Programme Area: Carbon Capture and Storage

Project: System Modelling Tool Kit

Title:

Context:

The two-and-a-half year, £3m project launched in September 2011 created a modelling tool-kit capable of simulating the operation of all aspects of the CCS chain, from capture and transport to storage to support the future design, operation and roll-out of cost effective CCS systems in the UK. It involved modelling technology provider Process Systems Enterprise (PSE), energy consultancy E4tech, and industrial partners EDF Energy, E.ON, Rolls-Royce and CO2DeepStore, who expected to be involved in capturing, compressing, transporting and storing CO2 in the future. The project has resulted in a commercial product (gCCS) built on PSE's gPROMS modelling platform. The tool-kit will be used to support the initial conceptual design and eventual detailed design and operation of CCS systems by helping to identify and understand system-wide operational issues such as the effects of power station ramp-up or ramp-down on downstream storage operation, or the effect of downstream disturbances on power generation.

Request for Proposal (RfP)

Title of Services for which Proposals are Requested: **Development of an Operational Modelling Tool-Kit for CCS Systems**
Request Issue Date: 22nd October 2010
Deadline for Notification of Intention to Submit a Proposal: 26th November 2010
Closing Date: Proposals must be received before 4pm on 17th December 2010
Contact for Enquiries: Mrs Olanrewaju Akpe Programme Management Officer Tel: +44 (0)1509 202004 Email: ccs@eti.co.uk
Address for Submission of Proposals: Energy Technologies Institute LLP FAO: Olanrewaju Akpe Holywell Building Holywell Way Loughborough LE11 3UZ Email: ccs@eti.co.uk

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1. Introduction and Overview of ETI Requirements

1.1. Introduction to the Energy Technologies Institute

The Energy Technologies Institute LLP (ETI) is a private organisation formed as an innovative Limited Liability Partnership between international industrial energy companies and the UK government.

Our mission is to accelerate the development, demonstration and eventual commercial deployment of a focused portfolio of energy technologies, which will increase energy efficiency, reduce greenhouse gas emissions and help achieve energy and climate change goals.

We will do this by leveraging the skills, capabilities and market access routes of our Members, working with other organisations worldwide to take the most challenging large-scale energy projects to full system demonstration, thereby bridging the gulf between laboratory proven technologies and full scale commercially tested systems. Our projects will also develop knowledge, skills and supply-chains, and will inform the development of regulation, standards and policy. Hence we aim to overcome major barriers, de-risk the future development and shorten the lead times to market for secure, affordable, low-carbon energy systems for power, heat and transport.

Our portfolio includes programmes in areas such as Wind, Marine, Distributed Energy, Transport, Energy Networks, Carbon Capture & Storage and Buildings.

Further information can be found on our web-site at www.energytechnologies.co.uk.

1.2. Background to the Project

Given the required speed of roll-out, cost and complexity of the future CCS infrastructure in the UK, modelling will play a crucial role in ensuring a practical, cost effective and robust network of assets. Modelling can potentially support decisions at a range of business levels, from strategic planning through to plant & system operation and maintenance.

Through detailed strategic analysis and stakeholder engagement, the ETI has identified that a need exists to develop a Modelling Tool-Kit for partial (but full-chain) CCS systems to develop understanding of and support business decisions around the design, operation and maintenance of assets (eg power stations, compressor stations) within a future CCS system.

The ETI has completed a study to define the requirements for such a Modelling Tool-Kit, both in terms of functionality of the component & whole system models and the modelling environment within which such models would be developed. The ETI is now seeking to establish and invest in a project to develop such a model through this Request for Proposals (RfP). It is anticipated that the ETI will provide funding of the order of £2 million to the successful bidders.

1.3. ETI approach to Health & Safety

The health and safety of those who may be affected by ETI Projects is of paramount importance to the ETI. The ETI expects those who receive ETI funding to demonstrate a commitment to best practice in health, safety and environmental management as well as demonstrating that legal requirements are met.

1.4. Required Outcomes

The ETI's primary required outcome from this project is a Modelling Tool-Kit, based on an established, robust and flexible modelling platform, capable of modelling the operation of future CCS systems and assets within that system.

Users of the Tool-Kit

The Tool-Kit would have three broad categories of potential users:

- Asset owners or developers (eg ETI member companies). These users would use the Tool-Kit to understand the effects that CCS chain components up- and downstream of their subsystem(s) will have on operation of their assets. A distinguishing feature of this user group is that they have deep expertise for at least one of the subsystems and already have access to detailed models for this subsystem;
- Technology suppliers, for example equipment suppliers, process vendors, engineering companies, consultants, etc;
- Policy makers (e.g. government agencies) and other organisations such as the ETI itself, who would not necessarily have in-depth technical expertise in any of the subsystems, but would need to understand issues around overall CCS system operation.

Uses of the Tool-Kit

The primary use of the Modelling Tool-Kit will for the engineering simulation of full-chain CCS systems and operational events occurring in that system. This will be used to support business decisions in the following phases of CCS roll-out:

- System conceptual design, e.g. to assess options for asset siting, pipeline network design, intermediate storage;
- System detailed design, e.g. to understand the impact of pipeline sizing, network design and component performance on overall system and asset operability;
- System operation, e.g. for operational and maintenance planning to understand how operational events might impact on overall system and asset operability.

Key Features of the Tool-Kit

The key features of the Modelling Tool-Kit will be as follows (see Appendix F for full list of requirements):

- The Tool-Kit must have an open architecture, enabling interfacing to a wide range of existing and future models, with a consistent, user-friendly and intuitive user interface;
- The Tool-Kit must interface to proprietary subsystem models and protect IP;
- The Tool-Kit must include a suite of non-proprietary subsystem models, covering the whole CCS chain;
- The suite of non-proprietary models must have capability to match each other on operating characteristics and size ('sizing' capability);
- The Tool-Kit must have the capability to deal with system dynamics at various time-scales ranging from seconds to steady-state;
- The Tool-Kit must be able to capture effects related to the composition of the fluid stream and track the fluid stream composition throughout the chain;
- The Tool-Kit must include a set of suitable physical property models, including stable physical property values close to the critical point for a range of CO2 mixtures (but explicit modelling of multi-phase flow behaviour is not a priority);

- The Tool-Kit must allow user-defined calculations and integration of external data;
- Model validation is a key concern, both in terms of validating the models developed in the project and future validation by model users (eg ability to import validation datasets).

At the end the project, the contractors will have delivered a working, validated Modelling Tool-Kit to the ETI, including handover and initial training of users within ETI Members, which demonstrates the key features outlined above.

1.5. ETI's requirements for investment in this Project

The ETI wishes to co-invest and collaborate with the successful bidding Participants to develop a Modelling Tool-Kit which will be of benefit to the ETI, its Members, the Participants and CCS developers more widely.

The ETI has identified a range of potential future users for the Modelling Tool-Kit within both its private and public sector Members. Respondents should consider how these potential ETI member users should be engaged in the Modelling Tool-Kit Development Project.

Respondents should demonstrate their capability and provide a business case for future support, development and commercial exploitation of the Modelling Tool-Kit. To be clear, it is expected that the model developer will make the Tool-Kit (or certain versions of it) available commercially to third parties. Separately, it is anticipated that ETI Members will be provided with preferential access to the Tool-Kit. Details of the proposed commercial approach form part of the proposal (see Section 16 of Appendix A).

The ownership and rights to the Intellectual Property rights relevant to and arising from the Project will be dealt with as set out in Section 12 of Appendix A.

Respondents should note that neither the ETI nor its Members will be in a position to provide ongoing support to the Tool-Kit and the ETI is unlikely to fund further development beyond this project.

1.6. ETI and State Aid

Funding from the ETI for this project may constitute state aid. The ETI has a specific state aid clearance from the European Commission. In relation to their Proposals, Respondents should note:

- Further information may be required to support the specific state aid requirements of any Proposal during the procurement process;
- Successful Respondent(s) will be required to provide full transparency of costs throughout the Project to ensure both the Participant(s) and the ETI comply with EU state aid law;
- Participants will need to agree to certain contractual obligations related to the state aid requirements including the duration of Project records and obligations to return ETI funding in certain exceptional circumstances.

1.7. Project Organisation Structure

It is anticipated that a number of Participant organisations/entities will be required to work together in order to provide all the necessary knowledge, skills, experience and inputs to complete the Project.

Organisations may choose either:

1. for a single organisation to act as 'Prime Contractor' who shall form a contract with the ETI, and shall manage the Project and act as primary interface with the ETI (and who may have Subcontractors);

2. to form a Consortium, contracted with the ETI, governed by its own Consortium Agreement and led by a 'Lead Coordinator' to manage the Project and act as primary interface with the ETI (each Consortium Member may have Subcontractors);

Either of these contracting arrangements is acceptable to the ETI, but there must be a single organisation (Lead Coordinator or Prime Contractor) leading and acting as the primary interface with the ETI. This organisation shall also act as the Respondent for the purposes of this Request for Proposals. This organisation shall appoint a Project Manager to lead and coordinate all activities of the Participants, and to liaise regularly with the ETI's Programme Manager to whom he/she is accountable on behalf of the Participants. The Participants must also appoint a Chief Technologist (the responsibilities of these two key individuals are described in Section 3.2 of Appendix A).

