to be achieved, then business and government must work together toward common economic goals. The 'partnership' between government is not always smooth or cooperative, but it remains dedicated to the common societal value for the common good.

Since the mid-1980s, Denmark has legislated programs, known as 'schemes', that combine social and economic national interests. Consider three such 'schemes' that provide potential new approaches for a new US economic policy:

1 the government IØ Fund for increasing industry 'market share'

2 government supported entrepreneurial employment and

3 partnerships of private industry and government research and development, especially in 'network' formation.

More detailed descriptions on each of these programs and presented elsewhere [11,13,14,38]. However, the purpose here is to provide concepts and specific programs here in order to suggest new US economic policies and programs.

## 6 Industrialisation Fund for Developing Countries (IFU)

### *6.1 Background*

The IFU is partially modelled after the German Development Corporation which supports, primarily through loan guarantees, German companies in their expansion into third world countries. The Danish version, IFU goes much further, however, by providing 'equity capital' to the new ventures in the third world, rather than loans or loan guarantees. The IFU promotes "economic activity in developing countries" and was "created to promote investments in these countries in collaboration with Danish trades and industries" [39].

The Danish government founded the IFU in 1977 as a 'self governing fund', which means that while it would have initial government funding, it acts independently and is expected to be self funded after a period of time. By 1978 the IFU was totally self financed and has remained so since then. The IFU 1993 funding was DKK 220 million (up from DKK 215 million in 1992) with a total of 24 new company projects giving the IFU 145 total companies, conducting business in Asia (14), Latin America (5), and Africa (5). The new companies provide 3,300 new jobs, aside from the indirect employment of suppliers, distributors, and others.

### *6.2 Functions*

The IFU participates in large and small joint ventures in companies (public or private) located in developing countries as an active equity partner. It normally provides expertise and mobilisation of 'supplementary sources of finance to ensure complete project financing'; is an active partner as a member of the Board of Directors for a limited period of time; and 'also contributes with supplementary finance, together with its partners, when an existing company is to be expanded' [39, p.1]. The supplemental funding (representing cash flow) is the cornerstone of the IØ Fund, which is described next. The IFU has 57 full time staff members, of whom 44 are in Copenhagen and 13 are located in three regional offices: Africa, Asia, and Latin America.

### *6.3 Performance/results*

Aside from the IFU success in self financing since 1987, it has participated in a total of 236 projects (companies) in 62 countries creating over 40,000 new jobs, not including indirect employment in other sectors. Danish goods and services worth over DKK 6.7

billion have been exported in connection with these projects. Furthermore, IFU has been successful in spreading the capital risk by involving other financial institutions and mechanisms. For each IFU DKK invested in 1993, 15 DKK was invested by other parties. *Consequently, the IFU share of investments decreased to 6% in 1993 from 7% in* 1992. Finally, the IFU has shifted its focus from primarily African countries to Asia and Latin America. Future prospects are particularly attractive in Latin America (e.g. Mexico) under the NAFTA agreement, since the IFU provides a local national mechanism for Danish companies to participate.

In terms of pure economic performance, the IFU audited Annual Report notes that despite project losses for some companies, the IFU had a net profit of DKK 18.1 million, or DKK 6.1 million more than 1992. However, part of the profits were restructured into bond investments which showed losses in 1994, and are off-set by positive company performance. The IFU has shifted one program from bond instrument investments into other areas for 1995, in order to maximise its profits.

## 7 Industrialisation fund for transitional economies of eastern & central Europe (IØ)

The following analysis and discussion is derived from an unpublished paper by Clark and Jensen, [40].

### *7.1 Purposes*

According to the IØ Annual Report [41, p.i],

> "the purpose of the Investment Fund (IØ) for Central and Eastern Europe is to promote Danish investments in Central and Eastern Europe and thereby support reformist countries in their efforts to achieve an increased economic, commercial and industrial development, and to enhance the possibilities for closer economic cooperation between Denmark and Central and Eastern Europe resulting in generally improved East/West relations which will benefit Danish trade and industry, as well as the employment situation in Denmark."

1 The IØ Fund states its purposes in five concrete ways, derived from the successes of the earlier and more established IFU. The IØ Fund focuses on Eastern and Central Europe in order to assist its transition from 'command control' to 'free market' economies. While this is an admirable 'social goal', there are very pragmatic and self serving Danish industrial concerns for economic development and job creation in Denmark itself.

