Historical Case Studies of Energy Technology Innovation

CASE STUDY 15: SYNFUELS (US).

THE US SYNTHETIC FUELS CORPORATION: POLICY CONSISTENCY, FLEXIBILITY, AND THE LONG TERM CONSEQUENCES OF PERCEIVED FAILURES

Laura Diaz Anadon
Harvard University

Gregory Nemet
University of Wisconsin

With contributions from:
Bob Schock
World Energy Council

AUTHORS' SUMMARY

The US government's immediate response to the rapidly rising oil prices of the late 1970s primarily involved demand-side measures such as price deregulation and energy efficiency incentives. Synfuels, however, were promoted as a supply-side response. Subsidies for the demonstration and deployment of synfuels – synthetic liquid or gaseous substitutes for conventional petroleum or natural gas products - received a rare confluence of support from both parties in government (which wanted to show a dramatic response to the public), industry (which saw a potentially profitable new market), and energy experts (Deutch and Lester, 2004). In 1980, the US Congress created the Synthetic Fuels Corporation (SFC) to use the country's extensive coal, heavy oil, and oil shale deposits to ameliorate the energy security and macro-economic consequences of oil import dependence. With cost estimates of only $60/barrel for the mid-1980s, the development of synfuels production capability was seen as a backstop or 'insurance' against seemingly ever-rising oil prices (Deutch, 2005). Five and a half years later, and after expenditures of about $4.5 m the long-term legacy of perceived innovation failure.

If referencing this chapter, please cite:
Anadon, L.D., Nemet, G. & B.Schock (2012). The US Synthetic Fuels Corporation: Policy Consistency, Flexibility, and the Long-Term Consequences of Perceived Failures. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

1 INTRODUCTION

Following the Iranian Revolution in 1979, oil prices doubled and eventually rose from about $14/barrel to $40/barrel (in 2008$). As shown in Figure 1, the US Department of Energy (DoE) projected that oil prices would continue climbing to $80-100/barrel by the mid-1990s (EIA, 2008). And “Project Independence”, President Nixon’s plan to end oil imports by 1980, was widely acknowledged to have failed.

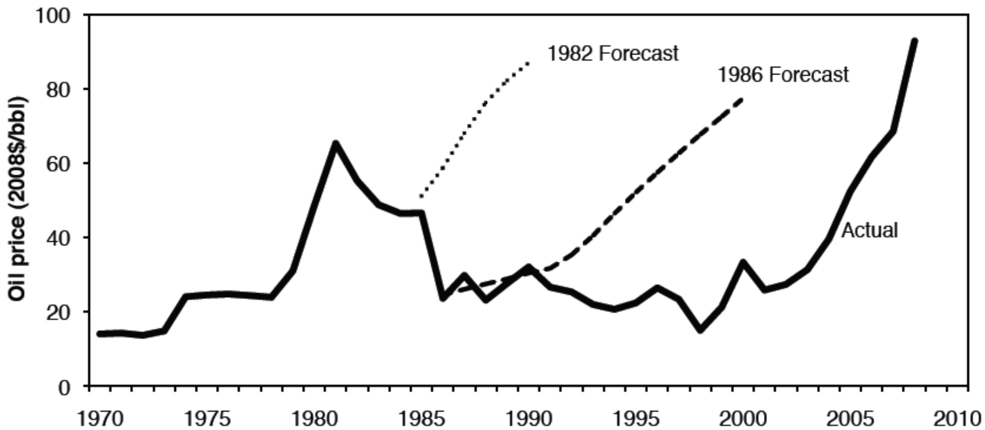

FIGURE 1. COST OF US OIL IMPORTS AND SELECTED WORLD OIL PRICE FORECASTS. NOTES: OIL IMPORT COSTS AND FORECASTS ARE EXPRESSED IN 2008 US$ (EIA, 2010A). OIL PRICE FORECASTS FROM THE EARLY 1980S ARE BY THE US ENERGY INFORMATION ADMINISTRATION (EIA, 2010B).

This was the backdrop for the 1980s Synthetic Fuels programme in the US. Synthetic fuels - synfuels - are liquid or gaseous substitutes for conventional petroleum or natural gas products, and in this context are derived from fossil fuels such as coal, shale or tar sands, rather than from biomass. A federally-funded R&D programme on synfuels dated back to the 1960s, and was revitalized during Project Independence with a focus mainly on pilot plants. In 1980, the US Congress passed the Energy Security Act which, among other things, created the Synthetic Fuels Corporation (SFC) and authorized $12.2 billion (in 1980 US$) for its first phase of operation. An expected second phase of operation never took place.

In the 1970s, both fiscal conservatives and environmentalists had opposed the creation of a large-scale government programme supporting the commercialization of synfuels because of production cost uncertainties at a commercial scale and environmental impacts of the processes involved. This strong opposition disintegrated in the face of high oil prices in 1979 and the introduction of federal incentives for other alternative sources of energy (including solar and bioenergy).

The SFC’s ambitious mandate was to achieve production of 0.5 million barrels per day by 1987, and 2 million barrels per day by 1992, equivalent to the replacement of over one quarter of US crude oil and petroleum product imports (EIA, 2010b). To achieve these goals, the SFC was to support private sector projects selected through a competitive bidding process, or by directly negotiating financial contracts for specific projects using production price guarantees, purchase agreements, as well as loan instruments and guarantees (Rothberg, 1983). Commercial and technical viability were the most important selection criteria, but the SFC also took a technology’s long-term prospects and environmental impacts into

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consideration. Contracts issued effectively created small market niches for synfuel project outputs, with the US Department of Defense as a principal purchaser.