Under either contracting arrangement, it is critical that the Lead Coordinator or Prime Contractor is sufficiently empowered to lead the Project and accept accountability for delivery to the ETI. It is also important that the arrangements enable sufficient flexibility for ongoing delivery optimisation to maximise value for money and achieve the project aims and critical success factors. In the case of option (2), in which there is no natural contractual hierarchy, bidders are required to explain fully in their Proposal the agreed principles of their Consortium Agreement.

The viability and strength of the project governance model will be a proposal assessment criterion.

It is a requirement that the ETI approves:-

(a) any Consortium Agreement;

(b) any Subcontractor (and may review Subcontracts).

2. Procurement Process and Estimated Time-Frames

2.1. Response to Request for Proposal

An eight (8) week period has been allowed for Respondents to provide a Proposal according to the structure set out in Appendix A and other components of the Submission set out in Section 3.1.

Respondents are required to enter into a Non Disclosure Agreement (NDA) with the ETI before submitting their Proposal. The form of NDA is provided in Appendix E: a clean copy is available on request from the ETI. Signed NDAs, which will be taken as formal notification of the intention to bid, should be returned to the ETI as soon as possible and at latest three weeks before the submission deadline. Respondents are, however, encouraged to return the NDA as soon as possible, as on return of the signed NDA, the ETI will send out the full draft Project Contract (see also Appendix B for a summary of contract terms and Appendix D in relation to the Statement of Compliance). The NDA must be completed by the Prime Contractor or in the case of a Consortium, each organisation forming part of the Consortium. In the latter case the NDA may be completed in counterpart with separate copies executed on behalf of each organisation.

Respondents are encouraged to seek advice from the ETI to ensure full understanding of ETI requirements. A project briefing and workshop will be held on Tuesday 16th November 2010 at the ETI. This will include a briefing session on ETI requirements and the opportunity to network with other potential project participants. The discussions at the workshop will be on a non-confidential basis.

Attendance at the workshop will subject to availability of places and ETI approval. Where there is more demand than places, priority is likely to be given to individuals from organisations which the ETI understands to (a) be interested undertaking the role of Lead Coordinator, (b) organisations with ownership of a suitable modelling platform and/or (c) known expertise in CCS system or asset design and operation. Expressions of Interest to attend the workshop should be returned to the contact given on the front of this Request for Proposal by 5th November 2010.

Any advice or clarifications of ETI requirements requested by and provided to any Respondent will be made available to all Respondents to ensure parity of information. Respondents should consider presenting requests for advice and clarifications in a way that the ETI can respond to all Respondents without comprising bidders' confidential information.

Following the closing date, the ETI will convene a Selection Panel to recommend which Respondent(s) should proceed to Project Detailing and Contract Negotiation based on the Selection Criteria (see Section 3.2). Respondents may be requested to make a presentation to ETI and the Selection Panel to support information provided through this Request for Proposals.

2.2. Project Detailing and Contract Negotiation

Following selection of a preferred Respondent (or Respondents), a process of detailing the proposal, due diligence and contract negotiation will be entered into. An overall period of 2 months has been allowed for this stage. This will include (as required and dependent on the level of detail provided in the Respondents' proposal):

(a) Negotiation and agreement of the detailed commercial offer;

(b) Detailing of the proposed technical programme, including definition of deliverables and acceptance criteria;

(c) Detailing and agreement of Project Stage Gates, where project performance, Tool-Kit functionality and the business case are critically reviewed and decisions taken on whether to proceed with the Project;

(d) Detailing and due diligence relating to the make up and breakdown of costs of the Project;

(e) Further intellectual property due diligence;

(f) Other due diligence activities as required: refer to Appendix C for further details;

(g) Negotiation and agreement of outstanding contractual issues;

(h) Agreement (and approval by the ETI) to terms of other key contractual arrangements (eg Sub-contracts, Consortium Agreement);

(i) Gaining all necessary Respondent and ETI approvals to undertake the project; and

(j) Any further information or assessment that may be necessary to meet state aid requirements.

Respondents are required to identify and provide a plan to address the issues for Stage 2 (see Appendix A, Section 16) and confirm that they will be able to make the key technical, commercial and legal resources available to meet the deadline.

As part of the process, Respondents will have the opportunity to present a Final Detailed Offer to the ETI, addressing all technical, commercial, legal and financial issues. Subject to acceptance by the ETI, this Offer will form the basis of the Project Contract.

2.3. Procurement and Project Timetable

The following timetable outlines the anticipated schedule for the procurement process. The timing and the sequence of events resulting from this Request for Proposals may vary and shall ultimately be determined by the ETI.

Event	Anticipated Date(s)
Issue of Request for Proposal	22nd October 2010
Deadline for application to attend briefing session and workshop	5th November 2010
Project briefing session and workshop	16th November 2010
Deadline for submitting intention to submit a proposal (return of signed Non-Disclosure Agreement)	26th November 2010
Closing Date for submission of proposal	4pm on 17th December 2010
Preferred Respondent(s) Notified	17th January 2011
Project Detailing and Contract Agreement	*Indicative Target Date: 18th March 2011*
Contract Approval and signature	*Indicative Target Date: 15th April 2011*
Project Start	*Indicative Target Date: 1st May 2011*
Project Duration	2.5 years (est)

3. Request for Proposals Process and Terms

3.1. Content and Format of Submissions

Interested organisations are required to make a collective Submission through their nominated Respondent as described in Section 1.7 above. The Submission shall comprise five components.

1. Detailed Proposal, arranged according to the structure set out in Appendix A. The content must clearly demonstrate how the bidding organisation/Consortium will meet the requirements and criteria set out in Sections 1 to 4 of this Request for Proposal. The Proposal must be written in a succinct manner and must not include imprecise statements, generalities or repetition. The Proposal must be easily readable with appropriate font sizes (11pt or larger), margins, etc, and **shall not exceed a maximum of 40 pages.**
2. Supporting information as specifically set out in Appendix A.
3. Risk Register, as described in Appendix A, Section 10.
4. Due-diligence information as set out in Appendix C;
5. Statement of Compliance and, if appropriate, supporting information, confirming compliance with or identifying exceptions to the specification or contractual requirements, as set out in Appendix D. This must be signed by the Respondent: if a Consortium structure is proposed, every member organisation of the Consortium must provide a separate Statement of Compliance.

Additional information (such as organisational brochures, etc) may be provided to accompany the Submission, but such additional information will not be taken into account when reviewing Proposals.

The Submission shall consist of **three (3) hard copies, with each component separately bound, and one (1) electronic copy**. The latter shall be provided in both PDF and Microsoft Word formats.

3.2. Acceptance, Review and Selection of Proposals

3.2.1. Selection Criteria

Proposals will be reviewed and judged primarily against the criteria listed below, in decreasing order of priority, and the supporting evidence supplied. Failure to meet minimum standards in any criterion may result in the ETI rejecting a Proposal.

- Suitability of the modelling platform on which the toolkit will be built.
    - Capability to incorporate key features outlined in Section 1.4 and Appendix F;
    - Current status of development of modelling platform and previous use for comparable toolkits.
- Ability of the Participants to deliver the project (it is stressed that quantifiable evidence will be given more weight than qualitative comments):
    - Experience and availability of key project roles (Project Manager and Chief Technologist);
    - Technical capability and experience to deliver the project, including:
        - Delivery of complex engineering software for commercial application
        - Engineering knowledge of key system component design and operability

        - Experience of existing modelling tools which might be interfaced with the Tool-Kit;
    - Availability and stability of deployable resources to mobilise sufficiently rapidly and for sufficient durations;
    - Record and ability in quality, timely and on-budget delivery of projects (of the type requested in this RfP) to the full satisfaction of the main stakeholders;
    - Access to data to enable effective validation of the Modelling Tool-Kit;
    - Project management systems and expertise appropriate for this sort of project;
    - Ability and experience in collaborative working;
    - Effectiveness of the contracting, organisational, governance and control structures and processes proposed for the participating entities/organisations, e.g. steering committee structure, meetings, interfacing with ETI, etc;
    - Project approach and plan, including Gantt chart, suitable Stage Gates & Payment Milestones;
    - Risk Management. Respondents will need to demonstrate clear evidence of a rigorous, risk-based approach to management of the project. A register identifying the key risks and how they will be managed is required.
- Ability and commitment of the Respondents to the future support and development of the Modelling Tool-Kit:
    - Long-term commitment to support and develop the modelling platform;
    - Quality, clarity and credibility of exploitation plans for the Modelling Tool-Kit, including productisation of the models developed in the project, future customers for the Tool-Kit (ETI Members and others), envisaged areas for future expansion of Tool-Kit capability and expected sources of funding for these developments;
    - Support arrangements for ETI Members (and others) to use the Tool-Kit.
- Ownership of Background Intellectual Property:
    - Ownership and/or appropriate rights in relation to existing modelling platform and related Background Intellectual Property for this Project and for future development of the Modelling Tool-Kit;
    - Willingness to make Background Intellectual Property available for the Project and to the extent needed for exploitation by ETI Members or use of the Modelling Tool-Kit by Members.
- Quality, clarity and credibility of the Modelling Tool-Kit development plan. Respondents should provide a clear, detailed and logical development, testing and validation plan, which demonstrates how it will address the required outcomes as set out in Sections 1.4 and 4 of this Request for Proposals.
- Attractiveness of initial commercial offer. Respondents should identify the value and the benefits arising from the proposed project to be delivered to ETI Members (public and private sector). Refer to Appendix A, Section 16 for details.
- Value for money with respect to ETI funding.
- Availability and security of Own Funds.
- Respondent's willingness to materially comply with the terms and conditions of the proposed Project Contract.
- Proposal Format and Compliance:

- Clarity and succinctness of Proposal;
- Completeness of information content, structure and quality of Proposal (against areas listed in Appendix A).

