Resting in peace?- regulatory approaches to the geological storage of radioactive waste and carbon dioxide

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1. Introduction

An emerging and much heralded technology for fighting climate change by reducing anthropogenic greenhouse gas emissions is carbon capture and storage (CCS). The final stage of CCS is the storage (or disposal)[2] of the carbon dioxide (CO_2) away from the atmosphere, typically in a deep geological formation. Although the risks posed by CO_2 differ from those presented by nuclear waste and spent fuel, the similarities – most noticeably the vast time scales involved and the preference for concentration and containment – make a comparison of regulatory approaches to such risks relevant and informative. The intention of the current paper is to carry out such a comparison. Using Sweden as a focal point, applicable legal frameworks for the management of captured CO_2 and spent nuclear fuel and nuclear waste will be juxtaposed. Two aspects in particular will be chosen for closer scrutiny: requirements pertaining to the selection of sites for disposal/storage of nuclear material and captured CO_2 respectively, and the nature and allocation of economic responsibility for handling and minimizing long-term hazards associated with those substances. In the case of nuclear residues, responsibility for spent fuel will be the main focus. However, the same principles mostly apply to other radioactive waste from the nuclear industry, such as parts of decommissioned nuclear reactors.[3] First, however, a short introduction to the storage/disposal-technologies at hand will be appropriate.

2. Technology

The fact that nuclear reactors produce high risk residual material[4] is well known. The costs – economic and other – for handling that material must accordingly be considered when calculating the financial viability as well as societal desirability of nuclear power plants. Not employing significant technological and economic resources in order to control the hazards is not a feasible option. The method for handling long-term risk opted for by the Swedish nuclear industry involves final disposal of spent nuclear fuel in deep bedrock.[5] The spent fuel is, according to current plans, to be encapsulated in copper canisters, placed in crystalline bedrock at a depth of 400-700 meters and embedded in bentonite clay. Subsequently, the tunnels leading to the deposited canisters will be permanently sealed.[6] Although a final

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[2] On the use of “storage” and “disposal”, see section 3 below.

[3] Under Swedish law, spent fuel is classified as nuclear waste once it has been placed in a repository for final disposal. Act (1984:3) on Nuclear Activties (Lag om kärnteknisk verksamhet), section 2, para. 3

[4] “Residual material” is used to denote both spent fuel and nuclear waste.

[5] For nuclear waste other than spent fuel there are already repositories in operation in Sweden, including one facility 50 m below the seabed for low and intermediate level waste and shallow land burials for short-lived low-level waste. Sweden’s Third National Report under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: Swedish implementation of the obligations of the Joint Convention, Ds 2008:73, at 12-13.

[6] “Our method of final disposal” at <http://www.skb.se/Templates/Standard____24109.aspx> (20 Nov. 2009) and Sweden’s Third National Report under the Joint Convention, at 14.

decision on the technique for final disposal is yet to be made by the Government, technical solutions and potential sites have been subject to discussion for a number of years.

The CCS-technology is less well known. As to CCS as such, it is a collective name for a set of techniques and methods which, when combined, allow CO_2 generated by combustion to be sequestered and thus prevented from reaching the atmosphere. Technically it comprises three main stages: capturing the CO_2, transporting it to a suitable storage site, and its final storage.[7] In addition to use with fossil fuel, CCS technology may also be employed when burning biomass, thereby sequestering the CO_2 taken up by plants. This is often referred to as resulting in "negative emissions" since it removes CO_2 from the active carbon cycle.[8] An elaborate description of the technical options may be found in the 2005 Intergovernmental Panel on Climate Change (IPCC) Report on CCS.[9] Estimates of the cost for CO_2 sequestration by means of CCS vary considerably but cost is widely perceived as a major challenge to the widespread deployment of the technology.[10]

When it comes to storing or disposing of captured CO_2 there are a number of options. Disused oil and gas fields are attractive storage sites because of the existing infrastructure and knowledge of geological conditions gained from previous extraction.[11] Most beneficial is if the CO_2 can be used to extract additional oil or gas before a field is abandoned with so-called Enhanced Hydrocarbon Recovery (EHR) technology.[12] Coal seams which are not attractive for mining may represent a good storage facility.[13] Saline formations, i.e. sedimentary rocks saturated with brine, probably offer the largest volumes of storage capacity.[14] Off the coast of Norway the Sleipner project injects up to 1 million tonnes of CO_2 annually into a saline formation, Utsira, 800 metres below the seabed of the North Sea, in one of the few operating, large scale CCS projects.[15]

3. Terminology

A few observations should be made about terminology. There have previously been plans in Sweden for using spent fuel for further energy generation.[16] However, the current program for spent fuel management is, as noted above, focused on containing the fuel in sealed facilities

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[7] See IPCC, 2005: "IPCC Special Report on Carbon Dioxide Capture and Storage", prepared by Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2005, at 3. The third step may be divided into the injection phase and the storage, or post closure, phase.