2 The IØ Fund establishes certain guidelines for use of its financial resources: Danish companies (especially Small Medium Enterprises or SMEs) must apply for the funds; in most cases, they must have identified a company in Eastern or Central Europe as a partner; establish a 'joint venture' which then may use the technical services (especially investment advice: locations, local banks, currency, related funds, etc.) provided by the IØ Fund staff.

3 The Danish company either has a special market niche or some technology that gives it a competitive advantage. This 'edge' enhances the Danish company's value (not necessarily financial or cash, but for example, in terms of intellectual property) in the joint venture.

4 The joint venture process for a Danish company to receive IØ Fund support includes a staff review of hundreds of applications annually with less than one hundred receiving some support at various stages. Those not receiving support are given constructive responses and, if appropriate, asked to apply again. There are not enough IØ staff to approve funds and participate in all the applications. Usually, the IØ Fund staff select companies based on profit potential through the diversification of the over-all pool of companies supported by the Fund. The goals for the IØ Fund also provide criteria for selection of Danish company applicants and the targeted companies within the Eastern and Central European region.

5 Most of the new companies are created in large part as a consequence of new technologies developed by the Danish partnering firm. Often these technologies are service, process or product oriented. Almost all have an EST component both due to Danish government policy and an inherent concern for the environment on the part of the Danish firms, their shareholders, and management.

6 The IØ Fund takes an equity position in each of the new companies (not more than one-third of invested capital), along with one-thirds equity from the other two (the Danish company and the partner firm in Eastern or Central Europe) joint venture partners. The Danish company's one-third equity contribution sometimes is in the form of fixed assets, or staff training or proprietary technology, rather than cash. The Eastern or Central European company's contribution is its facilities and equipment as its one-third contribution equity to the new joint venture. The IØ Fund places a senior member of its staff on the Board of Directors of the new company. While the new company is a multinational and global corporation, in reality the Fund financial support, along with the one third contribution of the Danish company, means that the new company is controlled by Danish interests.

### *7.2 Process*

There are three stages for joint venture projects. The Danish company must initiate the request for IØ Fund support. The first stage is the 'Feasibility Study', where the Danish company visits and seeks out a foreign partner to establish the basis for the investment decision. Part of the study is to invite the foreign company staff to Denmark and see its potential partner. The second stage is the actual starting of manufacturing or service or other business activity. Usually this stage is heavily on the Danish company since it will supply the technology and staff training for the foreign company. The last stage completely empowers the foreign company with the capacity for production from its own resources.

### *7.3 Performance/results*

In 1993, the IØ Fund had a budget of DKK 455 million; but in 1994 and again in 1995 (with two instalments), the budget totalled DKK 950 million. The trend held throughout

the 1990s. Overall for 1994, the Fund's economic performance was off because of its investment in Bonds in order to hedge interest rates. The Bond portfolios have been retired since Bond performance in 1994 was 25% below expectations as a result of interest rate increases. However, the major purpose of the Fund, that is to provide capital to Joint Venture Projects, showed considerable positive performance.

By country, Table 1 shows a summary of performance over the last three years of the IØ Fund operations. For the Baltic States, taken as one region, there are 14 projects for a population of about 20 million with at least US$2,000 annual Per Capital income. Only one company got into trouble and had to be reconstructed in order to survive. Russia presents a more unique and challenging situation. Aside from its larger population and improved per capital income – eight projects exist in Moscow and St. Petersburg.

Slovenia has a strong economy with a population of only two million and per capital income of US$6,300 as well as a stable political system. The same is not true of the Newly Independent States created from the old Soviet Union. These countries are not yet considered politically stable enough by Danish companies and investors for Fund projects.

Consider only three countries representative of the Central European region: Poland, Czech Republic and Hungary. Each is "Doing Well" which is defined as breaking even or making a profit, despite economic and governmental policies that are in transition.

## 8 Factors for success

### *8.1 Long term*

The IØ Fund supported 27 projects in 1993 and 33 in 1994. Estimates are for 35-40 in 1995, with increases yearly after that. Danish companies are more 'serious' than when the IØ Fund began. That is, the Danish companies want to achieve the IØ Fund goals and are not just seeking quick and easy profits. Thus the quality of the potential joint venture partners has improved significantly.