The ETI at its discretion may request further clarification of a Proposal, and may reject any Proposal which is unclear.

3.2.2. Selection Process

All proposals will be evaluated by the ETI against the Selection Criteria.

As part of its evaluation process, in addition to ETI staff, the ETI may convene a Selection Panel, comprising experts selected by the ETI to provide the necessary expertise to consider the technical, commercial, legal and financial aspects of each bid. This may include experts drawn from ETI Members and third parties.

As part of Project Detailing and Contract Negotiation, Respondents may be required to provide a Final Detailed Offer. In such a case, the ETI may convene a second Selection Panel and the Final Detailed Offer(s) will be reviewed against the Selection Criteria.

3.3. Disclaimer Notice

a. The ETI at its discretion may request clarification of a Proposal, and may reject any Proposal which is unclear.

b. Neither the issue of any documentation in the Request for Proposals process nor any of the information presented in it should be regarded as a commitment or representation on the part of the ETI or any other person to enter into a contractual arrangement. The Request for Proposals is not an agreement to purchase goods or services, and the ETI is not bound to enter into any contract with the Respondent. By responding to this Request for Proposals, the Respondent does not commit itself to entering into a contract with the ETI.

c. All decisions made by the ETI relating to the acceptance, review and selection or otherwise of Proposals are final.

d. All documents, including Proposals, submitted to the ETI become the property of the ETI. They will be received and held in confidence by the ETI, subject to the terms of the Non Disclosure Agreement (Appendix E). No part of a Proposal, or documents provided by Respondents, shall be returned.

e. The ETI reserves the right to (i) change the basis of, or the procedures for, the Request for Proposals process, including the timetable or Closing Date, (ii) make modifications to, or alter any of the information within, the Request for Proposals at any time until the execution of the Project Contract, (iii) reject any or all of the Proposal received, and (iv) not invite any Respondent to proceed further. In cases of changes (i) and (ii) before the closing date for the Request for Proposals, the ETI shall provide a minimum of five working days written notice.

f. Neither the ETI nor any of its agents or advisers accepts any liability or responsibility for the accuracy, adequacy or completeness of any of the information provided or any opinions contained in this Request for Proposals or of any other information made available during the Request for Proposals process. No representation or warranty, express or implied, is or will be given by the ETI or any of its agents or advisers with respect to such information provided or opinion given therein. Any liability is thereby expressly disclaimed.

g. Respondents must assess the information and terms contained in this Request for Proposals independently, having taken professional advice if necessary. The Respondent will be deemed to have examined all the documents enclosed with this

Request for Proposals and by its own independent observations and enquiries will be held to have fully informed itself as to the nature and extent of the requirements of the Request for Proposals. The Respondent must rely on its own enquiries and on the terms and conditions contained in any agreement, when and if finally executed, subject to such limitations and restrictions as may be specified therein.

h. Respondents shall be wholly responsible for the costs they incur in the preparation and submission of their responses to the Request for Proposals. The ETI shall not be responsible for, and shall not pay, any costs and expenses which may be incurred by the Respondent in connection with its participation in the Request for Proposals process, including but not limited to any costs or expenses incurred up to the execution of the Project Contract.

i. The ETI may, at its discretion, shortlist Respondents for the next stage. The ETI does not undertake to accept the lowest bid or to accept part or all of any Proposal and the acknowledgement of receipt of any Proposal shall not constitute any actual or implied agreement between the ETI and the Respondent.

j. The submission of a Proposal will confirm acceptance of the foregoing provisions by the Respondent without qualification. Any attempt to qualify any of the foregoing provisions in this Disclaimer Notice, either expressly or impliedly, may result in a Respondent being disqualified.

k. The copyright in the documentation and any other materials supplied by the ETI and/or its advisers in this Request for Proposals process, in whatever format, belongs to the ETI or its appointed advisers. Such documentation and materials may not, either in whole or in part, be copied, reproduced, distributed or otherwise made available to any other third party or used without the prior written consent of the ETI, except in relation to the preparation of the Proposal in the course of the Request for Proposals process. All documentation supplied by the ETI in relation to this Request for Proposals process must be returned on demand, without any copies being retained by the Respondent.

l. This Request for Proposals, and any dispute or claim arising out of or in connection with it (including any dispute or claim relating to non-contractual obligations), shall be governed by and construed in all respects in accordance with the laws of England and Wales and the parties agree that the Courts of England and Wales shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this document (including any non-contractual disputes or claims).

4. Project Structure and Scope

It is recognised that implementation of a fully comprehensive Modelling Tool-Kit, covering all the potential system components (potentially with multiple levels of model fidelity) and events listed in Appendix F would be potentially an almost open-ended task. Hence the focus of this project is to provide an initial Tool-Kit covering a subset of component types at the lowest level of modelling fidelity compatible with delivering robust and meaningful results, but which demonstrates the full set of features set out in Section 1.4 of this Request for Proposal.

The detailed structure of the project should be specified by Respondents, but it would be expected to include the following work packages:

1. Develop detailed technical specification;
2. Develop non-proprietary subsystem models (to the extent necessary to demonstrate the full set of features set out in Section 1.4). This should include at least two, contrasting power station/capture types (e.g. IGCC with pre-combustion and gas CCGT with post combustion);
3. Implement physical properties functionality;
4. Develop Tool-Kit framework, including integration capability for proprietary models;
5. Develop and run suitable test cases to demonstrate ability to model representative events for:
    a. Full chain, single line system with non-proprietary subsystem models;
    b. Incorporation of one or more proprietary models and models of different levels of fidelity;
    c. Systems with multiple sources, branched and parallel transmission lines and multiple sinks;
    d. Combinations of the above, including demonstrating robustness near extremes of operation;
6. Deliver models (to 'beta test' standard or equivalent) to ETI Members, provide training and initial support with implementation (e.g. over initial 3 month period).

Model validation and verification should form an integral part in work packages 2 – 5 above: Respondents should indicate how they will approach this and where they would source suitable data. It is anticipated that a hierarchical approach will be taken to validation, with component models being validated against experimental data, but moving towards verification (e.g. checking trends are supported by experimental data) and testing (i.e. the model operates stably without computational error) at subsystem and system level.

The project should, at the earliest opportunity, deliver an initial version of the Tool-Kit capable (as a minimum) of steady state simulation of a full chain, single line system with non-proprietary subsystem models. It is expected that this would be delivered around Month 12 of the project, and that a Stage Gate (see Glossary, Appendix G) be held shortly afterwards to review progress and value associated with completing the Project.

Although not forming part of this proposal, Respondents should indicate how they would manage future support, development and exploitation of the Modelling Tool-Kit.

A project timescale of 2 to 3 years is envisaged.

5. Project Funding and Payment

The ETI will provide funding of the order of £2M for the proposed project. Whilst, through its unique public-private partnership model, the ETI can potentially fund up to 100% of eligible project costs, it is anticipated that the Respondents will provide funding for a proportion of the project costs. The proportion of the funding proposed by the Respondents is expected to reflect the co-investment between the ETI and the successful Participants and in particular, the exploitation opportunities and future business benefits from the Modelling Tool-Kit for the Participants.

The Project Contract will include defined deliverables, with acceptance criteria, and defined Payment Milestones by which one or more deliverables will have been completed. Payments will be made against each defined Payment Milestone according to an agreed percentage of actual costs incurred by the Participants, up to the agreed maximum for each Payment Milestone. All payments will be subject to ETI acceptance of the deliverable(s) which contribute to that Milestone. Unless otherwise agreed as part of a formal contract variation process, the ETI shall not be liable for any payments above the maximum stated in the Project Contract.

ETI policy is that Payment Milestones should be based on points in the project where major deliverables and value have been delivered to the ETI (eg completion of major tasks/ work packages/ reports).

Further information is contained in Appendix A, Section 13 and the Summary of Terms contained in Appendix B.

An Accountant's report will be required to support selected financial reports and invoiced amounts, dependent upon the total contract value to be paid to each Participant. Details of these requirements will be agreed during Contract Detailing.

Respondents must identify all sources of funding or resources to be provided in addition to the ETI Funding (split amongst own funds, third party private funding and third party public funding) and provide evidence to the ETI to assure it that the funds will be available (see Appendix A, Section 13 for further details).

If Respondents anticipate accessing any public funding (eg national government, regional, European Union) in addition to any ETI funds, they should contact the ETI as early as possible to ensure the requirements of the ETI State Aid clearance can be met.

6. Terms and Conditions for Project Contract

The Project will be governed by a Project Contract. A summary of the key terms and conditions of the Project Contract are included in Appendix B of this RfP. This Contract shall incorporate appropriate information from the ETI's RfP, the Respondent's Proposal and information drawn up and agreed during the Project Detailing and Contract Negotiation Stage.

As indicated in Section 2.1, Respondents are invited to submit a notification of their intention to bid, together with a signed non-disclosure agreement in the form included at Appendix E of this RfP. On receipt of the properly executed non-disclosure agreement, the ETI will release the full terms and conditions of the draft Project Contract to the Respondent.

The Respondents are required to confirm their acceptance of (or identify any exceptions to) the terms and conditions of the full Project Contract in the Statement of Compliance (see Appendix D).