The SFC was structured as a quasi-governmental organization unlike other federal agencies: its salaries were higher and operated under a different model, and its budget was not subject to the yearly appropriations process. This structure was in part motivated by the US Congress' lack of faith in the DoE's capability to run large projects. DoE had already funded synfuel pilot projects that many perceived to have been unsuccessful (e.g., the Project Gasoline and CO_2 Acceptor pilot projects, see Figure 2). In addition, Congress hoped to insulate the operation from volatilities in the annual budget processes and use a model that would appear credible to the private sector (Deutch and Lester, 2004).

Over its 4 years of operation from 1982-1986, the SFC issued 9 separate solicitations requesting proposals for financial assistance to aid the construction and/or operation of synfuels projects, and received about one hundred distinct proposals (Cohen and Noll, 1991). During its first year of operation, the SFC gave loan guarantees for two shale projects and a heavy oil project, and provided price guarantees for two coal gasification projects (Herrick, 2002). Initially, these projects met project cost and schedule targets. However, once oil prices started to plummet in 1985 (see Figure 2), the cost of producing synfuels became considerably greater than their market value and serious discussions began about the continuation of the SFC. Then in 1986, the SFC was terminated.

2 SYNTHETIC FUEL PROGRAMMES IN THE US

2.1 Early History (1925-1978)

The Synthetic Fuel Corporation (SFC) built on a long-standing, federally-funded synfuels development programme. Between 1925 and 1956, the Bureau of Mines had conducted exploratory research and built small test units. Germany's production of synfuels from coal during World War II motivated Congress to pass the "Synthetic Liquid Fuels Act" in 1944 for the construction and operation of demonstration plants to produce synthetic liquid fuels from coal, oil shales, and agricultural and forestry products. This early phase of research and experimentation was characterized by technical difficulties and escalating and wide-ranging cost estimates. Two small pilot plants were built but subsequently shut down in the early 1950s as the cost of synfuel development became too high for the government to bear (US DOE, 2010a).

In 1960, the Office of Coal Research was created to find new markets for the politically powerful coal industry and promote the utilization of domestic coal resources in the face of dwindling supplies of oil and gas (Cohen and Noll, 1991). This newly institutionalised programme started by supporting research and pilot projects on two processes: coal liquefaction, and coal gasification (see Figure 2). Coal liquefaction consists of the production of liquids such as gasoline, methanol, and fuel oil from coal either directly (e.g., pyrolysis) or indirectly via coal gasification (producing gas from coal). In both cases, the hydrogen-to-carbon ratio in coal is increased in the liquid synfuels by putting coal in a hydrogen atmosphere, sometimes in the presence of catalysts, and using elevated temperatures and pressures. Coal gasification to produce natural gas substitutes rather than liquid fuels was also supported given the importance of increasingly expensive natural gas used in residential and commercial heating as well as industrial process heat and feedstock.

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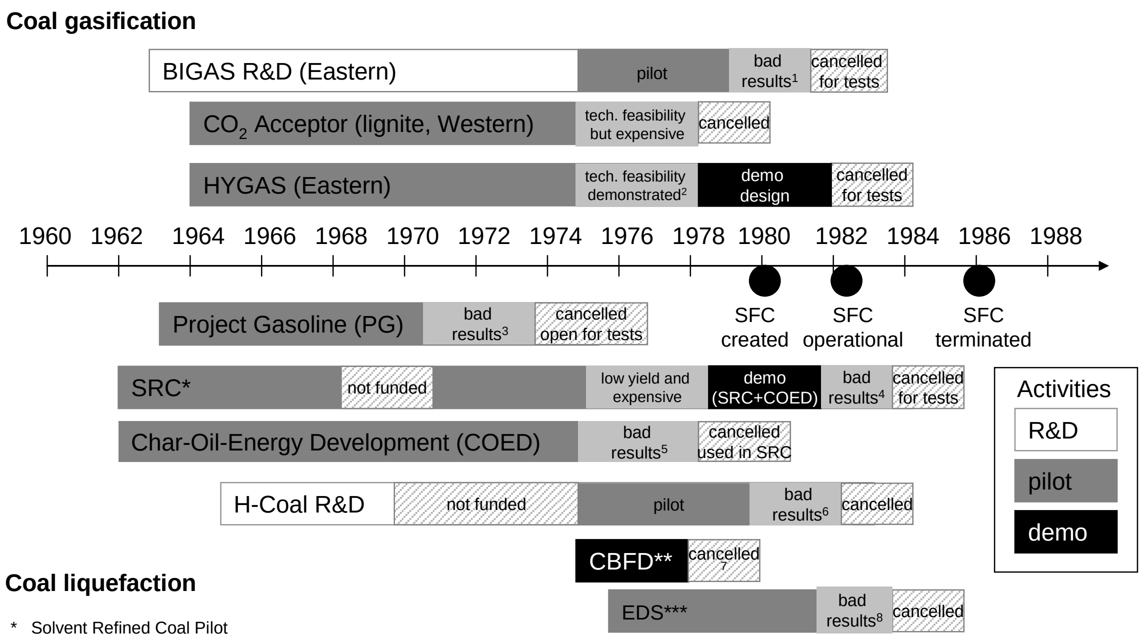
Attempts to scale up liquefaction and gasification projects from pilot plants to commercial scales faced several challenges, including: moving and processing large amounts of coal (solids handling), building components and large reactors to withstand high pressures and temperatures, refining or upgrading raw coal to liquids or to gas products, and dealing with large amounts of waste materials. These challenges were exacerbated by the programme's support for unproven direct liquefaction processes over a proven indirect liquefaction process using the Lurgi gasifier. This was possibly due to the latter's incompatibility with Eastern coals.



