A SEARCH FOR REGULATORY ANALOGS TO CARBON SEQUESTRATION

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ABSTRACT

Carbon capture and sequestration will require the management and storage of carbon dioxide either in geological reservoirs or in the ocean over many centuries. While the possibility of exposure leading to damages to public health, workers or the environment may be small, it seems inevitable that if there is to be widespread adoption of sequestration, then a regulatory system will need to evolve to manage the reservoirs. To better understand the drivers of a future regulatory system, the historical evolution of comparable regulatory regimes provides a useful guide. Other long-term storage problems that have at least some of the characteristics of carbon storage are evaluated according to the nature of risk, the credibility of the solutions, the regulatory environment and the potential to either borrow from or influence other policy problems across geographic or issue boundaries. While none are exact analogs, as a whole, the set offers variation in key variables critical for determining the success of carbon sequestration as a viable climate policy option.

INTRODUCTION

To date, almost all research into carbon sequestration has centered on evaluating the technical potential as well as the potential difficulties associated with the engineering challenge of capturing and then storing carbon dioxide. [1] Since the success of sequestration depends on its competitiveness relative to other mitigation and abatement options, some recent work has also focused on the economics of sequestration. [2] In both areas, significant progress has brought the technology to the point where many governments and private firms are keenly interested in bringing these activities to the point of large-scale experiment, pilot projects and even commercialization. While such studies are obviously critical to the early years of development of a new technology, relatively little attention has been paid to the political and regulatory obstacles that might impede the penetration of sequestration technologies into the market.

The paper briefly considers the prospects for carbon sequestration although the discussion is necessarily speculative because of the absence of real-world commercial sequestration projects. The central discussion reviews the long histories of risk assessment, political and regulatory design and public interaction of a variety of storage problems. These cases offer possible pathways for the evolution of sequestration.

Although there are obvious overlaps, regulatory analogs are not the same as physical or engineering analogs [3]. Most natural analogs (even those involving carbon dioxide) are unlikely to be useful because they are regulated little if at all. Thus, volcanic eruptions and other natural venting of CO_2 may well offer important technical insights in the design of reservoirs, but no government regulates volcanic processes! Even some storage problems can have many similar technical challenges, but because of public perceptions and the governing regulations, it may not be a terribly useful regulatory proxy. Conversely, storage problems can be quite dissimilar in terms of the technical obstacles, but may offer lessons for the permitting process or for the likely evolution of regulation.

The challenge is to develop a methodology that will offer some means of choosing and evaluating analogs in a systematic manner even though no single case can adequately reflect every aspect of sequestration. To build a comprehensive picture of the prospects for sequestration will require identifying relevant characteristics as well as a set of cases that can encompass the range those characteristics might assume.

RESOLVING PUBLIC GOODS PROBLEMS AND REGULATORY EVOLUTION

Before evaluating the set of analogs, it is essential to put forward some key open questions regarding carbon sequestration. At the forefront of current investigations is the question of risk. Potential damages (and benefits) to ecosystems, workers and communities will require years of careful study. Many cumulative, subtle or interactive effects will not be revealed until field experiments, pilot projects and even decades of commercial operation can provide a sufficiently long time series to properly assess the associated epidemiology, hazards, and accidents. Though still the subject of differing opinions, understanding risks is a necessary but not sufficient condition for moving forward with sequestration technologies.

While studies of risk will provide some indication of potential accidents and other low-probability events, unanticipated physical and human events can dramatically change both the economic calculus and the public perception of a new technology. While evaluation techniques such as FEP (features-events-processes) seek to associate probabilities with rare events, there is inevitably great uncertainty involved. Moreover, a strict risk-based approach will not capture the erosion in public support in the event of a major accident. Indeed, surprises or extreme events often serve as a powerful impetus for regulatory change. [4]

Complicating an assessment of regulatory evolution are the long timescales needed for managing carbon reservoirs. Political deliberations are ill suited to problems that persist for multiple decades because of the tendency to neglect the needs of future generations. This mismatch between the time scales of political decision-making and the needed regulatory system applies both to the larger question of climate change itself and to the specific question of managing carbon reservoirs over long periods of time. The possibility of slow leaks, the difficulty of monitoring over long time periods and the need to defend near-term costs of action against long-distant benefits are all familiar characteristics of a long-term policy problem.