Any third party funding agreements and, dependent on the selected Project structure, the Consortium Agreement between the Consortium Members and/or key subcontracts will require review and approval by the ETI prior to signature of the Project Contract with the ETI.

Appendix A Content and Format of Proposals

1. Executive Summary *[maximum 2 pages including work flow diagram]*

A summary of the Proposal, describing briefly:

- The Participants undertaking the work and contractual structure;
- The technology to be developed in the Project;
- The technical approach and ***key*** Deliverables, Milestones and Stage Gates, including a work flow diagram (see Section 6);
- ***Key*** deviations or requirements not fully addressed in the Proposal and issues to address prior to contract (including major contractual issues);
- Total Project cost, funding requested from the ETI, sources of own funding and duration.

2. Project Objectives *[typically < 1 page]*

The Respondent should provide a clear statement of Project objectives, demonstrating how these link through to the ETI's requirements and desired outcomes. The Respondent should also describe any Critical Success Factors which either characterise a successful Project outcome or which are required to facilitate a successful Project outcome.

3. Background to Proposed Participants

3.1 Project Participants [*maximum 1 page per Participant plus summary table*]

The Respondent should provide a brief description of each of the proposed Participant organisations, including any major Subcontractors, including:

- Key skills, knowledge, experience and previous track record in the area (technical, commercial and project management, including any UK-specific issues such as knowledge of UK CCS requirements, industry practice, market/industry knowledge, etc);
- Relevant quality, health, safety and environment management experience and systems (further details to be provided in Section 11).

If the Project is to be undertaken by a group of organisations (whether as a Consortium or as Subcontractors), a table should also be provided to identify which Participant(s) is/are proposed to satisfy each of the specific criteria (skills, experience, etc) listed in the 'Selection Criteria' section of the Request for Proposals. Specifically, the Respondents need to demonstrate that the collective skills/knowledge are sufficient to cover whole scope of project.

3.2 Key Individuals and Roles *[maximum 2 pages plus summary CVs]*

The ETI places great emphasis on two critical roles in major projects – Project Manager and Chief Technologist.

The Project Manager is responsible for managing and progressing the project team and programme to time and cost, handling information flows and commercial issues, ensuring effective team-working and the continued engagement and support of key stakeholders. In essence this responsibility is to make sure that the ETI benefits from a result at the end of the programme of work that meets the agreed outcomes within time and cost.

The Chief Technologist is responsible for the technical quality and content of the work, ensuring the competence of key technical staff allocated to individual work packages, the effective review

of key outputs and the effectiveness of detailed technical planning to ensure that the emerging results of work are fed back into the forward plan. In essence this responsibility is to assure the technical quality of the project and its outcomes.

The ETI will assess the competence, experience and authority of these two people and their ability to work together as critical to project success. The ETI expects these two roles to be filled by the same people throughout the life of the project.

Respondents should identify specific individuals for these key positions, including deputies, and other key roles as appropriate. Respondents should state the amount of each individual's time which will be dedicated to the Project, and detail their experience – with CVs included in an Appendix (maximum 2 pages per individual).

3.3 Collaborative Working *[maximum ½ page]*

If the Project is to be undertaken by a group of organisations (whether as a Consortium or as Prime Contractor/Subcontractors), evidence of previous collaborative working (and/or subcontract management as appropriate) should be provided, both within and outside the Participant group.

4. Project Organisation *[maximum 2 pages including organisation chart]*

The Respondents should indicate their intended Project organisational structure (refer to Section 1.7 of the Request for Proposals) and set out, in detail, the governance and control structures and processes that will be put in place.

The Respondent should indicate in the structure each Participant (including the ETI) and the position of the key individuals identified in Section 3 (including the Project Manager and Chief Technologist).

The Respondent should identify in their Proposal any foreseen issues or difficulties in executing any part of the contractual structure (including subcontractors, Background Intellectual Property licensing and/or the Consortium Agreement).

5. Proposed Modelling Platform *[maximum 2 pages]*

The Respondents should describe the modelling platform on which the Modelling Tool-Kit will be developed, including the following issues:

- Capability to incorporate key features outlined in Section 1.4 and Appendix F;
- Current status of development of the modelling platform and previous use for comparable tool-kits;
- Long term plans and commitment to support and develop the platform.
- Key ownership and rights to the Intellectual Property in the modelling platform.

6. Programme of Work *[typically 5 - 10 pages]*

The Respondent should provide a summary of the overall approach to the Project, including a Work Flow description which clearly identifies the key Work Packages, their interdependencies and how they contribute to the overall Project outcome. This Work Flow should identify key Review Points and Stage Gates (see also Section 9) where overall progress on the project will be critically reviewed.

Each Work Package should be broken down into Tasks and a Task-by-Task description of the proposed work provided, identifying for each Task:

- the Task leader;
- other Participants involved;
- key dependencies;
- the technical approach (including use of any specific methodologies, techniques or tools);
- Task objectives;
- deliverables, including for each deliverable a specification (e.g. quality, appearance, scope, function and purpose as appropriate) and proposed Acceptance Criteria.

As far as possible, the Respondent should be specific about the activities within the Task, e.g. including simulation matrices or stating a number of simulations.

The Programme of Work should explicitly describe the proposed approach to validation and verification of the models developed, and what sources of validation data would be used (within or outside of the participants). It is anticipated that a hierarchical approach will be taken to validation, with component models being validated against experimental data, but moving towards verification (e.g. checking trends are supported by experimental data) and testing (i.e. the model operates stably without computational error) at subsystem and system level. It is not anticipated that the Programme of Work will include any collection of validation data through experimental programmes.

Any issues or assumptions in defining the programme or schedule (e.g. inputs required from the ETI or other projects) should be explicitly stated.

A specific project management Task (or Tasks) should be identified describing all the activities in this area (e.g. regular meetings, reporting, Stage Gates etc). ***Note that throughout Project delivery the ETI will require reports of monthly progress with supporting financial data, reports to substantiate completion of each milestone, etc.***

Any relevant activities related to but not included within this Project, and the relationships with these activities, should also be described.

7. Deliverables and Payment Milestones *[typically 1 page]*

Following the detailed specifications of each deliverable in Section 6, a summary table should be provided here listing all the Project Payment Milestones (i.e. key points in the Project where one or more Deliverables will have been provided and payment is requested from the ETI), and their constituent Deliverables, acceptance criteria, costs, and delivery dates for each Deliverable and Payment Milestone.

Note that ETI policy is that Payment Milestones should be based on points in the project where major deliverables and value have been delivered to the ETI (eg completion of major tasks/ work packages/ reports).

Refer also to Section 13.

8. Project Schedule *[typically 1 page]*

The Respondent should provide a time schedule for the Project (e.g. in the form of a Gantt chart) showing the main Work Packages, Project stages and main Tasks within each Work Package and stage. This should clearly identify:

- Task durations and dependencies (including any inputs required from the ETI or other parties and any other external dependencies);
- Contingencies and Critical path;
- Project Deliverables;
- Payment Milestones and other relevant milestones;
- Project Stage Gates, if appropriate (i.e. major review point(s) in the Project).

9. Project Curtailment and Exit *[typically 1 page]*

In addition to ongoing termination rights relating to non-performance or breach of contract, the Project Contract will include specific termination rights relating to Stage Gate Reviews, should Stage Gate Criteria not be met. For each Stage Gate Review set out in Section 6, the Respondent should propose outline criteria against which Project progress towards the desired outcomes should be reviewed, in respect of:

(a) Project performance against plan (including time, cost, quality and health and safety management);

(b) Functionality of the Modelling Tool-Kit;

(c) External factors which may put delivery of outcomes at risk (e.g. access to validation data);

(d) Development of the business case for ongoing support and development of the Modelling Tool-Kit.

10. Risk Management *[maximum 2 pages plus risk register]*

The Respondent should describe the proposed Risk Management Strategy (i.e. how risks to the successful delivery of the Project will be identified and managed throughout the Project). They should also separately provide a Risk Register, identifying the key challenges, risks (including any assumptions or dependencies identified earlier), issues and opportunities which may affect the successful delivery of the Project outcomes and identifying planned activities to address/ mitigate each item.

Whilst not being prescriptive about the style and format of the Risk Register, it is expected that it will:

(a) Show clear evidence of triage into: those risks which are so serious in terms of frequency and impact that they need to be kept under review by the Project leadership (and regularly shared with the ETI); those risks that are sufficiently serious that they need to be managed within the project team; and those risks which have been recognised but which are not judged as material;

(b) Identify the causes of the risk and the likelihood of them occurring during the project;

(c) Identify the consequences of the risk and the scale of impact on project delivery and key stakeholders;

(d) Identify the degree of knowledge or uncertainty about the risk;

(e) Identify who is the risk (or issue) manager;

(f) Show what actions are in place to reduce the likelihood of the risk materialising (controls);

(g) Show what precautions or provisions will be implemented to reduce the impact of the risk, should it occur (mitigation);

(h) Identify any actions in place to investigate or increase knowledge of poorly understood risks; and

(i) Identify any systems or actions that will be implemented to detect that a specific risk is developing, has started to occur or its likelihood or impact has increased (monitoring).

It is expected that no more than ten risks would be managed by the top team, rather more at the next level and many more that have been recognised with no further action planned. The ETI will only consider to the top two categories, but proposers may provide the complete register.

A summary of key risks should be included in this section, with a complete risk register as described above provided as a separate document.