* Solvent Refined Coal Pilot
** Clean Boiler Fuel Demonstration
*** Exxon Donor Solvent Pilot
(1) Design complexities. Pilot operated only briefly in 1977, 1978 and 1979. Pilot scale was 120 tons coal/day.
(2) Costs twice as large as those of deregulated natural gas price. Pilot scale of 75 tons coal/day. Demonstration design was for 7,300 tons coal/day.
(3) Gasoline never produced, problems with all components. Pilot scale plant was 20 tons coal/day.
(4) Major cost overruns (greater than a factor of 2) were found. Performance shortfalls were predicted. The size of the demo plant was going to be 6,700 tons coal/day or about 20,000 barrels per day of oil equivalent. The pilot scale plant was 50 tons coal/day.
(5) Low yield and high sulfur content. Pilot scale was 25 tons coal/day.
(6) Twice as long to design and build, and 66% more expensive. Pilot scale was 250-600 tons coal/day, or 1,400 barrels per day of oil equivalent
(7) Conceptual design was never completed. Caking problems not solved. Demo plant design was 50,000 tons coal/day.
(8) Long delay in design and construction and cost overrun of 50%. Pilot scale was about 250 tons coal/day and 500 barrels per day of oil equivalent.

Figure 2. Major coal gasification and liquefaction projects in the US (1962-1986). Notes: Projects were supported by the Office of Coal Research (1960-1974), the Energy Research and Development Agency (1974-1978), and the Department of Energy (1978-1980), before the creation of the Synthetic Fuels Corporation in 1980. The timing of the projects is approximate. Data sourced from: Bohn et al., 1980; Cohen and Noll, 1991; Dravo Corp., 1976; Edgar, 1983a; Edgar, 1983b.

Cost overruns were endemic, indicating the severe difficulties with projecting costs at commercial scale. The Office of Coal Research (as later with DoE) persistently under-estimated the costs of unproven US gasification and direct liquefaction processes at levels below those of proven European processes (Cohen and Noll 1991). Figure 3 shows that between 1973 and 1977, the Lurgi fixed bed gasifier, a proven technology in places as varied as Germany, South Africa, the United Kingdom, Pakistan, and Korea (Blazek et al., 1979), was expected to be more expensive than newer unproven processes in the

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US such as BIGAS, CO_2 Acceptor, and HYGAS. Only in 1978 did the expected cost of deploying the proven Lurgi technology in the US fall to within the range of these newer processes. The same trend occurred in cost estimates for coal liquefaction. A RAND report attributed the almost 5-fold increase in costs between 1971 and 1977 principally to "improved cost estimating capability" based on more detailed engineering designs and more operational experience (Hederman, 1978).

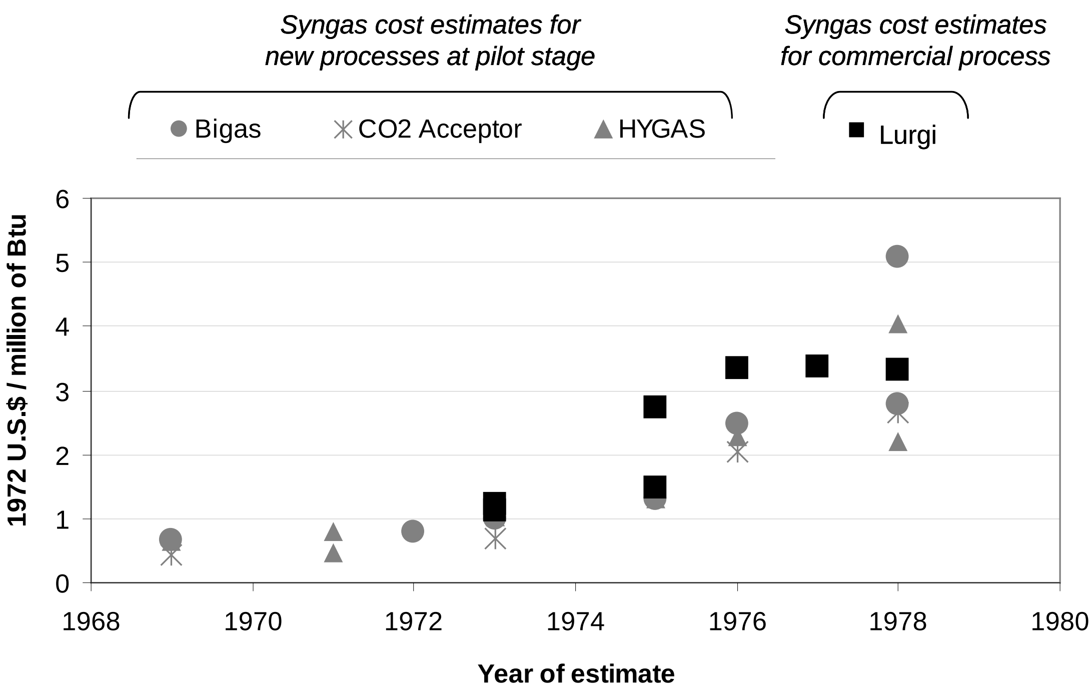

FIGURE 3. ESTIMATES OF SYNGAS PRODUCTION COSTS (1969-1978). NOTES: ESTIMATES FROM THE TECHNICAL LITERATURE AND GOVERNMENT REPORTS OF THE COST IN $ PER MILLION BTU OF PRODUCING SYNGAS FROM COAL USING DIFFERENT PROCESSES. SYMBOLS IN GREY REPRESENT ESTIMATES OF NEW PROCESSES ONLY AVAILABLE AT THE PILOT STAGE. SYMBOLS IN BLACK REPRESENT ESTIMATES (STARTING IN 1973) OF THE LURGI PROCESS THAT WAS ALREADY COMMERCIAL. DATA SOURCED FROM: Cohen and Noll, 1991, TABLE 10A-2**.**