For the long term, the IØ Fund has been successful for SMEs. Most Danish companies are SMEs, so that both the background of the company and expectations for the Fund are fairly well matched. SMEs require as much, if not more, attention as the larger companies. In other words, the transactional costs are the same for all companies, no matter what the size. Consequently, the management and staff have to be constantly alert to only favour large versus small deals. Larger deals take as much time as small and have much more visibility in the business community. Nevertheless, smaller deals often lead to larger ones and are one of the primary purposes of the fund.

### *8.2 Government/private sector relations*

The tradition of government and business collaborations is relatively new in Denmark. There are political opponents based upon ideology. However, the IØ Fund has broad based support, in part because it does not advocate any particular industry or sector. More importantly, the role of the government is to be an active partner and then exit the company through divestiture.

### *8.3 Self-sustaining short term government support*

Perhaps the most enduring success of the IØ Fund will be its total self sufficiency by 1999. At that time, the IØ Fund will have gradually reduced its requests for Government annual funding and become totally self sustaining. The IØ Fund estimates that it will have solid portfolio with established financial performance. Key to this is that the fund (acting for the government interests) retains equity in the new companies in the form of warrants and convertible bonds or stocks, depending on which financial mechanism works best for the company's cash flow and performance. The convertibility of these financial instruments is the important financial instrument for the company and the IØ Fund, so that the Fund continues to maintain an active interest in technology(s) and the company's success.

### *8.4 Private sector business factors*

Having the IØ Fund as a business partner, rather than as a regulatory adversary, has distinct advantages. For example, the basic definition of capital within the new joint venture is critical for any company. With the IØ Fund providing capital, some debt which can later be converted into equity, the company starts off on a solid financial basis. Another example involves regulation. In at least one case, an IØ Fund joint venture was established despite some questionable environment regulation violations in the host country. A time table was set for resolution.

In business areas, the IØ Fund plays a positive, but not 'meddling', role. The IØ Fund projects must also provide training for the joint venture partners. While the Fund will assign a person to the joint venture Board of Directors, this presence is important for strategic purposes, including financing needs, regulatory concerns including taxation, and for business networks and contacts.

In conclusion, the Danish example of the IØ Fund illustrates how government can play a critical role in both the capitalisation of new companies and the diffusion of ESTs, while creating jobs and without inference in the operations of the firm. Government and business can be partners for their mutual benefit. They need not be adversaries or conflictual opponents. In an ever increasingly global marketplace, government and industry must define new roles for one another. Finance and capitalisation of new technologies is a fundamental cornerstone to economic growth and development.

## 9 Environmentally Sound Technology (ESTs) commercialisation: fuel cells

Turning toward the capitalisation of environmental technologies, scepticism must be brought to bear on statements, such as the recent *Competitiveness of the US Environmental Products and Services Industry* from the US DOC [42]: 'The vast majority of US environmental R&D in the past two decades, which amounts to over $100 billion, has been conducted with little direction from the market or input from the private sector.' [42, Ch.1, p.5] Clearly the market is not the ipso facto sole purveyor of environmental demand, needs, and concern for ESTs or public environmental policy for that matter. Industry should not be the determining factor in consideration of publicly-funded ESTs.

The US DOC Report is correct, however, in stating that there will be a $180 billion environmental industry in the near future and that it will evolve from a pollution control and waste management service industry into a totally integrated resource management industry, expanding beyond the 'traditional resources of water, energy, timber, and land but include materials, property, people, and information.' [42, Ch.1, p.4]. Critical to the future of the environmental industry are:

1 the continuance of publicly-funded R&D for ESTs and

2 their diffusion into practical industrial applications.

Using an interactive, non-linear economic model has been successful with publicly-funded research and development.

As cited in the references Clark [5] Cooper and Clark [43] and Clark and Paolucci [34], zinc-air fuel cell technology (ZAFC – see Appendix A) was originally seen as a replacement or hybrid with batteries in vehicles. While ZAFC was not funded by the Partnership for New Generation Vehicles (PNGV) or other federally funded effort, it was internally supported by an American National Laboratories internal research and development funds. Subsequently, the US Department of Energy provided some further research funding.