11. Health, Safety & Environment Management (HSE) *[maximum ½ page]*

The anticipated work required for this study is a desk top study using available information. It is not anticipated that any site visits, field trials, experimental or laboratory work will be required.

Respondents must advise if any work which is not desk based is included in their Proposal. In those circumstances where non-desk based work is anticipated in the Project, the ETI will carry out a competency assessment of relevant Participants and require the Participants to agree to an appropriate performance assurance framework that provides the ETI with ongoing assurance that health and safety is being proactively managed throughout the Project.

12. Intellectual Property *[maximum 2 pages]*

12.1 Arising IP

ETI's IP Principles

Intellectual property arising from the Project (Arising IP) will be dealt with according to the ETI's IP principles as well as the appropriate ETI terms and conditions, (a summary of which is included in Appendix B). Proposed Respondents are advised to carefully read the information set out on the ETI's website about its IP Principles:

http://www.energytechnologies.co.uk/Home/Aboutus/IP.aspx

The ETI's IP principles deal with both the ownership of Arising IP and the rights to exploit it. The IP principles state that Arising IP should be owned by the party best placed to exploit this, which is likely to be one or more of the Project Participants.

The ETI will normally expect the Project Participants, Programme Associates, the ETI and its Members to have the right to an exclusive licence to exploit any Arising IP. This is achieved through the owner of the Arising IP granting the ETI an exclusive license to the Arising IP. The ETI will then sublicense the Arising IP on an exclusive basis to relevant Project Participants, Programme Associates and ETI Members.

Arising IP for the Project

The Respondent should provide a brief overview of the nature of any anticipated IP arising from each stage of the Project (the Arising IP), in particular, in what areas of the technology and what form of intellectual property rights. This should expressly include reference to development in any existing technology, any innovations, any results and know-how.

- The Proposal should identify which Participant would own each item of Arising IP and the reasons why such Participant should be the owner, including details of:

- the overall contribution of such Participant (including related Background IP);
- the IP-related experience and capabilities of such Participant which would justify granting it the rights and obligations of ownership, protection and maintenance of such Arising IP; and
- any other reasons why such Participant should be the owner of the Arising IP.

- The Respondent should provide details of the anticipated use or licences of Arising IP by the Participants. This should also expressly include reference to development in any existing technology, any innovations, any results and know-how. This is expected to set out the anticipated scope of such rights.
- The Respondent should note that it is a requirement that all Arising IP is exclusively licensed through the ETI and that, in addition to licences to relevant Participants, ETI Members are granted licences to exploit the Arising IP. Where the Respondent proposes an exception to this, Respondents should set details of the exception out together with (a) reasons for the proposed exception and (b) the alternative value offered to the ETI in return for waiving these rights.
- Where Respondents propose that Participants will have a licence to commercially exploit Arising IP a royalty is expected as part of the commercial offer to the ETI and its Members.

Participants should note that under state aid rules profit cannot be paid to a Participant in addition to the grant of a licence for Arising IP.

12.2 Background IP

The Respondent should describe any Background IP (e.g. patents, proprietary data, computer algorithms, know how or other IP) only to the extent there is Background IP:

- which is needed (whether by the ETI, or to be licensed from one Participant to another Participant or a Subcontractor, or to be licensed by a Subcontractor to a Participant or to another Subcontractor, or otherwise) to carry out the Project or which may be used during the Project; or
- which may be needed by the ETI to exploit the Arising IP.

The description of any such Background IP should detail:

- the nature of the IP (including the legal nature of the IP right);
- rights to that IP;
- ownership and control, whether this is by any of the Project Participants or by any third parties;
- details of the licences required by project participants and ETI Members (and estimated cost of such licences) to enable them to carry out the Project or exploit the Arising IP (including use of any software released for testing during the Project) or copies of the Modelling Tool-Kit supplied to ETI Members; and
- in relation to any Background IP owned by third parties, the current status of the acquisition of rights required for this Project and the exploitation of the Arising IP (including use of the Modelling Tool-Kit).

Please note that due diligence on Background IP will be required as part of this submission and during the Project Detailing and Contract Negotiation Stage (see Appendix C).

12.3 Academic Institutions/Publishing

Generally, the ETI will grant rights to Participants who are academic institutions for the purposes of academic research and teaching if requested. Publication of appropriate parts of the Project results will generally be permitted subject to an approval process. Participants should include details of any desired requirements in relation to academic research, teaching and publication in their Proposal.

13. Project Finances *[maximum 2 pages]*

13.1 Project Costs

(a) The Respondent should provide:

- a figure for the ***total project costs***, and ***the maximum (capped) level of funding requested from the ETI***
- a ***breakdown*** between Tasks, Payment Milestones and (for consortia or other Participant groups) ***between Participants against each Task/Milestone***.
- a figure for the maximum (capped) level of funding requested from the ETI for each Task.

If there are any assumptions or limitations to these costs, these should be clearly stated.

(b) The Respondent should also provide a ***breakdown of the total project costs (only) by category***, as specified in the Table below.

	Participant 1 (Lead Coordinator or Prime Contractor)	Participant 2	Participant 3	Participant 4	Participant 5	Total
Number of Person-days						
Base Labour						
Materials						
Subcontractors (minor)						
Travel & Subsistence						
Overheads						
Profit						
Other						
TOTAL ELIGIBLE COSTS						
ETI Funding						
ETI Funding (%)						
Own Funds						
Third Party Funding (Private)						
Third Party Funding (Public)						

Notes on Category Breakdown table:

1. Base Labour should include direct add-ons (eg NI, pension etc);
2. If a Prime Contractor/Subcontractor project structure is proposed, major Subcontractors should be considered as Participants and fill in a column in the table
3. Participants will be required to provide justification of overhead calculations during the Project Detailing and Contract Negotiation stage. ETI can provide a spreadsheet to calculate overheads on request
4. Participants should note that under state aid rules profit cannot be paid to Participants if they wish to receive a licence for Arising IP
5. Academic Consortium Members should determine their costs using the JeS system. Note that ETI funds Academic Consortium Members at 100% Full Economic Cost;.
6. Details of other funding should be provided as required by Section 13.2 (refer also to the Glossary for definitions of funding types)

Note that during Project Detailing and Contract Negotiation (prior to contract signature) the ETI will require more detailed cost breakdowns, including a schedule of payments

against the Payment Milestones identified in Section 5 above. This will require completion of ETI's financial monitoring forms. Whilst not compulsory, it is strongly recommended that Participants use these forms in support of this proposal to produce the project costings. These forms are available from the ETI on request.

13.2 Project Funding

For all sources of funding or resources to be provided in addition to the ETI Funding, the Respondent should provide full details of such funding.

(a) If the funding is to be made from the Respondent's Own Funds (i.e. not dependent in any way on third party lending to either the Respondent or member of the Respondent's group) the Respondent should provide evidence of the availability of those funds for the Project.

(b) If the funding is dependent on third party funding:

- details for the sources of the funding, including identifying where any such funding is Public Funding;
- the terms and status of such funding.

14. Exploitation Plan *[maximum 2 pages]*

The Respondent should set out how they intend to approach commercialisation of the Modelling Tool-Kit. This should include:

- Identification of target customers for Modelling Tool-Kit post project;
- Anticipated number of users and likely level of licence income;
- Plans for initial release of 'v1' of the commercial software;
- Arrangements for ongoing support of the Tool-Kit;
- Routes for further development of the Tool-Kit functionality;
- Potential sources of funds for future development and application;
- Other sources of income related to the Tool-Kit (eg consultancy services).

Progress with the exploitation plan during the Project will form part of the Stage Gate Reviews and this section should be clearly linked with and support the overall Project plan. For the avoidance of doubt, the ETI will not contribute to the costs of business development and sales activities.

15. Commercial Offer *[maximum 2 pages]*

The ETI intends to support the Modelling Tool-Kit Development Project for it to be available for use in the UK and more widely to support the roll out of CCS technology. The ETI anticipates that there will be significant mutual benefit for the ETI Members (public and private sector) and the Project Participants in working together on the Project and beyond. The ETI and its Members propose to fund the project in order to meet ETI objectives and in return for receiving value for the investment made.

The Respondent should provide a summary of the proposed value and benefits to ETI Members, under the broad headings set out in the Table below. Please note that this table is ordered to demonstrate the types of value that may arise through the course of the project in approximately chronological order. It is not intended to demonstrate the order of preference. A key aspect is intended to be preferential access to the Modelling Tool-Kit.

The Respondents are asked to bear in mind that although detailed negotiation of the commercial offer is expected during the Contract Negotiation stage, in the selection process the commercial offer will be assessed based on the information included in the Proposal.

Potential Benefits	Background Assumptions
Opportunity for Members to contribute their expertise in particular CCS assets or system design towards the specification, development, validation and testing of the Tool-Kit.	Members will have the option to act directly as Participants and/or will engage directly with the project steering group and/or will be consulted regularly, particularly during development of the detailed technical specification of the Modelling Tool-Kit. Please note, that in any case, the ETI and its Members will have contractual rights to participate in certain project meetings and will be involved in any formal ETI project reviews.
Early access to initial versions of the Modelling Tool-Kit (*) and other Arising IP from the Project.	Copies of all releases of the Tool-Kit as it is being developed and other technical outputs of the project will be available to ETI Members on a similar timescale to the Participants (allowing time for checking). ETI and its Members will require express rights to use relevant parts of Arising IP in order to gain this benefit. (Please also refer to section 13).
'First mover' access to the Tool-Kit (*).	Access to the 'beta test' version of the Tool-Kit and final version delivered at conclusion of the project. ETI and its Members will require express rights to use relevant parts of Arising IP in order to gain this benefit. (Please also refer to section 13).
Advantaged access to future commercial product (*)	The Respondent should set out their approach to this. This might take the form of some or all of: • Free licences for the Modelling Tool-Kit (Arising IP) • Early access to releases of Tool-Kit upgrades • Provision of support on advantageous terms • Provision of Background IP (eg the modelling platform) on advantageous terms
Royalty income for sale or use Modelling Tool-Kit licences	The Respondent should set out their approach to this. The Respondent should indicate the level of expected sales, amount of royalty returning to ETI and any limitations/caps.