[8] See further Azar, C., *et al.*, "Carbon Capture and Storage From Fossil Fuels and Biomass – Costs and Potential Role in Stabilizing the Atmosphere", 74 *Climatic Change* (2006), 47 at 68.

[9] IPCC, 2005.

[10] Attempts at establishing at what level of carbon cost – i.e. a cost for emitting CO_2 into the atmosphere effected e.g. through a tax or a cap and trade system – industry would find it economically viable to employ CCS have pointed in the direction of 30 US$/tonne CO_2, or slightly lower. IPCC, 2005, at 341 and 'The Future of Coal: Options for a Carbon-constrained World', An interdisciplinary MIT study, Massachusetts Institute of Technology, 2007, at xi. There are also significantly higher estimates, however. A study by McKinsey Climate Change Initiative expects cost of €35 - 50/tonne abated CO_2 for early full-scale commercial CCS projects in Europe with a slight drop to €30 to 45/tonne CO_2 abated by 2030. "Carbon Capture and Storage: Assessing the Economics", McKinsey & Company, 2008, available at <http://www.mckinsey.com/clientservice/ccsi/pdf/CCS_Assessing_the_Economics.pdf> (16 April 2008), at 6.

[11] IPCC, 2005, at 215.

[12] Ibid., at 405. In EHR a gas or fluid such as CO_2 is injected into an oil or gas field in order to recover oil or gas additional to that which could otherwise have been produced.

[13] IPCC, 2005, at 217-219.

[14] Estimates of global storage capacity range from 100 to 200 000 Gt/CO_2. Ibid., at 223.

[15] "National Inventory Report 2009 Norway" (TA-2507/2009, 15 April 2009), at 114 et seq., available at <http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4771.php>. On the Weyburn EHR project in Canada and the In Salah project in Algeria and other projects, see further IPCC, 2005, at 200 et seq.

[16] See section 7 below.

for at least 100,000 years. This process is widely referred to as "disposal" or "final disposal".[17]

With respect to captured CO_2 there currently exists no viable idea as to how it could be put to use in the future. Intentionally bringing the CO_2 back again from a geological formation is thus not considered a realistic option. Despite this, the pumping of CO_2 into deep geological formations, which are subsequently sealed, is referred to as "storage" in the applicable European community (EC) legislation and international instruments. There are, however, examples of a more adequate terminology.[18] This paper will mainly stick to the terminology of the applicable legislation. It should be noted, however, that it may, particularly with respect to "geological storage" of captured CO_2, convey a somewhat skewed impression of the aim of the activity.

4. Risks and benefits: Temporal and spatial dimensions

The benefits of both the operation of nuclear power plants and the industrial combustion of fossil fuels accrue primarily to the country or region in which the industry is located, and to generations contemporary with the activity. Doubtless, the wealth generated by both activities may spread geographically as well as in time. However, its long term distribution and effects are hard to calculate with any precision.

The risks associated with disposal of spent nuclear fuel and nuclear waste have been subject to extensive research and debate that will not be recounted here. In short, the dominant risk is that of radioactive material escaping from the disposal site and causing harm to living organisms, including humans. The development of cancer in humans is the most widely discussed consequence of exposure to radiation from nuclear waste.[19] These risks are relatively local or at least regional in nature. The eventual wider spread of radioactive material may not be ruled out, but the harmful effects are then likely to be attenuated by significant dilution. The time scales, however, are daunting. Spent fuel is likely to remain hazardous for hundreds of thousands of years. Any risk for harmful leakage will thus affect innumerable generations to come.

As to the climate aspect, nuclear waste and spent fuel are not associated with detrimental effects on the climate. Instead, such fuel and waste result from a technology which is often touted as a potential part of the solution to the climate change problem. Nuclear power plants produce energy with limited CO_2 emissions. Since climate change is a global phenomenon this may be deemed a global good.

The existence and nature of risks associated with CCS are far less well known, primarily due to the novelty of the technique, why a short description is called for. Storage of CO_2 entails two distinct categories of risk. The first has to do with the effects of exposure of

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[17] See, inter alia, "Final Disposal of Spent Nuclear Fuel" Swedish National Council for Nuclear Waste (KASAM) Report 2007:1e, Report from a seminar on November 15, 2006; "Final Disposal of Nuclear Waste", The Swedish National Council for Nuclear Waste Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Program 2007, SOU 2008:70; Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Vienna, 5 September 1997), Article 2 (d); and Article 2 (3) in the proposed Euratom directive on spent nuclear fuel and radioactive waste management, see Proposal for a Council (Euratom) Directive setting out basic obligations and general principles on the safety of nuclear installations and Proposal for a Council Directive (Euratom) on the management of spent nuclear fuel and radioactive waste, 30.1.2003, COM(2003) 32 final.