Another public goods problem associated with sequestration is best represented by the NIMBY or "not-in-my-backyard" phenomenon, that characterizes so many of the difficulties associated with siting any major industrial or energy facility.[5] The key questions surround the regulatory conditions needed for successful siting. Does public and non-governmental organization (NGO) participation facilitate resolution or entrench and encourage conflicts? Does the potential for human health damages (as assessed by experts) increase opposition or is the basis for opposition not influenced by peer-reviewed scientific studies? Can the permitting process facilitate progress or is it primarily the source of delay and obstruction?

Of course, a community can also fend off siting under cover of many legitimate guises including charges of environmental justice or racism, lack of public participation, scientific uncertainties, and the need to pursue a permitting process. That does not mean that there are not valid, even egregious, cases, but being able to distinguish bona fide cases is especially difficult in the midst of often-intense local disputes.

A final public good is information: how do problems and solutions travel across issue and geographic boundaries? If a storage facility in one jurisdiction experiences an otherwise unforeseen incident, will neighboring (or even distant) jurisdictions change practices? What is the primary driver of change: NGOs, the media, politicians or grassroots mobilization? In the event of an incident, will related policy problems also receive increased scrutiny? How far will these concerns travel across jurisdictions and issue areas?

Not every aspect of a carbon storage regime will be amenable to reasoning by analogy. Some elements of the regulatory regime will be unique, notably the system of emissions inventories, permitting and trading. Here, the closest analogs are similarly ill-formed – sequestration in forests and soils, ocean fertilization by iron, or greenhouse gases trapped in specific uses such as CO_2 in timber or hydrofluorocarbons in air conditioning units. Analogs offer few insights because all fall under the same unsettled regulatory regime.

STORAGE OPTIONS AND ALTERNATIVES

Storage and/or disposal problems available as analogs include (i) waste disposal (solid waste, hazardous waste, high- and low-level nuclear waste); (ii) energy storage (natural gas storage, liquefied natural gas, petroleum reserves); and (iii) energy production (enhanced coalbed methane and enhanced oil recovery).

Since storage problems provide a particular form of political and social solution, it is also important to consider the fate of available alternatives. For the waste disposal cases, competing options have included incineration, ocean disposal, recycling, and source reduction. Source reduction and recycling are valuable options for common industrial waste and municipal solid waste but are rather limited in the other cases because of limited opportunities to recycle and the incentives offered by regulations to minimize the amount of waste produced in the first place. Incineration and ocean dumping have been alternatives investigated over many decades, but both have faced more serious obstacles (and hence higher costs) than land disposal.

As late as the 1970s, some 120 ocean disposal sites (including hazardous wastes) were operated by the U.S. Coast Guard until the Marine Protection, Research, and Sanctuaries Act of 1972 and the Ocean Dumping Ban Act of 1988 restricted ocean disposal.[6] Similarly, the United States and seven other nations spent over $100 million on research into ocean disposal of radioactive wastes before public and NGO opposition led Congress to cut funding to concentrate on geologic disposal. Incineration also suffered from adverse public and NGO attention arising from concerns over toxic byproducts.[7] Siting had become a substantial impediment to further penetration so that by the early 1990s all alternatives except deep-well injection were effectively banned. Yet even the costs of ordinary land disposal of solid waste have increased with increased regulatory oversight, greater community opposition to siting and lengthy permitting processes.

While energy storage requires monitoring to avoid the economic and health problems associated with leaks, the benefits of storage include improved availability, greater security against price fluctuations and evening out demand. While alternatives exist in the sense that any other energy supply (or demand) option could offset the stored energy, few of these options have the temporal or security benefits.