(*) Respondents should identify any requirements to purchase licences for Background IP (including the costs of such licences) to realise such Benefits. Access to such Background IP on advantageous terms (eg provision of free or reduced cost licences) would be viewed as an important benefit for ETI Members.

Respondents should identify what impact the ETI funding would have on their development and exploitation plans, for example:

- Acceleration of Tool-Kit development to meet UK market needs;
- Extension of Tool-Kit capability to meet UK requirements;
- Enable sharing of experience in the project to accelerate CCS implementation more generally.

Respondents should outline what development path they would follow in the absence of ETI funding.

16. Plan for Contract *[maximum 1 page]*

Respondents should, in this Section, identify key issues to resolve before contract, for example:

- Detailing of the technical proposal: what further actions are needed;
- Project Contract – key provisions to resolve;
- Timing sequences for the setting up of the selected project organisational structure (eg subcontracts, Consortium Agreement etc), including any dependencies or other factors which could impact or delay the Project;
- Internal approvals - confirm what internal approvals will be required for all key Participants in the bid in order to enter into contract;
- Third Party Background IP rights – what the status of arrangements are and how these will be finalised and agreed prior to the contract.

The Plan for Contract should be structured, and link clearly back to, the previous Sections of the proposal.

The Respondent should explicitly confirm that all key technical, commercial and legal resources (across all participants) required to meet the contract deadline for signature (see Section 2) will be available to achieve a signed contract by that date. Any key risks or issues which may impact on meeting this deadline should be identified.

Appendix B Summary of Terms and Conditions for Project Contract

Introduction

The following represents a summary of the key contractual terms which the ETI would expect to be included in the Project Contract.

Structure

1. The Project is subject to state aid rules. Certain requirements relating to information on costs, IP and return of funding are a requirement of State Aid requirements. The ETI cannot fund a Project with a Participant who is unable to agree to terms relating to state aid requirements.
2. If the project is carried out by a multi-party consortium, the project participants shall be represented in dealings with the ETI by a lead co-ordinator, who shall, in the majority of instances, be the intermediary for any communication between the ETI and the project participants. This role includes providing notices of meetings and other activities to the ETI, reviewing and commenting on project reports (as required under the project) and administering payment of invoices for all project participants.

Project Management

3. The project participant[s] will be required to appoint a project manager for the day-to-day management of the project normally from a lead organisation. The ETI will appoint a programme manager to act on behalf of the ETI with regards to the project.
4. The project participant[s] shall form a steering committee to make decisions on day-today matters (excluding decisions affecting the overall scope structure and timing of the project). The frequency of meetings of the steering committee will be agreed. The ETI and its members shall be entitled to attend any meetings of the steering committee.
5. The project participant[s] must fulfil various reporting obligations which will include monthly reports and milestone reports covering both technical/project management reporting and detailed financial reporting. Each report must address a specified list of topics required by the ETI.
6. The ETI will require the right to carry out a stage gate review on completion of a "stage" (or at least once a year) in order to assess (a) overall performance in the project (b) whether the project continues to deliver against ETI outcomes and (c) also in order to carry out a validation exercise against the business case. The ETI may carry out stage gate reviews more frequently if the project is in jeopardy. The need for stage gate reviews and the definition of a stage will depend upon the exact nature of the project.

Finance

7. The project participant[s] will be obliged to fund their share of the project costs in accordance with agreed funding milestone.
8. ETI will pay sums (capped in aggregate in the sum agreed against milestones and only in respect of actual costs incurred (or at pre agreed profit margin, if appropriate) for the work done under the project. Only eligible costs will be payable. Ineligible costs include interest charges, bad debts, advertising costs and legal costs incurred in finalising contracts and carrying on the project.

9. Acceptance of milestones will be determined by the ETI against acceptance criteria agreed with the project participant[s]. Any increase in costs in carrying out the project over and above the agreed contractual amounts will only be payable by the ETI when such charges are agreed in accordance with the contractual variation control procedure.
10. Costs are payable in Sterling and ETI will pay valid invoices within 30 days of receipt of invoice following acceptance of a milestone. An accountant's report will be required to support selected financial reports and invoices, in accordance with a standard ETI matrix.
11. The ETI reserves the right to require the return of funding in certain circumstances (such as in the event of corruption or fraud, overpayment, costs incurred in respect of unapproved project changes and failure to comply with State Aid obligations).

Representatives, Warranties and Covenants

12. The Project Contract will contain representations and warranties in favour of the ETI as to the accuracy of information provided by the project participant[s] to the ETI prior to entry of the Contract including relating to Background Intellectual Property.
13. The Project Contract will contain on-going covenants on project participant[s].

Key Personnel

14. Project participant[s] will be obliged to retain key personnel involved in the project, throughout the term of the Contract.

Confidentiality

15. Restrictions on disclosure of any other party's confidential information will apply. Any publication of results (if appropriate) will be subject to the confidentiality provisions in the agreement.

Audits and Records

16. ETI will require the right to audit the project and project participants during the project and, in certain circumstances, up to 7 years from the end of the project on financial or technical grounds.
17. The parties will be required to maintain the majority of project records for a minimum of 10 years from the project end date to comply with state aid rules.
18. The project participant[s] will be required to keep relevant project records for more than 20 years where the records relate to registered intellectual property rights.

Sub-contracting and assignment

19. Sub-contracting or assignment (other than by the ETI) is not permitted without consent. However, details of known sub-contractors (and therefore the requisite consent) can be given in the Project Contract at signing.
20. The terms of any material sub-contract will be subject to the prior approval of the ETI.

Variation

21. Any variations to the project must be made via the variation control procedure.

Liability

22. The liability provisions relating to project participant[s] will be tailored on a case-by case basis. It is expected to be capped at no less than the amounts payable under the project except in relation to the agreed indemnities, return of funding or other liabilities which cannot be limited or certain excluded by law. For those indemnities and liabilities, no cap will apply. Recovery of indirect, consequential etc. damages will usually be excluded.
23. The ETI will require an indemnity in respect of (a) third party infringement claims (b) certain claims brought by any third parties against the ETI as a result of the acts or omissions of the project participant[s] under the project and in relation it, the terms of which will be negotiated on a case by case basis.

Insurance

24. Project participant[s] will be obliged to carry appropriate insurance which will be tailored on a project by project basis.
25. Project participants will be obliged to report any self-insurance throughout the Project.

Withdrawal

26. Withdrawal from the project is only possible with the ETI and in the case of a consortium, the unanimous consent of all other contracting parties. Withdrawing participant[s] cannot recover outstanding costs, unless otherwise agreed.

Termination and Suspension

27. The ETI reserves the right to terminate the agreement in certain circumstances (such as breach by a participant, withdrawal of a participant, insolvency, change of control of a participant etc).
28. The ETI also reserves the right to terminate the agreement unilaterally upon giving a (to be agreed) period of notice to the project participants. Upon unilateral termination, the ETI will pay the eligible costs (pre-approved by the ETI) incurred by the project participant[s] up to the date of termination.
29. The ETI will reserve the right to suspend the project in certain defined circumstances.

Intellectual Property

30. The ownership of Arising IP will be agreed on a project by project basis. Appropriate licence provisions will be put in place to ensure adequate rights are granted to the ETI members and, where relevant, project participant[s].
31. The project participant[s] will be required to licence their Background IP: (i) to other project participants on a royalty free basis where required for the purposes of the project; (ii) to the ETI or sub-licensees of the ETI, on fair and reasonable terms, where required for the use or exploitation of the Arising IP.

Governing Law

32. The Project Contract will be governed by English law and the parties will submit to the exclusive jurisdiction of the English Courts.

Appendix C Due Diligence Information Requirements

The ETI requires due diligence information in two stages: (1) submission of the Proposal and (2) contract detailing and negotiation. Certain information is required with the Proposal as part of the first stage of the procurement process. Further information will be required if any Proposal is selected to proceed to the contract detailing and negation.

Please note that successful completion of all elements of the due diligence is a pre-requisite to any contract award: failure to meet due diligence requirements at any stage may result in the exclusion of that Respondent or the Proposal from the ETI's selection process.

1. Submission of the Proposal

1.1 State Aid

All Consortium Members shall confirm that there are no potential, threatened, pending or outstanding recovery orders by the European Commission in respect of any funding received by any Consortium Member.

1.2 General Due Diligence

All Consortium Members (except ETI Members, universities/higher education institutions and UK/EU government laboratories/agencies) which provide more than 20% of the resources for the Project or which provide an input which is critical to the Project's success, shall provide due diligence Information to the ETI according to the table in Annex C1.

1.3 Insurance

The Respondent should confirm that insurance cover for the following risks is held, and should confirm levels of cover and expiry for each. The ETI will require evidence of these during the Project Detailing phase.