[18] Under the Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, 7 November 1996, "London Protocol") 'Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-Seabed Geological Formations' have been adopted. 'Report of the Twenty-ninth Consultative Meeting and the Second Meeting of the Contracting Parties' (14 December 2007), LC 29/17, Annex 4.

[19] Riley, P., *Nuclear Waste: Law, Policy and Pragmatism*, Ashgate, 2004, at 13 and 46.

humans and many other living organisms to elevated levels of CO_2. The second category pertains to the climate policy consequences of faulty CO_2 storage, including what may be referred to as the "political risk" of CCS.

In the event of leakage, CO_2 may cause asphyxiation at relatively modest concentrations. Levels above 7-10% in ambient air can lead to unconsciousness and death.[20] Since CO_2 is heavier than air it may accumulate in confined or low-lying spaces or areas. Leakage from storage sites below the seabed are less likely to cause harm to human beings compared to leakage on land. Contamination of groundwater is another potential consequence of leakage.[21]Any harm to humans and other organisms is likely to occur in the immediate vicinity of the leak. In most circumstances the CO_2 quickly gets diluted to harmless levels in ambient air or water. Any risk for leakage may remain almost indefinitely, although the prospect of so-called geological trapping may eventually make the CO_2 solid. The potential health risks associated with a leak will, however, be local and short-time (unless the leakage itself is gradual and continues over a long period of time). The risk that leakage of CO_2 undermines the positive climate effect of CCS is, on the other hand, global. In order to significantly affect the climate, leakage would have to occur on a very large scale.

Due to the novelty of CCS there is limited experience to draw on when estimating the risks associated with its potential future large-scale deployment. There are, however, a number of technologies or phenomena which provide useful analogues. These include natural geological accumulations of relatively pure CO_2 and underground installations for natural gas storage as well as the use of CO_2 for EHR[22].

The level and nature of leakage risk associated with CO_2 storage sites are likely to vary considerably depending on the nature of the reservoir.[23] Analogous experience indicates small risks, but quantitative estimates are hard to make.[24] According to an estimate by the IPCC, the fraction of stored CO_2 retained over the first 100 years is, on average, very likely to be more than 99%. It is likely to be 99% also over the first 1000 years. These figures are premised on the storage sites being well selected, well designed and operated, and appropriately monitored.[25]

Apart from any physical leakage, CCS as a technology is also associated with a "political risk" to a larger extent than nuclear power generation. Although the construction of nuclear power plants has often turned out to be contentious and to significantly exceed budgets, there can be no doubt that such plants can be built and successfully operated on a large scale; that has been done for decades. With CCS, however, there is still an uncertainty as to the practical and economic viability of the technology as such on the scale needed to make it a useful instrument for climate change abatement. It is not inconceivable that CCS, due to, inter alia, cost or widespread public resistance, could fail to be employed on a significant scale. The financial, scientific and political resources invested in its development and facilitation would then largely have been wasted. That would be particularly problematic since the only purpose of CCS is climate change abatement. The wasted resources would thus likely have been diverted from other, potentially successful, climate change abatement

[20] IPCC 2005, at 246.
[21] Ibid., at 247. The risks stem from the potential of migrating CO_2 altering the groundwater chemistry causing a drop in pH level and the mobilization of toxic metals such as lead in high concentrations. Ibid. and Damen, K., *et al.*, "Health, Safety and Environmental Risks of Underground CO_2Storage – Overview of Mechanisms and Current Knowledge", 74 *Climatic Change* (2006) 289, at 298.
[22] On EHR, see note 12 above.
[23] On abandoned oil and gas fields, currently unminable coal seams and saturated rock formations, see IPPC 2005, at 215 and 217-219.
[24] The Future of Coal, at 50.
[25] IPCC, 2005, at 246.

projects. This potential problem is not, however, specifically linked to the storage of captured CO_2 but rather pertains to CCS as such.

With respect to nuclear waste and spent fuel it should be appreciated that intentional spread by humans could result in exposure to harmful radiation. Spent fuel is also associated with risk for nuclear weapons proliferation. And there may be harm in the other end of the nuclear fuel chain, e.g. associated with the mining of uranium. The intentional release of stored CO_2 has little potential to serve any meaningful purpose, and should thus be less alluring than intentional spread or release of radioactive material. Since CO_2 is not explosive, a storage site is unlikely to be an attractive target even for terrorist activities. Like with uranium, the production of coal and other fossil fuels are associated with significant environmental and health issues which need to be considered when policies for CCS are decided.