2.2 From Opposition to a Coalition of Support (1973-1980)

The 1973 OPEC oil embargo highlighted the importance of developing synthetic fuels, and catalysed President Nixon's creation of "Project Independence" which aimed to make the US energy self-sufficient by 1980. In 1975 President Ford set a goal to produce 1 million barrels of synthetic fuels per day (Ahrari, 1987) and established the "Synfuels Interagency Task Force." The Task Force carried out a cost-benefit analysis that excluded noneconomic benefits and showed that unless unrealistically low synfuels prices and very high oil prices were used, the programme's costs would exceed its expected benefits. Although the need to develop synthetic coal and gas was clear, the cost and development risks were very high, and so without government support they would not happen (Synfuels Interagency Task Force, 1975). In this regard, The Task Force recommended that loan guarantees be used to enable regulated utilities to access capital markets, and price guarantees be used to remove market risk from future declines in oil prices.

A broad 'coalition of opponents' opposed a proposed loan guarantee programme on the grounds that it would involve commitment of enormous resources, highly uncertain outcomes, and excessive government involvement in the industry (Ahrari, 1987). Two reports released in 1976 by spending oversight bodies concluded that the loan guarantee policy lacked adequate economic justification and had been insufficiently discussed (Cohen and Noll, 1991). Environmental groups joined fiscal conservatives to oppose commercial synfuels facilities because they anticipated "massive environmental problems, including air pollution, groundwater contamination and disposal of huge amounts of toxic wastes" (League of Conservation Voters, 1987; McCloskey, 1981).

The tide turned in support of the commercialization of synfuels in October 1978, when Iranian oil workers went on strike, followed by protests and the exile of the pro-western Shah in early 1979. Iranian production dropped from 6 to 1.2 million barrels of oil per day within 2 months. In June 1979, a legislative measure was passed to provide loan guarantees, loans, and price contracts to support the domestic production of 0.5 million barrels per day of synfuels. In July 1979, President Carter, who had been criticized for not doing enough, proposed an even bigger 10-year commitment of $88 billion (1980$), supported by an oil windfall profits tax levied on oil producers in the same year. This federal spending would be divided into an initial 4-year phase with $20 billion to be disbursed by a proposed new institution, the Synthetic Fuel Corporation (SFC), and a second phase with the remaining $68 billion (Time, 1980).

The SFC's mandate was to achieve production of 0.5 million barrels per day by 1987, and 2 million barrels per day by 1992, which would have replaced one quarter of crude oil and petroleum imports. With some modifications, this proposal was incorporated into the Energy Security Act and signed into law in 1980 (Ahrari, 1987). The creation of the SFC was supported by technical experts and lawmakers alike (Deutch and Lester, 2004), enshrining their belief that it would be possible to move from liquefaction and gasification plants processing tens or hundreds of tons of coal per day, to plants processing thousands and tens of thousands within 7 years. The Energy Security Act also included a further $6.8 billion (1980$) of funding for synfuels (through the DoE, through Department of Defense purchase contracts, and for the production of alcohol fuels) as well as $1 billion for solar energy and conservation R&D (Deutch and Lester, 2004).

2.3 The Synthetic Fuel Corporation (1980-1986)

The short history of the SFC was characterized by high turnover in its administration, slowness in the processing of proposals, scandal, and falling support - but a relative success in meeting construction deadlines. Delays associated with a change in government meant the SFC did not become operational until February 1982 (Raloff, 1982). Between mid 1980 and early 1982, DoE was given about $6 billion (1980$) to serve as the implementing agency for the SFC (Cohen and Noll, 1991). In 1981, DoE committed to supporting three projects, two of which were subsequently transferred to the SFC when it became operational (see Table 1).

SFC solicited more projects and by 1985 had received about 100 distinct proposals of which three were funded (Cohen and Noll, 1991). The SFC used several criteria to make decisions about projects to support. Since its goal was to meet its production goals, two major criteria used were commercial and technical viability (i.e., technically realistic, lowest cost projects), but the SFC also considered the value of having a diversity of technological approaches, of good long-term prospects, of low environmental impacts (including water consumption).

The 6 projects shown in Table 1 differed from those supported during the 1960s and 1970s in that all were completed on time, and in the case of the three coal gasification projects, all utilized Western coal and indirect liquefaction, as opposed to direct liquefaction which had been used previously for Eastern coals.

Table 1. New Synfuel Projects in the US (1980-1986). Notes: All projects managed by the SFC except Great Plains Project. Data sourced from Bohn et al., 1980; Raloff, 1986; Andrews, 2006; Holt, 2005; Priddy, 2008; The PACE Company Consultants & Engineers, 1985.Additional Information on Exxon-TOSCO project from Bartis et al., 2005; Exxon, 1982, on Great Plains project from United States v. Great Plains Gasification Associates, 1987; US DOE, 2010b, on Union Oil project from Bartis et al., 2005; O&G Journal, 1991, on Cool Water project from Cohen and Noll, 1991, and on Forrest Hill project from Bayrer, 1991.