- Property damage (both any Property occupied by the Participants and any third party properties)
- Business interruption
- Employer's liability
- Public liability
- Product liability (or justify its exclusion if not appropriate)
- Professional Indemnity of no less than £1 million per occurrence

The Respondent should identify if it self-insures for any of these risks.

The Respondent should identify if it is intending to take out any project-specific insurance for the Project and the scope and intended beneficiaries of such insurance.

2. Contract Detailing & Negotiation Requirements

These are only required if a Proposal is selected to proceed to the Project Detailing and Contract Negotiation Stage, and will include:

(a) In the event that any part of this project is not wholly desk based, a full health and safety competency assessment will be carried out by the ETI, to assess the

organisation's health & safety management systems and specific technical competence to manage the risks in this Project.

(b) Further intellectual property due diligence. This will include a detailed Background IP questionnaire and evidence of any relevant licences or other agreements of Background IP will need to be supplied to the ETI;

(c) Financial due diligence on the breakdown of costs for the Project to enable the ETI to assess value for money and ensure that it meets State Aid requirements;

(d) Copies of insurance policies;

(e) Any other information that the ETI reasonably requires in order to fund the proposed Project including any information necessary to meet state aid requirements.

Annex C1 Organisational Due Diligence Questionnaire

Details of organisation
Full name:
Registered Office:
Type of Business (sole trader, limited company, partnership etc):
Names of directors/partners/owner:
VAT number:
Details of directors, partners or associates
Have any directors, partners or associates of the organisation been involved in any organisation which has been liquidated or gone into receivership? (Yes/No)
Have any directors, partners or associates of the organisation been convicted of a criminal offence relevant to the business or profession? (Yes/No)
Please give (and attach if necessary) full details if you have answered 'Yes' to either of the two previous questions.
Audited Financial Accounts
Please supply Audited Financial Accounts for the last 3 years for the organisation, or relevant part thereof.
Claims or litigation
Please provide (and attach if necessary) details of any claims or litigation against the organisation, outstanding and/or anticipated.

Appendix D Statement of Compliance

The Respondent shall provide a Statement of Compliance which confirms:

- That the Respondent has full authority to submit a bid on the basis of this Request for Proposal;
- That the Submission has been appropriately reviewed by technical, commercial, financial and legal representatives; and
- The level of internal approval obtained by key subcontractors in order to make the Proposal (letters of support from each key subcontractor should be included).

In the case of a Respondent responding on behalf of a Consortium, a separate Statement of Compliance must be signed by an authorised signatory of each Consortium Member.

The Respondent shall provide a statement that the Proposal is fully compliant with the Specification and all other aspects of the Request for Proposal including the Project Contract, or shall state clearly any exceptions, deviations, alternative approaches or additions to the required Specification, with justification. Additional comments and clarifications should also be listed where appropriate (for example to clarify interpretation of requirements), but these must be differentiated from any deviations/exceptions above.

With respect to the Project Contract, the Respondent must either:-

- Expressly confirm that the Proposal is made on the basis of the terms and conditions of the Project Contract; or
- Expressly confirm that the Proposal is made on the basis of the terms and conditions of the Project Contract subject to clarifications and exceptions. In these circumstances, the Respondent must include in their Submission either:
    - A copy of the Project Contract, marked up with the Respondent's proposed clarifications and exceptions; and
    - A separate commentary against the clarifications and exceptions setting out the reason for those clarifications and exceptions.

Appendix E Non Disclosure Agreement

Note: a separate version of this NDA is available on request to ccs@eti.co.uk

File Ref No: **CCS/Network Modelling Main Project/RFP/NDA**

MULTI-PARTY CONFIDENTIALITY AGREEMENT

THIS AGREEMENT is made on of 2010

BETWEEN:

(1) **ENERGY TECHNOLOGIES INSTITUTE LLP,** a limited liability partnership (company no. OC333553) whose registered office is at Holywell Building, Holywell Way, Loughborough, Leicestershire, LE11 3UZ (the "**ETI**"); and

(2) **The parties named in Schedule 1 of this Agreement** (the **"Respondents**"),

(collectively the "**Parties**" and individually a "**Party**")

BACKGROUND:

The Parties intend to exchange certain Information on or after the Effective Date for the Purpose. The Parties agree to receive such Information, which shall be treated as confidential information, for the Purpose on the following terms and conditions.

IT IS AGREED:

In consideration of the above and for other good and valuable consideration the receipt and sufficiency of which is hereby acknowledged, and intending to be legally bound, the Parties agree as follows:

1 In this Agreement, unless the context requires otherwise, the following words shall have the following meanings:

"Bidders Workshop" means the workshop to be held by the ETI on 16 November 2010;

"Disclosing Party" means any Party that discloses Information pursuant to this Agreement;

"Effective Date" means the date of this Agreement;

"ETI Affiliates" means the Secretary of State for Business, Innovation and Skills (and any successor governmental department or agency from time to time) and any other entity which is entitled to appoint the directors or otherwise having the ability to direct management policies of the ETI (together with any affiliates of those entities), together with their respective officers, employees, agents and consultants;

"**Information**" means any and all confidential information or data submitted in respect of or further to the Purpose or prepared in relation to the Purpose, including but not limited to written proposal documentation, due diligence materials, contractual documentation, reports, and the fact that the Parties have entered into this Agreement and are discussing and considering a business relationship (but excludes information exchanged at the Bidders Workshop);

"**Procurement**" means the procurement by the ETI of the Project including any stages set out in the RFP or as later may be notified or published by the ETI;

"Project" means the proposed research and development project, to be funded (in part or in whole) by the ETI to develop a CCS Operational Modelling Tool-Kit;

"Project Contract" means a project contract as defined as such in the RFP;

"Proposal" means a proposal as defined as such in the RFP;

"**Purpose**" means:

a the preparation of documents and the making of any Proposal in response to the RFP or for Stage 2;

b any activities related to the assessment of a Respondent's Proposal for the Project including, the negotiation of a Project Contract and any related due diligence activities and activities including activities to obtain consents, licences or clearances related to the Project; and

c any related exchanges of Information, clarifications, discussions, meetings, or negotiations in respect of the RFP, the Procurement and the Project (excluding such exchanges made at the Bidders Workshop);

"Receiving Party" means any Party that receives Information pursuant to this Agreement;

"Respondent Affiliate" means any undertaking that is:

a a holding company of such Respondent;

b the ultimate holding company of the group to which such Respondent belongs; or

c a subsidiary of any holding company or subsidiary of the group to which such Respondent belongs,

and for the purposes of this definition, the terms above are as defined in section 1159 of the Companies Act 2006;

"**RFP**" means the request for proposals relating to the Project, issued by the ETI on 22nd October 2010; and

"**Stage 2"** means the second stage of the Procurement following the ETI's initial selection of any proposals received in response to the RFP and as described in the RFP and further notified or published by the ETI.

2 The Receiving Party shall with regard to any Information disclosed pursuant to this Agreement by or on behalf of a Disclosing Party to the Receiving Party on or after the Effective Date:

a hold the Information in confidence and except as is otherwise stated herein or agreed in writing by the Disclosing Party, shall not disclose or make available the Information by publication or otherwise to any third party (including for the avoidance of doubt, disclosure in any patent application or to any patent office) and shall use any Information disclosed to it pursuant to this Agreement only for carrying out the Purpose;

b make copies of the Information (or any further information derived from the Information) in whatever form or medium only to the extent that the copies are reasonably necessary for the Purpose and clearly mark all such copies as confidential;

c take all necessary and proper security precautions (and at least as great as those it takes to safeguard its own information) to safeguard every part of the Information to prevent it from being disclosed or otherwise made available to any third party except as permitted by this Agreement; and

d at the request and direction of the Disclosing Party, and without delay, return or destroy any Information provided to it pursuant to this Agreement and any copies of such Information, except that one copy may be kept by the Receiving Party for archival purposes and for the purpose of defending itself against any claims arising in connection with this Agreement.

3 The obligations set out in clause 2 shall not apply to Information that:

a the Receiving Party can prove (using written or electronic records), was lawfully known to the Receiving Party or in its possession prior to its communication by or at the direction of the Disclosing Party and was not communicated to the Receiving Party subject to any restrictions on disclosure or use; or

b is or becomes a part of the public domain through no wrongful act of the Receiving Party or any person on its behalf, provided that this clause 3(b) shall only apply from the date that the relevant Information so enters the public domain; or

c the Receiving Party receives from a third party without similar obligations of confidence in circumstances where the third party did not obtain that Information as a result of a breach of an obligation of confidence; or

d is required to be disclosed or made available by the Receiving Party pursuant to any applicable law, governmental regulation, or decision of any court or tribunal of competent jurisdiction or any government body, agency or regulatory body.

4 If a Receiving Party believes it is required by law to disclose any Information under clause 3(d) above, the Receiving Party shall (in each case and to the extent not prohibited in law):

a provide the Disclosing Party with prompt written notice of such requirement or obligation, (together with a copy of any relevant access request, court order or other evidence giving rise to such belief) to enable the

Disclosing Party to seek appropriate protective relief and/or to take other steps to resist or narrow the scope of any required disclosure;

b where it is not permitted in law to notify the requirement for disclosure in advance of the required disclosure, notify the Disclosing Party as soon as reasonably practicable after the disclosure confirming the nature of and extent of the disclosure; and

c co-operate with the Disclosing Party with respect to such matters,

and in any event disclose only such Information as it has ascertained, after taking advice, it is legally compelled to disclose.