In sum, there is a partial asymmetry between the temporal and spatial aspects of risks and benefits associated with storage of CO_2 and spent fuel/nuclear waste respectively. Both activities, if successfully conducted in a secure manner, are likely to bring climate benefits. Both kinds of materials also typically derive from processes that generate power, a good in high demand. However, CCS may also be seen as associated with certain climate risks which are largely missing in nuclear power generation. The immediate physical hazards associated with leakage, on the other hand, may be more local for CCS compared to radioactive material. The fact that CO_2 storage is (and, perhaps more important, is perceived as being) associated with local and concrete risks, whereas the benefits – of CO_2 storage as such, rather than of fossil fuel use – are inherently global make it particularly challenging to weigh up the risks and benefits of individual, proposed storage sites. If, however, the elimination or at least drastic reduction of CO_2 emissions from fossil fuel use is eventually recognized as an absolute necessity, then the storage of any significant volumes of CO_2 produced should be perceived not as an option, but as an inevitable consequence of fossil fuel use, just as spent fuel and nuclear waste management is an inevitable aspect of nuclear energy production.

5. Regulatory frameworks

On the domestic level, Sweden has had rules on the responsibility for the safe management of nuclear waste and spent fuel for decades.[26] The regime for economic liability for such material was revised in 2007. It resulted in the adoption of a new Act on Financing of Management of Residual Products from Nuclear Activities.[27] It aims, together with a supplementary ordinance,[28] to guarantee the availability of sufficient resources for safe management of spent fuel and nuclear waste. When it comes to the handling of residual products from the nuclear industry, not least siting, permitting and operation of disposal facilities, provisions in domestic environmental law – in the case of Sweden primarily set out in the Environmental Code[29] – are also pertinent. There is also particular domestic legislation

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[26] At least since the adoption of the Act (1981:669) on financing future costs for spent nuclear fuel etc. (Lag om finansiering av framtida utgifter för använt kärnbränsle m.m) in 1981 it has been clear that the nuclear industry should, in principle, bear the economic responsibility for the safe handling of residual products. The debate on cost responsibility for spent fuel from the nuclear industry, however, dates back to the commencement of commercial operation of nuclear power plants in Sweden in the early 1970s. Betalningsansvaret för kärnavfallet, SOU 2004:125, at 33-34 (Economic Responsibility for Nuclear Waste, Government Official Reports 2004:125).

[27] Act (2006:647) on Financing of Management of Residual Products from Nuclear Activities (Lag om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet).

[28] Ordinance (2008:715) on Financing of Management of Residual Products from Nuclear Activities (Förordning om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet).

[29] Environmental Code (1998:808) (Miljöbalk).

for nuclear installations and activities involving radiation in the form of the Nuclear Activities Act and the Radiation Protection Act.[30]

On the EC level there is, despite attempts in that direction, no comprehensive legislation pertaining to management and disposal of spent fuel and nuclear waste. In 2003 the Commission presented, as part of a nuclear policy package, a “Proposal for a Council Directive (Euratom) on the management of spent nuclear fuel and radioactive waste” to the Council.[31] However, it hasn’t attracted sufficient support from the Member States in order to be adopted.[32] Some EC legal acts will be of relevance for, inter alia, the conduct of an environmental impact assessment of a spent fuel or nuclear waste repository.[33] However, regulating responsibility for the management of residual material from the nuclear industry is largely left to the Member States.

There are also, since fairly recently, binding rules on spent fuel and radioactive waste management in international law. Sweden, as well as most European countries and Euratom are parties to the IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention), which came into force in 2001.[34] For the present analysis, the Joint Convention is relevant mainly because it sets out certain general obligations of the Parties with respect to the management of spent fuel and radioactive waste.[35] There are also non-binding international standards, notably safety standards developed under the auspices of IAEA.[36]

The legal situation for CO_2 storage looks very different from that for spent fuel and nuclear waste disposal. Since CCS has yet to be scaled up to industrial proportions there is very little experience of regulating the geological storage of CO_2. The countries in which more large-scale pilot projects are operated have largely relied on existing legislation after some adaptation. Typically laws on oil and gas extraction and distribution have been used.[37] On the international level rather extensive assessments of existing rules have been conducted, mainly aimed at identifying potential legal obstacles to the deployment of CCS technology. So far there have been some facilitative amendments of international agreements. These include amendments to the London Dumping Protocol[38] and the OSPAR Convention.[39] Both

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[30] Act (1984:3) on Nucelar Activties and Act (1988:220) on Radiation Protection.

[31] Proposal for a Council Directive (Euratom) on the management of spent nuclear fuel and radioactive waste, COM(2003) 32 final. An amended proposal was adopted by the Commission in 2004. See Amended proposal for a Council Directive (Euratom) on the safe management of the spent nuclear fuel and radioactive waste, 8.9.2004, COM(2004)526 final. On the proposals, the developments leading up to them, and the attendant political controversies see (in Swedish) Cramér, P., Erhag, T., Stendahl, S., *Nationellt ansvar för använt kärnbränsle*, Santérus Academic Press, 2009, at 179 et seq.