Project	**Project Type & Design Capacity**	**Contract Date**	**Type of Award**	**Amount in $ billion (current year $)**	**Brief History**
Exxon-TOSCO Oil Shale Project (Colorado) *- transferred to SFC from DoE*	Oil Shale 47,000 barrels per day	Aug 1981	Loan guarantee	$1.15 bn	Costs increased up to 200% associated with production at half design capacity and falling oil prices. Terminated by Exxon in May 1982.
Great Plains Coal Gasification Project (North Dakota) *- not managed by SFC*	Coal Gasification (Lurgi gasifier) 137.5 million cubic feet syngas per day (about 16,000 tons of coal per day)	Jan 1982	Loan guarantee	$2.02 bn	First use of Lurgi gasifier in the US. Completed in 1984 on time and under budget. Operator defaulted on loans in 1985 due to low gas prices. DoE took over plant in 1986 then sold it on to Dakota Gas. Plant still produces syngas and is now being used to demonstrate CO_2 capture.
Union Oil Parachute Creek Shale Oil Project (Colorado) *- transferred to SFC from DoE*	Oil Shale 10,400 barrels per day	Jul 1981	Price Guarantee ($42.5[a] per barrel)	$0.4 bn	Completed on time. Operated until June 1991 but at half design capacity due to performance problems.
		Oct 1985	Loan and Price Guarantees	$0.5 bn	
Cool Water Gasification Project (California) *- SFC project*	Coal Gasification (Texaco gasifier with GE107E turbine) 100 MW (660-850 tons coal per day)	Jul 1983	Price Guarantee ($12.5[a] per million Btu)	$0.12 bn	First integrated gasification combined cycle (IGCC) demonstration plant. Completed on time and under budget. Operated successfully until closure in 1998.
Dow Syngas Project	Coal Gasification	Apr 1984	Price	$0.62 bn	Dow's gasifier at three times larger

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(Louisiana) - *SFC project*	(Dow E-Gas gasifier) 155 MW (1,580 tons of dry sub-bituminous coal per day)		Guarantee ($12.5[a] per million Btu for 10 years)		scale than previous pilot. Operated from 1987 until 1995
Forest Hill Heavy Oil Project (Texas) - *SFC project*	Heavy Oil 1,000-1,400 barrels per day	Sep 1985	Loan & Price Guarantees ($40[a] per barrel for first 50,000 barrels)	$0.06 bn	Completed within budget. Defaulted on loans after 2 years of operation likely due to price guarantee not covering actual production costs, and filed for bankruptcy.

[a] adjusted for inflation

3 THE END OF THE SFC AND THE SYNFUELS PROGRAMME

Congressional support for the SFC declined due to a combination of falling oil prices, the increasing likelihood that synfuels would not be needed, the failure to meet production goals, as well as corruption involving the SFC president. By July 1985, SFC projects had only produced 2% of the 0.5 million barrels per day goal (Raloff, 1986), and oil prices had fallen to around $20/barrel, a third of the early estimated cost of synfuel production. In addition, the SFC was investigated for nepotism and further criticized for "administrative largesse" - generous salaries and pension benefits for its administrators (Raloff, 1985).

Public support for strong government action on energy seemed restricted to crises. Surveys between 1973 and 1985 found that only in 1974 and 1979, immediately after the two major supply shocks, was energy considered to be America's "most important problem" by more than one quarter of the people surveyed (Ahrari, 1987). Environmental organizations mounted a campaign in 1981 to stop the development of synfuels and abolish the SFC (Friends of the Earth, 2010). With all of these factors running against the SFC, the 'coalition of opponents' was formed again, and the Synthetic Fuels Corporation was abolished in January 1986.

The SFC itself only spent $960 million: 60% went on the Dow Syngas project, 29% on other projects, and 11% on administrative expenses (Priddy, 2008). Adding in the $1.5 billion loan default by the Great Plains Coal Gasification project, the total investment in the US Synfuels programme was $4.5 billion (in 2010$). A further $7.6 billion had been invested in coal liquefaction and gasification R&D and pilot programs through the 1960s and 1970s. And after the authorization of the SFC, an additional $0.6 billion were spent between 1982 and 1984. Nevertheless, the goal that had motivated these investments - producing 2 million barrels of synthetic oil per day by 1992 - were not achieved.

4 GASIFICATION TECHNOLOGY DIFFUSION AND SPILLOVERS

Although the SFC's production targets were not met, the three gasifiers used in the coal gasification projects shown in Table 1 are among the most widely used gasification technologies today. These are the Lurgi, GE Energy (previously Texaco), and E-Gas ConocoPhillips (previously Dow) gasifiers. In 1984, there were already 26,000 MWth of installed syngas capacity worldwide, three quarters of which were produced by SASOL, the South African energy company using the Lurgi gasifier, and further processed using Fischer-Tropsch synthesis to produce liquid fuels. By 2007, total gasification capacity globally had more than doubled to 56,000 MWth (Tennant, 2010). As shown in Figure 4, most of this was produced by six types of gasifiers of which the three noted above accounted for over two thirds. Most of this capacity is used to produce chemicals and liquid fuels.

Several factors may have enabled the diffusion of the GE (Texaco) and E-Gas ConocoPhillips (Dow) designs. First, price guarantees under the SFC created a protected market niche which allowed experience and data to be accumulated on 12 years of operation of the Cool Water project and 9 years of operation of the Dow Syngas project. Second, there was relative continuity in the companies engaged in the projects that then commercialized the gasification technologies and the networks that were created.

Constructed in 1984, the Cool Water plant was the first integrated gasification combined cycle (IGCC) demonstration plant in the world. Cool Water was essential to the decision by Tampa Electric company, with Texaco, GE, and other partners (and supported by DoE), to build the Tampa Polk IGCC plant. GE's direct involvement with the Cool Water and Tampa Polk plants allowed it to gain installation and operational experience with the gasification technology and the integration of the IGCC plants. Cool Water also enabled subsequent scale up of gasification and IGCC plant integration for other plants, including two in the US and two in Italy. GE claims that Cool Water demonstrated fuel flexibility (e.g., use of coal and fuel oil), and that Tampa Polk proved power and process heat integration.