By contrast, in the energy production cases, the benefits are primarily derived from price competition often abetted by regulations. Thus, thermal enhanced oil recovery (EOR) constitutes over half of the 12% of US production from EOR, but this figure will decline as EOR using CO_2 floods continues to grow with access to cheap CO_2; this option already constitutes a quarter of EOR production. Economic viability is intricately intertwined with regulation: enhanced oil recovery has been encouraged by Section 43 of the Internal Revenue Code and recent rapid growth in coalbed methane production (CBM) was, in part, the product of a tax credit under Section 29 of the Federal Windfalls Profits Act amounting to almost half the price of gas.[8]

Which analog is most relevant to the case of carbon storage is still unclear. Obviously, the economics will be heavily dependent on the relative attractiveness of alternatives including those considered more environmentally benign such as renewables, fuel switching, and conservation. Nevertheless, all these options are limited, especially for a more aggressive target and the remaining options, such as nuclear power, suffer from their own set of problems. Carbon sequestration has always offered the hope of near-term economic benefits, the question then turns to whether the regulatory regime will be its undoing.

EVALUATION CRITERIA

The characteristics fall into four main categories: the nature of the risk, the credibility of the solutions, the regulatory environment and the potential for solutions to spread across jurisdictions and issues.

Nature of Risk

Compared to many other risks to public and occupational health, the risks associated with the storage problems investigated are quite small. Moreover, risks have diminished considerably after regulations were introduced. Cases divide into risks arising from contamination of drinking water, catastrophic events and reaccumulation. Hazardous wastes and low-level nuclear waste generally fall into the first category, liquefied natural gas and high-level nuclear waste are cases where a cataclysmic event is the prime concern and CBM and natural gas storage are cases where the danger of reaccumulation is present.

How do these compare to the CO_2 case? All three have some relevance, but the reaccumulation case is the most pertinent. Contamination of neighboring media (whether air or water) is not an issue and the potential for catastrophe is very small, if not zero. While the Lake Nyos case in Cameroon offers a vivid image, there is little basis for expecting that this natural process will have any bearing on real carbon storage. Similarly, natural tree kills at Mammoth Mountain may be a more realistic product of manmade storage activities, but this too is unlikely to represent the types of events under any moderate regulatory system. One might look to the events surrounding the Yaggy natural gas storage case in Kansas for the types of reaccumulation problems that might be anticipated.[9] Failure modes tend to be unanticipated human failures that go undetected, are in express violation of existing regulations or are residues of earlier laissez-faire eras.

Credibility of Solutions

Siting of waste and energy facilities has brought accusations of discrimination in siting decisions. The so-called environmental justice movement began with a series of independent reports in the mid-1980s that found an association between waste facilities and minorities and income. Studies by the General Accounting Office in 1986 and the United Church of Christ's Commission for Racial Justice in 1987 led to RCRA Amendments that businesses inform the local community of toxic chemicals on their premises or released. Local boards were established to decide how to deal with the associated risks and community organizations could receive federal funding to hire scientists and engineers to assist the organizations.[10]

Successful, if costly, efforts to engage the local community can also be found in the few examples of Mineral Extraction Agreements (MEA) designed to offset local resistance to coalbed methane projects. The MEA allows for local approval of development plans and site selection, places limits on workers and access to sensitive areas and includes other provisions ensuring pursuits such as hunting and fishing.[11]

Of course, the benefits of either trade or siting in poorer communities can be extremely attractive. The large disparity in costs between countries prompted negotiation of the Basel Convention on Trade in Hazardous Waste in 1989, which seeks to eliminate such trade on moral grounds even though the economics may be appealing (although the US is not a party). Similar concerns were aroused after Russia indicated its would accept 10,000 tons of nuclear fuel for disposal. Identical logic led to massive investment in LNG facilities in Baja California to service the West Coast, which had thwarted repeated efforts at siting a facility within US borders. But even in Rosarito, Mexico, the main beneficiary of investment, opposition grows.[12]

Some attempts to introduce greater equity have even produced perverse outcomes. South Carolina, Nevada and Washington were the only states to house low-level nuclear sites until the Low-Level Waste Policy Amendments of 1985 (PL 99-240), required all states to form compacts where one or more states in the compact would act as the host of the waste. Unfortunately, this effort to share out burdens brought construction of storage facilities to a standstill.[13] Seeking to break the logjam has led to efforts to employ native American lands that beg charges of environmental racism. First the Mescalero Apache of New Mexico during the mid-1990s, and more recently the Skull Valley Goshute of Utah have been approached to accept wastes engendering significant opposition and controversy.