[32] Veuchelen, L., 'The Legal Value of General Principles, Technical Norms and Standards in European Nuclear Safety Law: The Imbalance Between Soft and Hard Law and the Need for Global Regulatory Governance', 18 *European Energy and Environmental Law Review* (2009), 215, at 218.

[33] See Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, [1985] OJ L 175/40. Annex I, para. 3 (b). On the partly disputed competence of the EC to regulate the environmental risks posted by nuclear activities, including the handling of spent fuel and nuclear waste see (in Swedish) Cramér P., Erhag, T., Stendahl, S., 2009, at 159 et seq.

[34] Vienna, 5 September 1997. The total number of Parties is 52 as of 21 October 2009. See further <http://www-ns.iaea.org/conventions/waste-jointconvention.htm> (19 Nov. 2009).

[35] See, inter alia, the Joint Convention, Articles 1, 4 and 11.

[36] See Veuchelen, 2009, at 219 et seq.

[37] See on Australia Fahey, J. and Lyster, R., ‘Geosequestration in Australia: Existing and Proposed Regulatory Mechanisms’, 4:5 *Journal for European Environmental and Planning Law* (2007), 378-392; on Norway, see Hallenstvedt, N. K., ‘Current CCS Regulation in Norway’, <http://www.ucl.ac.uk/cclp/pdf/CCS_in_Norway_April2008.pdf> (25 Nov. 2009).

[38] Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, 7 November 1996).

[39] Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) (Paris, 22 September 1992).

are intended to do away with obstacles to the storage of CO_2 in the sub-seabed.[40] There are also ongoing discussions on the role of CCS in the future climate regime which may be highly significant for the prospect of large-scale deployment of the technology, particularly in developing countries.[41]

The EC has developed and recently adopted what must be deemed the most comprehensive legal framework for CCS anywhere in the world. EC directive 2009/31 on the geological storage of carbon dioxide (the "geological storage directive"), adopted in April 2009, establishes a minimum level for the regulation of geological storage sites for CO_2 throughout the European Union.[42] It applies to storage sites in the Member States' territories as well as within their marine jurisdictional zones.[43] The adoption of the directive also entailed amendments to a number of other EC legal acts in order to make them apply to and accommodate various aspects of CCS. These include the directives on environmental impact assessment (EIA),[44] integrated pollution prevention and control (IPPC),[45] waste,[46] and environmental liability[47]. Of huge significance for the economic viability of CCS is the inclusion of CCS operations within the EC emission allowances trading scheme for CO_2 (ETS).[48] From 2013 CO_2 captured for geological storage will not be counted as emitted under the ETS. Instead any subsequent emissions of such CO_2, during handling, transport or storage, will have to be covered by emission allowances.[49] The geological storage directive is to be implemented in the domestic legislation of the Member States no later than 25 June 2011.[50] This will require significant amendments to existing laws and, probably, the adoption of new legislation. The manner in which the directive will be implemented in Sweden is currently not known.

6. Conditions for storage/disposal facilities

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[40] See further Langlet, D., "Safe Return to the Underground? - The Role of International Law in Subsurface Storage of Carbon Dioxide", 18 (3) *Review of European Community and International Environmental Law* (2009) (forthcoming).

[41] See section "REGULATING CLIMATE RISKS" in ibid.

[42] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006, [2009] OJ L 140/114. The directive is based on Article 175 of the EC Treaty and does not prevent the Member States from applying more far-reaching – in terms of environmental and health protection – rules as long as they don't deviate from the minimum standard set by the directive. On the relationship between the directive and domestic legislation, see further (in Swedish) Langlet, D, "Europeisk reglering av koldioxidlagring: analys utifrån miljörättsliga aspekter", 2009:1 *Nordisk Miljörättslig Tidskrift*, (forthcoming), section 6.

[43] On CO_2 storage and marine jurisdictional zones see "The Marine Environment" in Langlet, 2009, "Safe Return to the Underground?".

[44] Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, [1985] OJ L 175/40.

[45] Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control, [2008] OJ L 24/8.

[46] Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste, [2006] OJ L 114/9.

[47] Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage, [2004] OJ L 143/56.

[48] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, [2003] OJ L 275/32, Article 12 (3a) and Annex I as amended by Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community, [2009] OJ L 140/63.

[49] Directive 2003/87, Annex I.

[50] Directive 2009/31, Article 39 (1).