Similarly, the Dow E-Gas gasifier used in the Dow Syngas project was later used by ConocoPhillips, having acquired the technology, in the 262MW Wabash River IGCC plant under a 50% cost-share with DoE. For at least 3 years ConocoPhillips employees worked at the Dow Syngas facility, creating the opportunity to transfer tacit knowledge (or know-how) in addition to physical infrastructure and technology. The Wabash River plant has also been used to test components, such as ceramic membranes, a warm gas clean up process, syngas cooler coatings, and gasifier temperature measurements (US DOE, 2002).

DoE was a common partner in the Cool Water and Dow Syngas projects, as well as in the Tampa Polk and Wabash plants, and also served to provide some continuity. The Great Plains project was able to provide operational data because once the original operators had defaulted on their loan and plant ownership transferred to DoE, DoE had the incentive to recover some of its costs and use it for testing. The Oil Shale Symposium proceedings, the Cameron (later named PACE) Synthetic Fuels reports which date back to 1964, and DoE reports on coal gasification in the early 2000s, all contributed to make more technical information available to the wider community (e.g., NETL, 2002).

While lack of a counterfactual makes it hard to determine whether the diffusion of these technologies would not have taken place if the US government had not incentivized commercialization, the actions of the US government are likely to have accelerated diffusion processes. The gasification technologies developed and the operational experience gained may also play an important role if the capture of CO_2 from IGCC plants becomes an important strategy for reducing CO_2 emissions. Spillover benefits can similarly be identified from the $170 million of support for the two oil shale projects (Parachute Creek and Forest Hill) and the heavy oil project (Exxon-TOSCO) shown in Table 1. The Exxon-TOSCO project has provided valuable information regarding the cost, energy consumption, and environmental impacts of oil shale underground mining. The Parachute Creek project's performance problems have uncovered some of the complexities involved in shale oil retorting, which involves heating the rock at high temperature to obtain hydrocarbon liquids for further refining (Bartis et al., 2005).

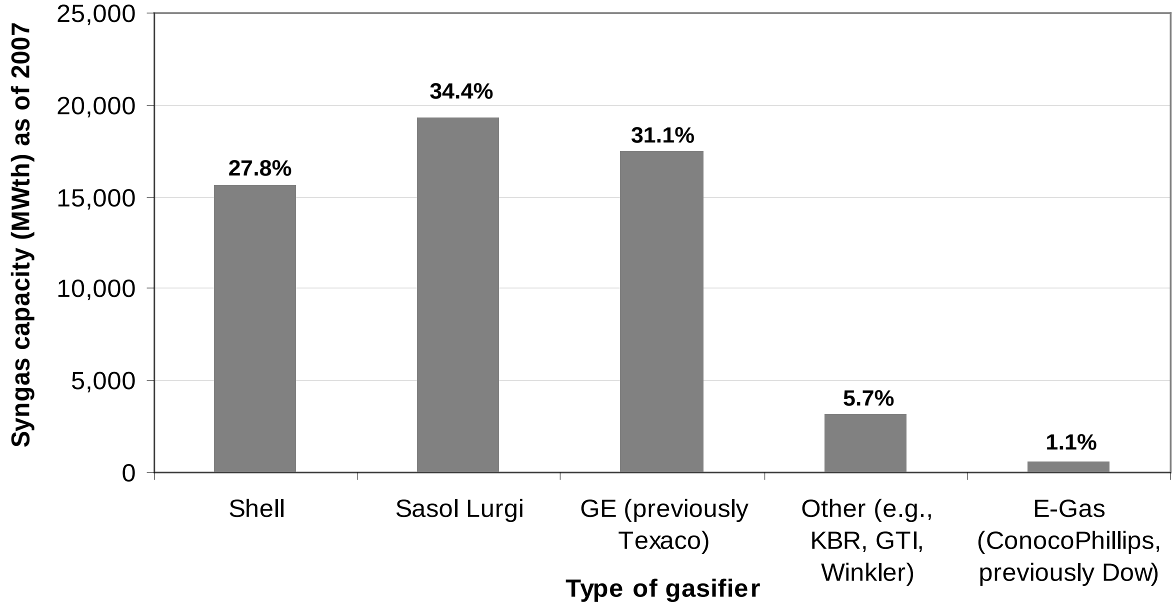

FIGURE 4. WORLDWIDE GASIFICATION CAPACITY IN 2007 BY TECHNOLOGY. NOTES: KBR = KELLOGG BROWN ROOT. DATA SOURCED FROM TENNANT, 2010.

5 LESSONS FROM THE SYNTHETIC FUELS PROGRAMME

Was the SFC a mistake? The simplest interpretation of the SFC is that it represents a policy failure because the projects it funded failed to achieve the programme's aggregate production targets. Some conclude that the government's primary mistake lies in its miscalculation of future oil prices, or in its decision to promote the demonstration and deployment of synfuels, rather than some other means of addressing high oil prices. However, given the notoriously poor history of forecasting energy prices (Craig et al., 2002) a programme like the SFC is better viewed as insurance against high prices in the future (Deutch, 2005; Schock, 1999). Under this interpretation, just because the insurance proves unnecessary does not mean it was a bad idea to buy it.

Another set of interpretations emphasizes the SFC's technical legacy. Projects funded by the SFC, such as the Cool Water project, established the technical foundations for future IGCC plants (PCAST, 1997; US DOE, 2009). The Dow Syngas project laid the foundations for the commercial scale use of the E-Gas gasifier. In addition, the plants served as test beds for new technologies. The Great Plains project, for example, is still used to test CO_2 capture technologies.

In addition, some have suggested that the novel structure of the SFC could serve as a model to support future large demonstration efforts, as it had the flexibility, tools, and competence not present in other

US energy-related entities.[1] As an example, the Cool Water project was completed ahead of schedule and under budget despite being the first IGCC demonstration plant in the world (PCAST, 1997). The newly established Advanced Research Projects Agency for Energy, or ARPA-E, which provides financial support for high-risk, high pay-off energy technology projects was modelled after DARPA (an equivalent agency promoting defense-related research) but has elements that are also common to the SFC.