Among communities with similar incomes, coordination problems will inevitably result if it is possible to move to other jurisdictions with little or no effective regulation. For example, although New Jersey had adopted strict hazardous waste regulations it was easy to export wastes to Pennsylvania unimpeded. The inability of jurisdictions to effectively regulate hazardous wastes encouraged initial federal involvement.

How does carbon sequestration compare to the analogs? In some sense, carbon sequestration faces more of a challenge than "simple" NIMBY battles because of principled opposition to sequestration by certain national and international NGOs.[14] Thus, the experience would fall somewhere between EOR and CBM where the issues are purely local and high-level nuclear waste where the problem has risen to the very highest political levels. For cases such as low-level nuclear waste and hazardous wastes, siting is possible although battles are both lost and won and the expense of these battles over permitting and in other lawsuits is often considerable. But carbon storage also has some advantages, if the wider opposition can be overcome because of the less dangerous image of CO_2 in comparison.

Regulatory Environment

Major shifts in government policy can change the investment environment. For example, the 1953 Atoms for Peace Program radically shifted the American position from one of guarding all information and access to nuclear materials to one of greater openness. Indeed, to discourage proliferation, the US even reached an agreement (which later lapsed in 1988) to accept the waste from research reactors in twenty-eight nations.

Regulation responds to new science. For example, the 1984 RCRA Amendments reflected studies showing hazardous waste generation amounted to more than three times more than previously believed and that even the state of the art double plastic liners used in Subtitle C landfills were eventually subject to leeching.

The regulatory regime is subject to swings in attitudes towards regulation. The past half-century has seen the rise and then virtual disappearance of price controls in the energy sector even as federal environmental regulation grew from almost negligible levels. In 1938, the Natural Gas Act regulated pipelines under the Federal Power Commission (and by the Federal Energy Regulatory Commission (FERC) after 1977). In 1978, the Natural Gas Policy Act began to deregulate wellhead prices and FERC Orders 436, 500, and 636 between 1985 and 1993 transformed the industry by deregulating pipeline transportation and allowing customers to buy gas directly.[15]

Changing public attitudes and economic conditions can also bring dramatic changes. Optimism about the prospects of nuclear power led to three private facilities to reprocess nuclear fuel built at Barnwell, SC, Morris, IL, and West Valley, NY to supplement government facilities in Idaho, South Carolina and Washington. Many expected that there would be a vigorous reprocessing program, but with the changed regulatory and public mood, all three facilities closed during the 1970s.

Finally, a site involving even the faintest risk increasingly requires a myriad of permits from organizations including the Army Corps of Engineers, the Fish and Wildlife Service, the Environmental Protection Agency, state and local agencies regulating air and water quality, the oil and gas industry, and occupational health and safety. Each permit provides an opportunity for opponents of a project to voice their opposition and seek to delay a specific project if not derail it entirely. In addition, technical review revolves around satisfying state and federal bureaucrats, requiring extensive site characterization establishing management systems, plans for testing, monitoring, corrective action plans, and even post-closure management.

The regulatory environment for carbon storage is still largely a blank slate since it will likely involve new legislation. While permitting problems are inevitable, regulations will be sensitive to shifts in the science, the climate regime and accidents or other unforeseen events in the first years of development.

Geographic and Issue Spread

Hazardous waste provides a clear example of the dynamic nature of regulatory policy. In the late 1960s and early 1970s, the focus was primarily on solid waste, which shifted after public attention to contamination from hazardous materials at Love Canal, NY and Louisville, KY. RCRA, passed in 1976 was expected to be the main weapon against hazardous wastes but even at the time of its passage, hazardous wastes were hardly central to the Act and the section addressing hazardous wastes received little attention in Congress or the media either during Congressional hearings or immediately afterwards.