In early 1997, an international financial and manufacturing 'consortium' lead by international investors successfully entered into a Cooperative Research And Development Agreement (CRADA) with the national laboratory and began a two year concentrated effort to bring ZAFC to the marketplace. However, transportation was not the market driver, as previously envisioned by the inventor and laboratory. Instead the financial backers saw greater potential, applications, and positive environmental impact when ZAFC was used as an energy storage device to store energy and redistribute power for later use in conjunction with a related 'zinc recovery unit' or recycle unit developed at a major American university.

Transportation could then be integrated onto the ZAFC energy storage systems. The commercialisation pathway for the ZAFC focused initially on 'green' bus transportation for the Sydney Olympics, which would also include power-utility applications for the energy storage. The key was that the ZAFC is used for energy storage on buses and for utility power. The concept is to 'map' the transportation and power infrastructures over one another through the use of the common ZAFC energy storage technology. Arriving at this strategy was an internationally collaborative effort among financial backers and researchers which was an intensely interactive process between all parties [34].

*The Economist* [44], as similarly done by other popular mass publications including *Time* magazine, featured a story in its Science and Technology section, 'At last, the fuel cell' that acknowledged the transportation and power-utility dual applications of fuel cells. Scientists and engineers, the article noted, have turned from designing fuel cells for space and military applications because of the "growing demand for pollution-free energy sources" and now:

> "…seem to have created something that may revolutionize two industries – power generation and motor cars' which 'makes fuel cells a double friend to the environment: if put in vehicles, they would not pollute the city streets; if put in power stations (or vehicles, for that matter) they could not add to any global warming that might be going on." [44, p.89]

Some fuel cells produce electricity by reacting hydrogen and oxygen together electrochemically (not with combustion) and 'exhaust' only water such that 'there are no noxious pollutants such as carbon monoxide and oxides for nitrogen. Nor, at least from the fuel cell itself, is there any carbon dioxide ($CO_2$) that might contribute to the greenhouse effect.' [44, p.89]

> "It is these arguments (reduced greenhouse gases and improve air quality), and the threat – or, in some cases, fact – of legislation to back them up, that have stimulated research into cells which might actually be candidates for use in vehicles and commercial-electricity generation." [44, p.89]

ZAFC, and fuel cells in general, are considered as one of the most promising technologies for achieving zero emission vehicles (ZEV), far ahead of lead-acid batteries and other battery technologies.

## 10 Conclusions

The commercialisation of the ZAFC had started with an Australian group of investors who, by all accounts, put up some of their own funds and then later got other investors. This new start-up consortium, like most new ventures, was undercapitalised and under-estimated the daunting challenge of transferring technologies from a university or laboratory into a viable business venture. More 'demonstration' funding along with the difficult administrative requirements required more capital. The publicly funded ESTs (ZAFC) is clearly the laboratory and university contribution to effort. Nevertheless, the start up company wanted more funds or at least in-kind services (use of office space, telephones, even the logo of the laboratory) as it pursued more capital.

Enter the Danish program which can help close the gap between the commercialisation of a new technology and the financial needs to sustain the company, especially if it is either new or a SME. New technologies need demonstration and proof of concept funding that few business people fully appreciate. Furthermore, there are vast differences between the 'business culture' and the 'research culture' in terms of work style, the need to move quickly, and a variety of other issues. In other words, there needs to be a bridge between the two worlds. The Danish IFU and IØ funds provided that mechanism with the appropriate guidelines and structures to safeguard problematic business decisions and trouble-shoot strategic issues such as trade policies, currency fluctuations, financial instrument conversion, and nation-to-nation political concerns.

Four basic themes encompass placing US capital and investment in the financing of advanced technologies (ESTs or otherwise) for SMEs. First, while there are increasing amounts of venture capital available for new ideas, products, services and technologies, there are few resources for 'bridge capital' (not mezzanine or seed capital financing) to move patents and technologies from the experimental stage of R&D into the demonstration, field test, and prototype stages. In other words, it is critical to add another D to R&D.

The second financial theme of the US investment community concerns internationalisation and global trade. For decades, US foreign policy was very much interlinked to its domestic economic policies. This macroeconomic characteristic can be seen in two ways. Today, with the passage of the NAFTA and other regional trade policies, the capitalisation of firms is becoming more 'globalised'. Within even the last

decade, many US companies are seeing much of their revenue come from outside the USA. In many industries, especially high tech firms, as much as 60-70% of the gross sales come increasingly from foreign business. If companies (SMEs) have not experienced this new globalisation, then they certainly will in the next century, with the new international trade laws.