The criticisms of the SFC that remain most relevant relate to the programme's overall objective. The imposition of a production goal independent of prevailing energy market prices and without significant experience in full-scale synfuel demonstration projects meant that the SFC programme was likely to be much more expensive, risky, and prone to years of backlash than it would have been if its initial goal had been to provide information to the private sector on the technical, environmental, and economic aspects of a synfuels technology (Deutch, 2005). A focus on knowledge generation rather than production may have resulted in selection of different projects, and perhaps a large number of smaller projects - although some of the same projects may have still received funding. On the other hand, it's unclear that a large set of small projects would have generated the same information and spillover benefits as six large ones. And in any case, a knowledge generation approach would not have been consistent with ambitions to dramatically reduce oil import dependence. These expectations for the programme were excessively high, with the SFC presented by the government as the solution to energy security concerns. When oil prices collapsed and it became obvious that synthetic fuels were not needed - at least not in the short to medium term - and that the SFC was nowhere near its goal of producing 0.5 million barrels of oil per day, it became politically impossible to maintain the programme even though most projects were of technical value. High salaries and corruption exacerbated the SFC's loss of support. This 'boom and bust' cycle of excessive hype followed by periods of lower support does not foster a consistent environment for innovation, though it is worth noting the tension between managing expectations and building political support for large (and long-range) programs like the SFC.

The SFC experience also points to the fact that investing large amounts of money to accelerate innovation in a particular area does not guarantee results over a short (or any) period of time. As innovation inputs, time and money are not always interchangeable. Resources at the SFC's disposal were large, but its production goals over the short timeframe set by policymakers was not met.

The SFC experience also indicates that having a good management and independent programme evaluation mechanism becomes essential to reduce government expenditures and backlash as soon as there is a high level of certainty that a programme will not be cost effective over the necessary timeframe. This is particularly important in cases like the SFC, because as discussed previously, costs were tied to the market and expectations were set very high. If the programme, market, and political developments had been followed more closely, it might have been possible to redefine the SFC goals without shutting down the whole effort before its continuation became politically unsustainable. Redefining programme goals might also have reduced the damaging perception of the programme being a complete failure. This point also highlights the tension between having consistent initiatives and flexible programs that allow cutting losses.

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[1] A new institution established in 2007 but funded in 2009, ARPA-E (or Advanced Research Projects Agency for Energy) provides financial support for high-risk, high pay-off energy technology projects was modeled after DARPA (an agency promoting research in defense-related topics after which ARPA-E was modelled) but has elements that are also common to the SFC.

The ultimate legacies of the SFC programme are threefold. First, the perceived failure of the SFC has imposed costs that go well beyond the $4.5 billion (in 2010$) spent between 1981 and 1986. The interpretation of technical failure as poor policy has contributed significantly to the US government's aversion to large-scale demonstrations. The first large energy technology demonstration project since the days of the SFC is the controversial FutureGen carbon capture and storage project which was first announced in 2003 but is not expected to be completed until 2015. Second, the apparent technical infeasibility of direct and indirect liquefaction is likely to have affected the funding and development of biomass to liquid conversion technologies in the United States until today - an effort that has been almost exclusively focused on biochemical as opposed to thermochemical conversion technologies (Williams, 2007). Third, and more favourably, the SFC improved and accelerated the diffusion of liquefaction and gasification technologies that are used in many countries, and which have the potential to address current energy problems. And lessons have been learnt. Current efforts to produce biologically-derived transportation fuels combine a serious commitment to research with a production goal that is much less ambitious than that of the SFC.

6 FURTHER READING

There are two excellent book chapters on the US synthetic fuels programme in books by Cohen and Noll (1991) and Deutch and Lester (2004).

7 REFERENCES

Ahrari, M. E., 1987. Public Opinion and Synfuels Policy. *Political Science Quarterly,* 102(4): 589-606.

Andrews, A., 2006. *Oil Shale: History, Incentives, and Policy,* Congressional Research Service Report.

Bartis, J. T., LaTourrette, T., Dixon, L., Peterson, D. J. & Cecchine, G., 2005. *Oil Shale Development in the United States: Prospects and Policy Issues,* Rand Corporation, Santa Monica, CA, USA.

Bayrer, R. L., 1991. Appraisal of current projects in synthetic fuels technology. *Fuel,* 70(November): 1328.

Blazek, C. F., Baker, N. R. & Tison, R. R., 1979. *High-Btu Coal Gasification Processes,* Institute of Gas Technology, Chicago, IL, USA.

Bohn, E. M., Cowles, J. O., Iyer, R. I., Dadiani, J. & Oyster, J. M., 1980. *Utilization of Synthetic Fuels: An Environmental Perspective,* U.S. Environmental Protection Agency, McLean, VA, USA.

Cohen, L. R. & Noll, R. G., 1991. *The Technology Pork Barrel,* Washington, DC, Brookings.

Craig, P. P., Gadgil, A. & Koomey, J. G., 2002. What Can History Teach Us: A Retrospective Examination of Long-Term Energy Forecasts for the United States. *Annual Review of Energy and Environment,* 27: 83-118.

Deutch, J. M., 2005. *What Should the Government Do to Encourage Technical Change in the Energy Sector?,* Massachusetts Institute of Technology, Cambridge MA.

Deutch, J. M. & Lester, R. K., 2004. *Making technology work: applications in energy and the environment,* Cambridge, UK, Cambridge University Press.