Under Subtitle C, EPA was to determine what was a hazardous waste and then establish standards for all treatment, storage, and disposal facilities (TSDF) borrowing heavily not only from other sections of RCRA, but also from earlier environmental legislation including the clean air and water statutes. In terms of jurisdictional borrowing, Congress relied heavily on California's 1972 hazardous waste regulations.

Perhaps the most extensive information sharing is in high-level nuclear waste because of parallel struggles and concerns over proliferation. However, even natural gas storage, which does not involve the potential externalities seen in other cases, professionals have created a tight-knit worldwide network, so that almost immediately after the explosion at the Yaggy field in Kansas, many Europeans called seeking information.

Thus, carbon storage, which already involves an international community and which offers similarities to problems both in and out of climate change, will inevitably see extensive borrowing.

LESSONS LEARNED?

Characterization of analogs is not static. The analogs discussed have all changed over the course of many decades and so it should be expected that both the analogs themselves and carbon sequestration would continue to vary over time. Carbon sequestration's attractiveness will change in response to public health concerns, changing economics relative to alternatives, and shifts in the carbon management regime, in the underlying science, and in public perceptions. While risk assessments presenting the best possible science is useful and can influence regulatory policy design, it does not determine public or regulatory acceptance.

The regulatory treatment of substitutes is key. The rationale for each storage analog depends upon a combination of regulation and resulting economics that have favored the geological storage solutions relative to other less environmentally, politically and economically attractive alternatives and because of serious limits placed on more environmentally "benign" alternatives. Any regulatory regime will have to decide whether to tax or subsidize both carbon storage and its competitors – the outcomes of those decisions will likely be the factor that moves carbon sequestration from a marginal competitor to a favored option.

While NIMBY is a frequent impediment to siting, it is not insurmountable. Strategies that offer concrete benefits or promote trust in affected communities and that remove legitimate arguments as camouflage for self-interest can overcome public goods problems. Committing to compensation, openness, information sharing, monitoring and enforcement can help diffuse legitimate grievances. This strategy will add to the costs and lead to delays, but so too will a permitting process where the public feels disenfranchised.

Early failures are not easily overcome. In all cases reviewed, significant problems in the early years of a technology's development affected public perceptions and produced regulatory regimes and political battles that took decades to reform or resolve. A corollary: *regulatory reaction can be harmful and long lasting*.

As a first step, this brief review can only establish that all the analogs reviewed have important lessons for the evolution of carbon capture and sequestration. A more extensive characterization is necessary to identify which analogs serve as better proxies and how these analogs change over time.

REFERENCES

1. Holloway, S. (1997) *Energy Conversion and Management*, **38**, 241-245.
2. McFarland, J.R., Herzog, H.J., Reilly, J. (2002) *GHGT-6*, Kyoto, Japan.
3. Skolnikoff, E.B. (1990) *Foreign Policy* **79**, 77-93.
4. Pearce, J. M., et al. (1996) *Energy Convers. Mgmt.* **37**, 1123–8.
5. McAvoy, G.E. (1999) *Controlling Technocracy* Georgetown University Press, Washington, D.C.
6. Copeland C. (1999) Congressional Research Service Report RL30022.
7. S.M., Teaf, C.M., and Bean, J.A. (1998) *Hazardous Waste Incineration* CRC Press, Boca Raton, FL.
8. Energy Information Administration (1999) *Federal Financial Interventions and Subsidies in Energy Markets 1999* Report SR-OIAF 99-03.
9. Kansas Geological Survey (2002) Hutchinson Response Project.
10. Committee on Environmental Justice, Institute of Medicine (1999) *Toward Environmental Justice: Research, Education, and Health Policy Needs* National Academy Press, Washington, D.C.
11. Roberts, R.D. (2001) *SPE* **66572**.
12. Fox, B. (2002) *San Diego Union-Tribune* May 20.
13. Albrecht, S.L. (1999) *Forum for Applied Research and Public Policy* **14**, 96-102.
14. Bradley, R. (2002) *Climate Network Europe Hotspot* **18**, 3.
15. Michaels, R.J. (1993) *Regulation* **16**, 20-31.