General rules on siting and operation of environmentally hazardous activities in the Swedish Environmental Code will apply to spent fuel and nuclear waste repositories as well as to CO_2 storage facilities.[51] With respect to nuclear material, certain provisions in the legislation on nuclear activities and radiation will also apply.[52] Their main focus, as far as is relevant here, is on certain safety issues. The Environmental Code contains broader considerations pertaining to environmental and health protection and sustainable development.[53] This entails, inter alia, that sites for e.g. storage/disposal facilities are to be chosen in such a way as to make it possible to achieve the facilities' purpose with a minimum of damage or detriment to human health and the environment.[54] A permit should be denied if the proposed activity – despite the best site having been chosen and best available technology applied – is likely to cause *significant* damage or detriment to human health or the environment. If, however, an activity is of "particular importance for reasons of public interest" the Government may grant a permit despite any attendant environmental effects, unless the activity is also likely to be detrimental to public health.[55]

Any decision on authorizing a storage site for either captured CO_2 or spent nuclear fuel must be preceded by an environmental impact assessment procedure, partly governed by EC law.[56] This tallies with the Joint Convention, which requires Parties to establish procedures to evaluate all relevant site-related factors likely to affect the safety of a proposed spent fuel management facility and to evaluate the likely safety impact of the facility on individuals, society and the environment.[57] The procedures for authorizing the siting, construction and operation of spent fuel repositories under Swedish law have been extensively discussed elsewhere and will not be addressed here.[58]

Under EC law, sites for geological storage of CO_2 may not be allowed to operate without a permit issued by the Member State on whose territory a planned storage is to be located.[59] The geological storage directive recognizes the unconditional right of each Member State to decide whether it accepts the siting of any CO_2 storage facility within its territory.[60] For any State which accepts, in principle, storage within its territory there are, inter alia, requirements on the siting of such a facility. A geological formation[61] may only be selected as a storage site, "if under the proposed conditions of use there is no significant risk of leakage, and if no significant environmental or health risks exist".[62] Although the directive provides a definition of "significant risk", that is too opaque to provide much guidance.[63] Member States

[51] See, in particular, the Environmental Code, Chapter 2. In the case of a storage facility being located under the seabed, beyond Swedish territorial waters, the environmental code is likely to be applicable only to a limited extent. However, since Swedish law has yet to implement any specific provisions on geological CO_2 storage the exact applicability of the Code cannot yet be established.
[52] See Act (1984:3) on Nuclear Activities and Act (1988:220) on Radiation Protection.
[53] See the Act (1984:3) on Nuclear Activities, section 3, Act (1988:220) on Radiation Protection, section 1, and the Environmental Code, Chapter 1.
[54] Environmental Code, Chapter 2, section 6.
[55] Environmental Code, Chapter 2, sections 9 and 10.
[56] Directive 85/337, Annex I, paras. 3 and 23.
[57] Joint Convention, Article 13 (i)-(ii).
[58] See e.g. "Premises and conditions for permits and licences" in "Final Disposal of Spent Nuclear Fuel", 2006, at 11 et seq.
[59] Directive 2009/31, Article 6 (1). However, geological storage of CO2 with a total intended storage volume below 100 kilotonnes, undertaken for research, development or testing of new products and processes is not covered by the directive. Directive 2009/31, Article 2 (2).
[60] Directive 2009/31, Article 4 (1).
[61] A "geological formation" is defined as "a lithostratigraphical subdivision within which distinct rock layers can be found and mapped". Directive 2009/31, Article 3 (4).
[62] Directive 2009/31, Article 4 (4).
[63] A "significant risk" is "a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the purpose of [the] Directive for the storage site

may, however, establish other requirements that are more protective of human health and the environment, as long as they are in keeping with the purpose of the directive. These specific EC law siting requirements have no counterpart when it comes to spent nuclear fuel repositories.

7. Cost responsibility

Until the mid-1970s the prevailing view in Sweden was that spent nuclear fuel should be reprocessed and plutonium recycled. The reprocessing was to be carried out abroad. Until 1982 approximately 140 tons a fuel were shipped to Windscale (later Shellafield) in the UK. From the mid-1970s a condition for the loading of fuel into a new nuclear reactor was that the utility could present either an agreement for reprocessing of spent fuel or a plan for the safe disposal of the high level radioactive waste (incl. spent fuel) which would result from the operation of the reactor. This requirement prompted the launch by the nuclear industry of a joint research project on nuclear fuel safety, including surveys for identifying suitable bedrock sites for potential future disposal of highly radioactive waste. From 1984 the carrying out by the nuclear industry of an R&D program and its regular submission for regulatory evaluation have been required by law.[64]

From the early 1980's a set of fundamental principles for the management of spent fuel and radioactive waste has been formulated and repeatedly confirmed by the Swedish Government and Parliament.[65] Among these is that the expenses for the disposal of spent nuclear fuel and nuclear waste shall be covered by revenue from the energy the production of which caused those expenses. Furthermore, reactor owners are to safely dispose of spent nuclear fuel and nuclear waste. However, it is also a fundamental principle that the State bears the ultimate responsibility for such fuel and waste. The long-term responsibility for the handling and disposal of such material rests with the State. After a repository has been closed, a requirement should be established to ensure that some kind of responsibility for and supervision of the repository can be made and maintained for a considerable time.[66]