From a firm's microeconomic level, such internationalisation means new sources of revenues and even more significantly, new sources of capitalisation. Companies can take advantage of currency rates of exchange. They can finance new ventures, form joint ventures with foreign firms, and use other national funding mechanisms for expansion and growth. The use of international sources of capitalisation must be linked with the national governmental expenditures, for example, on R&D. Even more significant today are the increasing numbers of firms forming 'networks' that can take the form of joint ventures and strategic alliances. This is not just true of large companies, but also of SMEs. Technology can often be the link or hook that unites the interests of these firms. This is especially the case with ESTs where private sector funding is in short supply.

Financial resources may come to a company in a variety of ways, but the fact that further RD&D funds may come from outside the US market is the significant point. Capitalisation of the firm is no longer bound by national geopolitical borders. The example of the Danish program to fund new technologies and companies internationally is so appealing in the restrictive context of shrinking budgets, especially in R&D for ESTs, because they typically lack the 'D' or demonstration funding resources.

The third theme is the 'US entrepreneurial spirit' that fosters innovation through research and development. As noted above, the creation and growth of many new firms is directly linked to new discoveries that are financed when they are more 'mature' by venture capitalists for entrepreneurs who attempt to commercialise the technologies into product(s). The organisation and operation of the resulting new companies generally only benefit directly from venture capitalist form of finance, experienced management, access to funds and markets, and a network of business contacts. The outcome is even more significant: new industries and new capital are recycled again into more companies. Rarely, however, are the funds placed into the second 'D' (demonstration) and certainly not in the R&D itself. The role of government (and perhaps its equity for the investment) must continue there.

Another approach are funds from states. Nineteen (19) states have 'Seed Capital Funds' for use as high risk capital, critical for the development of new technologies into new industries. California, furthermore, is considering a variation of the Danish program models, called the 'Direct Investment Fund', which would allocate a small percentage from its State pension funds to advance new technologies into the market place. Legislation was introduced in California in 1995 and re-introduced in 1998.

However, it was not until autumn 2001 during the California Energy Crisis that the State implicitly recognised the need for its being an equity partner in new and advanced technologies. At that time, the State issued a report (California Commission on the 21st Century) that supported the State ownership of projects and companies to which it contributed substantial funds. This policy change, while not legislated directly, also took the form of State Senate Emergency Bill, SB#1 that approved the creation of the California Power Authority which does have direct capability for funding and owning power companies.

The last theme of the US financial and capitalisation of firms involves the equity side of the ledger or the one often cited most often in the literature: high risk investment. Throughout this paper, we have discussed technologies, capital, and economic models. Unique to America, perhaps, is its free market history, especially over the past quarter century, for venture capitalists (but also investment bankers and the general public in terms of stocks in firms listed on NASDAQ, for example) to place their money at high risk in new industries and technologies.

Other countries, seeing the tremendous value in terms of economic growth and employment from new industries, are creating their own venture capital funds, usually with the government involved (a distinct difference from the US experience). What is unique in this paper is to also look at the financing programs in other countries (e.g. Denmark) and understand how they might be used to fund new advanced ESTs (ZAFC) in the USA. With shrinking public resources for R&D and venture capital not directed toward research or demonstration and field tests, but more anxious to pick winners, new funding concepts become more and more attractive.

More research into the direct relationship between government environmental regulations and successful business development will be forthcoming. We are undertaking some of those studies now, but encourage others to do so. The outcomes of such research using our framework, theoretical model and methodological techniques would also be fruitful. Clearly innovation in other industrial sectors will be just as enlightening for both the research community, business executives and governmental decision-makers.

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## Appendix A Zinc-air fuel cell [34,43]

Developed by John Cooper at a United States National Laboratory in the early 1990s, the ZAFC is a closed system whereby the ZAFC produces electricity (left side unit) and then recycles the spent zinc into a recycle unit (right side unit) to be made into pellets for refuelling. The system was a demonstration on a bus with the ZAFC on board the bus and the recycling unit located in the bus service garage.