Dravo Corp., 1976. *Engineering Support Services Clean Boiler Fuel Demonstration Plant*, Energy Research and Development Administration, Technical Information Center, Chemical Plants Division.

Edgar, T. F., 1983a. Chapter 7 - Coal Gasification. *Coal Processing and Pollution.* Houston, TX, USA: Gulf Publications Company.

Edgar, T. F., 1983b. Chapter 8 - Coal Liquefaction. *Coal Processing and Pollution.* Houston, TX, USA: Gulf Publications Company.

EIA, 2008. *Annual Energy Outlook Retrospective Review. Table 4. World Oil Prices, Projected vs. Actual,* Energy Information Administration. U.S. Department of Energy.

EIA, 2010a. *January-last update, Annual Oil Market Chronology* [Online]. Energy Information Administration. U.S. Department of Energy. Available: http://www.eia.doe.gov/emeu/cabs/AOMC/Overview.html. 12 October 2010.

EIA, 2010b. *October-last update, Petroleum Navigator* [Online]. Energy Information Administration. U.S. Department of Energy. Available: http://tonto.eia.doe.gov/dnav/pet/hist/wttimus2W.htm. 16 October 2010.

Exxon, 1982. Exxon's abrupt exit from shale. *Fortune,* (May): 105-106.

Friends of the Earth, 2010. *Our History* [Online]. Friends of the Earth. Available: http://action.foe.org/content.jsp?key=3653. 10 October 2010.

Hederman, W. F., 1978. *Prospects for the Commercialization of High-Btu Coal Gasification,* Rand Corporation, Santa Monica, CA, USA.

Herrick, J. A., 2002. Federal Financing of Green Energy: Developing Green Industry in a Changing Energy Marketplace. *Public Contract Law Journal,* 21(2): 259-260.

Holt, N., 2005. *Gasification and IGCC - Status, Challenges, Design Issues & Opportunities,* Powerpoint Presentation at the GCEP Advanced Coal Workshop, 15-16 March, Provo, Utah, USA.

League of Conservation Voters, 1987. *How the 99th Congress Voted on Energy and the Environment* [Online]. League of Conservation Voters Report. Available: http://www.lcv.org/images/client/pdfs/1985-1986_Scorecard.pdf. 16 October 2010.

McCloskey, M., 1981. The Environmental Impacts of Synthetic Fuels. *Journal of Energy Law and Policy,* 2: 1-12.

NETL, 2002. *Wabash River Coal Gasification Repowering Project: A DOE Assessment,* National Energy Technology Laboratory, US Department of Energy (US DOE), Report DOE/NETL-2002/1164, January.

O&G Journal, 1991. Unocal to close sole U.S. commercial oil shale plant. *Oil & Gas Journal,* 8(April): 38.

PCAST, 1997. *Federal Energy Research and Development for the Challenges of the Twenty-First Century,* President's Council of Advisors on Science and Technology, Executive Office of the President, Washington D.C., USA.

Priddy, H., 2008. *History of the United States Synthetic Fuels Corporation,* 28th Oil Shale Symposium, Colorado School of Mines, 13-15 October.

Raloff, J., 1982. Synfuels Corp. finally comes to life. *Science News,* 121(8).

Raloff, J., 1985. Washington deals synfuels a big blow. *Science News,* 128(6).

Raloff, J., 1986. Congress kills the U.S. Synfuels Corp. *Science News,* 129(2).

Rothberg, P., 1983. *Synthetic Fuels Corporation and National Synfuels Policy,* Congressional Research Service, Science Policy Research Division, Washington D.C., USA.

Schock, R. N., Fulkerson, W., Brown, M.L., San Martin, D., Greene, R.L. & Edmonds, J., 1999. How Much is Energy Research & Development Worth as Insurance? *Annual Review of Energy and Environment,* 24: 487-512.

Synfuels Interagency Task Force, 1975. *Synthetic Fuels Commercialization Program,* Synfuels Interagency Task Force for the President's Energy Resources Council.

Tennant, J. B., 2010. *Overview of DOE's Gasification Program,* National Energy Technology Laboratory, U.S. Department of Energy.

The PACE Company Consultants & Engineers, 1985. *Pace Synthetic Fuels Report,* The PACE Company Consultants & Engineers.

Time, 1980. Synfuels Success. *Time Magazine*, 2 June.

United States v. Great Plains Gasification Associates, 1987. *8th Circuit Court of Appeals, 813 F.2d 193, No. 86-5256,* United States Court of Appeals.

US DOE, 2002. *Wabash River Coal Gasification Repowering Project: A DOE Assessment,* U.S. Department of Energy (US DOE) National Energy Technology Laboratory report DOE/NETL-2002/1164.

US DOE, 2009. *Pioneering Gasification Plants* [Online]. Washington, D.C.: US Department of Energy (US DOE). Available: http://www.fossil.energy.gov/programs/powersystems/gasification/gasificationpioneer.html. 1 April 2009.

US DOE, 2010a. *Early Days of Coal Research* [Online]. Washington, D.C.: US Department of Energy (US DOE). Available: http://www.fe.doe.gov/aboutus/history/syntheticfuels_history.html. 2 November 2010.

US DOE, 2010b. *Energy Timeline: from 1971-1980* [Online]. Washington, D.C.: US Department of Energy (US DOE). Available: http://www.energy.gov/about/timeline1971-1980.htm. 16 October 2010.

Williams, R. H., 2007. *Written Testimony of Robert H. Williams. Hearing on the Future of Coal under Carbon Cap and Trade,* U.S. House of Representatives.

8 ACKNOWLEDGEMENTS

This chapter has benefitted from discussions with Bob Frosch (Harvard), John Deutch (MIT), and from the excellent book chapters listed under 'Further Reading'.