ANNEX I

CRITERIA FOR THE CHARACTERISATION AND ASSESSMENT OF THE POTENTIAL STORAGE COMPLEX AND SURROUNDING AREA REFERRED TO IN ARTICLE 4(3)

The characterisation and assessment of the potential storage complex and surrounding area referred to in Article 4(3) shall be carried out in three steps according to best practices at the time of the assessment and to the following criteria. Derogations from one or more of these criteria may be permitted by the competent authority provided the operator has demonstrated that the capacity of the characterisation and assessment to enable the determinations pursuant to Article 4 is not affected.

Step 1: Data collection

Sufficient data shall be accumulated to construct a volumetric and three-dimensional static (3-D)-earth model for the storage site and storage complex, including the caprock, and the surrounding area, including the hydraulically connected areas. This data shall cover at least the following intrinsic characteristics of the storage complex:

(a) geology and geophysics;

(b) hydrogeology (in particular existence of ground water intended for consumption);

(c) reservoir engineering (including volumetric calculations of pore volume for CO_2 injection and ultimate storage capacity);

(d) geochemistry (dissolution rates, mineralisation rates);

(e) geomechanics (permeability, fracture pressure);

(f) seismicity;

(g) presence and condition of natural and man-made pathways, including wells and boreholes which could provide leakage pathways.

The following characteristics of the complex vicinity shall be documented:

(h) domains surrounding the storage complex that may be affected by the storage of CO_2 in the storage site;

(i) population distribution in the region overlying the storage site;

(j) proximity to valuable natural resources (including in particular Natura 2000 areas pursuant to Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds[(1)] and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora[(2)], potable groundwater and hydrocarbons);

(k) activities around the storage complex and possible interactions with these activities (for example, exploration, production and storage of hydrocarbons, geothermal use of aquifers and use of underground water reserves);

(l) proximity to the potential CO_2 source(s) (including estimates of the total potential mass of CO_2 economically available for storage) and adequate transport networks.

Step 2: Building the three-dimensional static geological earth model

Using the data collected in Step 1, a three-dimensional static geological earth model, or a set of such models, of the candidate storage complex, including the caprock and the hydraulically connected areas and fluids shall be built using computer reservoir simulators. The static geological earth model(s) shall characterise the complex in terms of:

(a) geological structure of the physical trap;

(b) geomechanical, geochemical and flow properties of the reservoir overburden (caprock, seals, porous and permeable horizons) and surrounding formations;

(c) fracture system characterisation and presence of any human-made pathways;

(d) areal and vertical extent of the storage complex;

(e) pore space volume (including porosity distribution);

(f) baseline fluid distribution;

(g) any other relevant characteristics.

The uncertainty associated with each of the parameters used to build the model shall be assessed by developing a range of scenarios for each parameter and calculating the appropriate confidence limits. Any uncertainty associated with the model itself shall also be assessed.

Step 3: Characterisation of the storage dynamic behaviour, sensitivity characterisation, risk assessment

The characterisations and assessment shall be based on dynamic modelling, comprising a variety of time-step simulations of CO_2 injection into the storage site using the three-dimensional static geological earth model(s) in the computerised storage complex simulator constructed under Step 2.

Step 3.1: Characterisation of the storage dynamic behaviour

At least the following factors shall be considered:

(a) possible injection rates and CO_2 stream properties;

(b) the efficacy of coupled process modelling (that is, the way various single effects in the simulator(s) interact);

(c) reactive processes (that is, the way reactions of the injected CO_2 with in situ minerals feedback in the model);

(d) the reservoir simulator used (multiple simulations may be required in order to validate certain findings);

(e) short and long-term simulations (to establish CO_2 fate and behaviour over decades and millennia, including the rate of dissolution of CO_2 in water).

The dynamic modelling shall provide insight into:

(f) pressure and temperature of the storage formation as a function of injection rate and accumulative injection amount over time;

(g) areal and vertical extent of CO_2 vs time;

(h) the nature of CO_2 flow in the reservoir, including phase behaviour;

(i) CO_2 trapping mechanisms and rates (including spill points and lateral and vertical seals);

(j) secondary containment systems in the overall storage complex;

(k) storage capacity and pressure gradients in the storage site;

(l) the risk of fracturing the storage formation(s) and caprock;

(m) the risk of CO_2 entry into the caprock;

(n) the risk of leakage from the storage site (for example, through abandoned or inadequately sealed wells);

(o) the rate of migration (in open-ended reservoirs);

(p) fracture sealing rates;

(q) changes in formation(s) fluid chemistry and subsequent reactions (for example, pH change, mineral formation) and inclusion of reactive modelling to assess affects;

(r) displacement of formation fluids;

(s) increased seismicity and elevation at surface level.

Step 3.2: Sensitivity characterisation

Multiple simulations shall be undertaken to identify the sensitivity of the assessment to assumptions made about particular parameters. The simulations shall be based on altering parameters in the static geological earth model(s), and changing rate functions and assumptions in the dynamic modelling exercise. Any significant sensitivity shall be taken into account in the risk assessment.

Step 3.3: Risk assessment

The risk assessment shall comprise, inter alia, the following:

3.3.1. Hazard characterisation

Hazard characterisation shall be undertaken by characterising the potential for leakage from the storage complex, as established through dynamic modelling and security characterisation described above. This shall include consideration of, inter alia:

(a) potential leakage pathways;

(b) potential magnitude of leakage events for identified leakage pathways (flux rates);

(c) critical parameters affecting potential leakage (for example maximum reservoir pressure, maximum injection rate, temperature, sensitivity to various assumptions in the static geological Earth model(s));

(d) secondary effects of storage of CO_2, including displaced formation fluids and new substances created by the storing of CO_2;

(e) any other factors which could pose a hazard to human health or the environment (for example physical structures associated with the project).

The hazard characterisation shall cover the full range of potential operating conditions to test the security of the storage complex.

3.3.2. *Exposure assessment — based on the characteristics of the environment and the distribution and activities of the human population above the storage complex, and the potential behaviour and fate of leaking CO_2 from potential pathways identified under Step 3.3.1.*

3.3.3. *Effects assessment — based on the sensitivity of particular species, communities or habitats linked to potential leakage events identified under Step 3.3.1. Where relevant it shall include effects of exposure to elevated CO_2 concentrations in the biosphere (including soils, marine sediments and benthic waters (asphyxiation; hypercapnia) and reduced pH in those environments as a consequence of leaking CO_2). It shall also include an assessment of the effects of other substances that may be present in leaking CO_2 streams (either impurities present in the injection stream or new substances formed through storage of CO_2). These effects shall be considered at a range of temporal and spatial scales, and linked to a range of different magnitudes of leakage events.*

3.3.4. *Risk characterisation — this shall comprise an assessment of the safety and integrity of the site in the short and long term, including an assessment of the risk of leakage under the proposed conditions of use, and of the worst-case environment and health impacts. The risk characterisation shall be conducted based on the hazard, exposure and effects assessment. It shall include an assessment of the sources of uncertainty identified during the steps of characterisation and assessment of storage site and when feasible, a description of the possibilities to reduce uncertainty.*

(**1**) OJ L 103, 25.4.1979, p. 1.

(**2**) OJ L 206, 22.7.1992, p. 7.