These principles have been operationalized in the Financing Act. Under this, the holder of a license to operate any nuclear activity (the licensee) which gives or has given rise to residual products must pay a nuclear waste fee.[67] The fee paid by each licensee should cover the licensee's share of the total costs to be covered by the fee. Those include a number of costs incurred by the licensees, the State and certain other actors. Most importantly, the funds generated by the levying of the fee shall cover the licensee's costs for decommissioning and dismantling nuclear facilities and the safe handling and final disposal of residual

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concerned" (Directive 2009/31, Article 3 (18)). The purpose of the Directive is not set out explicitly. However, it "establishes a legal framework for the environmentally safe geological storage of carbon dioxide (CO_2) to contribute to the fight against climate change." (Directive 2009/31, Article 1 (1)). The purpose of "environmentally safe geological storage of CO_2" is defined as "permanent containment of CO_2 in such a way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health." (Directive 2009/31, Article 1 (2)). Hence, the purpose of the Directive may be assumed to be at least that. Accordingly, a "significant risk" should be at least a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the ability of a permanent containment of CO_2 to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health. Reasonably, it is a tall order to establish, inter alia, when a risk calls into question the ability to eliminate as far as possible negative effects and any risk which may not be prevented!

[64] Sweden's third national report under the Joint Convention, at 10-11. For the current obligation, see Act (1984:3) on Nuclear Activities, section 12.

[65] See, inter alia, Government bills 1980/81:90, Appendix 1, at 319, 1983/84:60, at 38, and 1997/98:145, at 356, and final reports of the Standing Committee on Industry and Trade, 1988/89:NU31 and 1989/90:NU24.

[66] Sweden's third national report under the Joint Convention, at 44.

[67] Act (2006:647) on Financing of Management of Residual Products from Nuclear Activities, section 4.

products, including spent fuel, as well as the research and development necessary for carrying out these activities. The fee shall further cover the State's costs for research and development needed to review those activities and for the supervision of decommissioning and dismantling of nuclear facilities. It shall also cover the costs for providing certain information to the public and for economic support to non-profit organizations for efforts in connection to the siting of certain facilities. Finally, the State's costs for administration of funded means and review of measures taken according to the Financing Act are to be covered by the fee.[68] As to the time span of the activities financed through the nuclear waste fee, supervision and other activities associated with a final disposal facility are included until the time of the sealing of that facility. After that time, any activities, such as monitoring and the remedying of any unforeseen security problem, are the responsibility of the State.[69]

In addition to paying the nuclear waste fee, the licensee must provide guarantees for the calculated costs which are to be covered by future fee payments by that licensee. This is intended to protect the State from having to step in and compensate for the missing funds in case the licensee loses its ability to make further payments before the full costs have been covered.[70] The guarantee shall also cover estimated costs for unforeseen occurrences related to decommissioning, dismantling, waste handling and final disposal and the associated research.[71]

The utilities that operate nuclear reactors in Sweden have set up a special company, The Swedish Nuclear Fuel and Waste Management Co. (SKB) to dispense with many of the industrie's obligations.[72]

The requirements of the Financing Act are largely in keeping with the Joint Convention. The latter requires Parties, inter alia, to "aim to avoid imposing undue burdens on future generations" with respect to spent fuel and radioactive waste management.[73] Furthermore, the IAEA's Principles of Radioactive Waste Management refer to the "ethical consideration that the generations that receive the benefits of a practice should bear the responsibility to manage the resulting waste."[74] What is considered acceptable to pass on to future generations is e.g. the continuation of institutional control over disposal facilities. To the extent possible, however, management should not rely on long-term institutional arrangements or actions.[75] There appears to be broad agreement on deep rock disposal being the best option for long-term management of spent fuel.[76]

The Convention also requires that a financial provision be made that will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility.[77] The only such "financial provision" in Swedish law appears to be the general acceptance by the State of responsibility for a repository from the point of its closure. This says little of what measures will in fact be taken and under what conditions. It is also a questionable policy in the light of the "polluter pays principle" since it means that future taxpayers – provided that the State or a

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[68] Act (2006:647) on Financing of Management of Residual Products from Nuclear Activities, section 6.
[69] Government Bill 2005/06:183, at 30.
[70] Section 14 and Ordinance (2008:715) on Financing of Management of Residual Products from Nuclear Activities, section 21.
[71] Ordinance (2008:715), section 2.
[72] Sweden's third national report under the Joint Convention, at 9, and www.skb.se.
[73] Joint Convention, Articles 4 (vi)-(vii) and 11 (vi)-(vii).
[74] "The Principles of Radioactive Waste Management", Safety Series No. 111-F, International Atomic Energy Agency, 1995, at 7.
[75] Ibid.
[76] Proposal for a Council (Euratom) Directive, COM(2003) 32 final, at 30.
[77] Joint Convention, Article 22 (iii).

similar polity exists and is funded through similar mechanisms as today – will have to foot the bill for any safety measure deemed necessary after closure.

Under EC law the operator of a geological CO_2 storage site is responsible for taking preventive as well as remedial action with respect to environmental damage caused and to cover any leakage of CO_2 with emission rights under the ETS also after the cessation of CO_2 injection into a storage site. Before commencement of injection of CO_2 into such a site a valid financial security shall be presented by the potential operator. This is to ensure that all obligations arising under the permit, including post-closure requirements, as well as any obligations arising under the environmental liability directive, can be met.[78]

However, the geological storage directive provides for the transfer of responsibility, if certain criteria are met, from the operator to the Member State under whose jurisdiction the storage site is operated once the site has been closed. For transfer to happen, all available evidence must indicate that the stored CO_2 will be completely and permanently contained.[79] Normally, a period of at least 20 years shall have elapsed from the closure of the site before transfer of responsibility takes place. Member States are allowed to accept transfer at an earlier date if the conditions are met. A draft approval of transfer must be sent to the EC Commission which may issue an opinion on it. A Member State depart from the Commission's opinion, but must state its reasons.[80]

Prior to the transfer of responsibility the operator of a CO_2 storage site is required to make a financial contribution available to the State. It shall cover at least the monitoring costs anticipated to be incurred by the State over a period of 30 years.[81] The operator may also be held responsible under the environmental liability directive and the ETS directive for CO_2 leakage, which occurs after the transfer of responsibility, if there has been fault on the part of the operator.[82] In such cases the competent authority shall recover from the former operator the costs incurred after the transfer has taken place.[83] Provided, that is, that the operator still exists and has the ability to pay. It should be noted that liability for injury to humans and to private property is not covered by EC law, but is for the Member States to regulate. Since all the pertinent EC legal acts constitute minimum regulation, Member States are generally free to impose more far-reaching requirements if they so chose.

8. Conclusions

Placing spent nuclear fuel and captured CO_2 in sealed repositories in the ground with no intention of retrieval are activities with similar characteristics. Despite this, the terminology used to describe them differs. While "disposal" is often used with respect to spent fuel/nuclear waste the injection of CO_2 into the ground is generally referred to as "storage". Despite this, the prospect of intentional future retrieval of spent fuel from the ground is probably far greater than that for geologically stored CO_2.

While the benefits of successful spent fuel disposal and geological storage of CO_2 are similar, the risks are more varied. Both activities involve daunting timescales. Any direct physical harm resulting from leakage of CO_2 is likely to be very local. Radioactive material may, if it escapes from a repository, spread more, particularly if moved intentionally by humans. CCS, of which storage of captured CO_2 is a part, is also associated with a

[78] Directive 2009/31, Article 19 (1).

[79] It is for the operator to submit a report demonstrating at least that there is no detectable leakage, that the actual behaviour of the injected CO_2 is in conformity with its modelled behaviour, and that the site is evolving towards a situation of long-term stability. Directive 2009/31/EC, Article 18 (1) and (2).

[80] Directive 2009/31/EC, Article 18 (4) and (6).

[81] Directive 2009/31/EC, Article 20.

[82] "Fault" includes cases of deficient data, concealment of relevant information, negligence, wilful deceit or a failure to exercise due diligence.

[83] Directive 2009/31/EC, Article 18 (7).

“political risk” pertaining to the uncertainties surrounding the feasibility of its future large-scale deployment, which is not to the same extent found with nuclear energy.

Although regulation of CO_2 storage is so far found mostly in EC law, whereas repositories for spent fuel and nuclear waste are subject mostly to domestic rules and some general obligations under international law, the regulatory situation is similar for the two kinds of activities. The most significant difference is perhaps the explicit, although somewhat opaque, requirements for siting of geological CO_2 storage sites. With neither activity is the operator expected to pay for supervision of storage/disposal sites and related activities for any extensive period of time, at least not compared to the period during which they could pose a hazard to the surrounding environment. In the case of CO_2 storage, however, Member States shall require a financial contribution covering at least the foreseen costs for supervision for 30 years after transfer of responsibility. Such transfers should, typically, occur 20 years or more after closure of the storage site. In the case of a repository for nuclear spent fuel, the Swedish State accepts full responsibility from the closure of the repository. This requires a fairly liberal understanding of the polluter pays principle in order to be acceptable. It is also open to question if current Swedish law is consistent with the Joint Convention’s requirement regarding financial provision for future supervision.

Although the difference are not that big, EC law on CO_2 storage is more consistent with the idea that those who benefit from an activity should also pay for attendant future costs than is Swedish law on nuclear waste management.

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