5 ETI shall be entitled to disclose or make available any Information it receives from the Respondents to such of the ETI Affiliates, and either the ETI's or the ETI Affiliates' employees, officers, secondees, agents, consultants, sub-contractors, proposed sub-contractors, professional advisers and proposed professional advisers where such disclosure is necessary for the Purpose, provided that in the case of disclosure of Information to ETI Affiliates, that this is limited to disclosure as is reasonably necessary for the purpose of ETI's governance of the Procurement and the Project.

6 ETI shall be entitled to disclose or make available any Information it receives from the Respondents to the Department of Business, Innovation and Skills (or other relevant Government department) and to the European Commission and their advisers as is necessary to seek advice in relation to the application of state aid, to notify or as part of any detailed assessment of state aid in the Project.

7 ETI shall ensure that all such persons to whom any Information under clause 5 of this Agreement is disclosed are bound by obligations of confidentiality and ETI shall be responsible for breaches of the obligations by such persons.

8 ETI shall be entitled to disclose or make available any Information it receives from a Respondent to the other Respondent where it is necessary for the Purpose.

9 Each Respondent shall be entitled to disclose or make available any Information it receives from the ETI or the other Respondent to such of its employees, officers, consultants, subcontractors and professional advisers where such disclosure is necessary for the Purpose provided that all such persons to whom any Information is disclosed are bound by obligations that are no less restrictive than those in this Agreement. The Respondent disclosing Information shall be responsible for breaches of the obligations by such persons.

10 Each Respondent shall be entitled to disclose or make available any Information it receives from the ETI to the other Respondent where it is necessary for the Purpose.

11 The Parties acknowledge that the Bidders Workshop is intended to facilitate non-confidential information and so the Parties agree that they are not restricted from disclosing any information exchanged or received at the Bidders Workshop.

12 The Receiving Party expressly agrees and accepts that except in the case of fraud, no representation or warranty, express or implied, is made by the Disclosing Party as to the accuracy, completeness, reasonableness or otherwise in respect of the use of the Information, and that neither the Disclosing Party or any of its affiliates nor any of its or their respective employees, officers, secondees, agents, consultants, sub-contractors and professional advisers (as applicable) shall have any liability to the Receiving Party as a result of the Receiving Party's possession or use of the Information.

13 The Parties agree that money damages would not be a sufficient remedy for any breach of this Agreement and that the Disclosing Party shall be entitled to specific performance and injunctive or other equitable relief as a remedy for any such breach. Such remedy shall not be deemed to be the exclusive remedy for breach of this Agreement, but shall be in addition to all other remedies available at law or equity.

14 No rights or obligations other than those expressly set out in this Agreement are to be implied and nothing contained in this Agreement:

a constitutes an offer by or on behalf of the Disclosing Party; or

b confers upon the Receiving Party a licence or other transfer of rights in respect of any Party's interest in any Information or in any present or future patent or patent application; or

c affects the present or prospective rights of the Disclosing Party under the patent laws of any country or precludes the filing or prosecution of any patent applications by the Disclosing Party.

15 This Agreement represents the entire agreement between the Parties in relation to the subject matter contained herein and supersedes all other agreements and representations, whether oral or written. This Agreement may only be modified if such modification is in writing and signed by a duly authorised representative of each Party.

16 Neither Party will make any public announcements, statements or otherwise publicise the subject matter of this Agreement (or its existence) without the prior written consent of the other Party and neither Party will use the business names or trade marks of the other Party in any way without that Party's prior written consent.

17 This Agreement shall come into force on the Effective Date and shall apply to any information disclosed under it and shall continue in full force and effect, notwithstanding the completion of the Purpose, for a period of seven years from the Effective Date unless extended or superseded by a subsequent written agreement.

18 It is not intended that a third party (other than an ETI Affiliate) should have the right to enforce a provision of this Agreement pursuant to Contracts (Rights of Third Parties) Act 1999.

19 The rights of the Disclosing Party under this Agreement are in addition to and not exclusive of rights under the general law and may be waived only in writing and specifically. Delay in exercising or non-exercise of any right under this Agreement is not a waiver of that or any other right, partial exercise of any right under this Agreement shall not preclude any further or other exercise of that right or any other right under this Agreement and waiver of a breach of any term of this Agreement shall not operate as a waiver of breach of any other term or any subsequent breach of that term.

20 If any provision of this Agreement is or become illegal, invalid or unenforceable in any jurisdiction, that shall not affect:

a the legality, validity or enforceability in that jurisdiction of any other provision of this Agreement; or

b the legality, validity or enforceability in any other jurisdiction of that or any other provision of this Agreement.

21 Nothing in this Agreement is intended to or shall operate to create a partnership or joint venture of any kind between the Parties, or to authorise either Party to act as agent for the other, and neither Party shall have authority to act in the name or on behalf of or otherwise to bind the other in any way.

22 Except as provided otherwise, no person may assign any of its rights under this Agreement or any document referred to in it.

23 This Agreement may be executed in any number of counterparts, each of which when executed and delivered shall constitute an original of this Agreement, but all the counterparts shall together constitute the same agreement. No counterpart shall be effective until each Party has executed at least one counterpart.

24 This Agreement shall be construed in accordance with and governed by English law and the Parties hereby submit to the non-exclusive jurisdiction of the English Courts.

The Parties have caused this Agreement to be executed by their duly authorised representatives.

ENERGY TECHNOLOGIES INSTITUTE LLP

By: _____

Name: _____

Title: _____

Date: _____

SCHEDULE 1

Respondents	Signature
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________
[*Insert name of Company*] (company no. [*Insert Company number*]) [*Insert address of Company*]	By: __________________ Name: __________________ Title: __________________

Appendix F Modelling Tool-Kit: Statement of Requirements

1. Findings of Stakeholder Survey

Each subsection below will describe a key topic that emerged from discussions with stakeholders. It will contain a brief summary of the information provided by stakeholders and will also include numbered findings that will be referenced in subsequent sections of this report. Findings are numbered with the following format: **F01**.

1.1. Potential users of the Tool-Kit include both asset owners and policy makers

Discussions with the stakeholders identified three broad categories of potential users for the Tool-Kit. The first category is the asset owners or developers such as the ETI member companies. These users will want to model the effects of the CCS chain components up- and downstream of their subsystem(s). A distinguishing feature of this user group is that they have deep expertise on at least one of the subsystems and have access to detailed models for this subsystem. The second group of potential users can be broadly described as technology suppliers, for example equipment suppliers, process vendors engineering companies, consultants, etc. A third group are policy makers (e.g. government agencies) and other organisations such as the ETI itself.

F01 The Tool-Kit must allow asset owners and subsystem developers to model the effects of subsystems up- and downstream of their subsystem.

F02 The Tool-Kit must allow other potential users to model entire CCS chains even though they do not necessarily have deep technical expertise in any of the subsystems.

1.2. Tool-kit must have an open architecture, enabling interfacing to a wide range of existing and future models

The stakeholders indicated that they use a very wide range of tools and models in a broad range of modelling platforms. Specific platforms and tools that were mentioned as being used in analysis relevant to CCS included (in alphabetical order):

- ANSYS / FLUENT
- Aspen Plus / ACM
- Aspen Hysys
- Dymola / Modelica
- Eclipse
- Flowmaster
- gPROMS
- GTPro
- In-house and legacy models in a variety of computer languages such as Fortran, C, C++
- Matlab / Simulink
- MultiFlash
- Olga
- Phast Risk

- PIPESIM
- Proates
- Promax
- PROSPER
- Simona

There is significant experience base and expertise in using these models and tools in the stakeholder organisations, and in particular the in-house tools often capture and represent key elements of company intellectual property. In addition, these models also represent significant past and on-going resource investments. Thus stakeholders clearly expressed a requirement to be able to continue to use their existing models or model content and/or know-how in any CCS system studies. Findings that emerge from these observations are:

F03 Tool-kit must allow stakeholders to re-use their existing component and subsystem models, either directly or by straightforward re-implementation.

F04 Tool-kit must include very flexible interfacing capability that enables it to exchange data with a wide range of modelling platforms, models and tools.

1.3. Tool-Kit must interface to proprietary subsystem models and protect IP

As discussed in 1.2, the stakeholder proprietary models often capture and represent significant elements of company expertise and intellectual property. Stakeholders clearly expressed the requirement that they be able to use their proprietary models in conjunction with the Tool-Kit and, that if, in the process of the analysis, data were to be shared with other stakeholders, that this be done in a manner that protects the company intellectual property (IP).

F05 Tool-Kit must allow proprietary subsystem models to be used within system models.

F06 If the Tool-Kit is being used to share data between different user organisations, the Tool-Kit must be able to protect any proprietary information that is in a proprietary subsystem model.

1.4. Tool-Kit must include a full suite of non-proprietary subsystem models

Stakeholders clearly identified the ability to explore and evaluate the impact of other CCS chain subsystems on their assets/subsystems as a primary desired functionality of the Tool-Kit. Stakeholders also recognized that to use this functionality they would need to be able to model subsystems for which they themselves were not experts and for which they often did not have subsystem models (**F01**). Indeed, some stakeholders, such as government agencies, would likely want to model entire CCS chains without necessarily having deep technical expertise in any of the chain subsystems (**F02**). Findings that emerge from these observations are:

F07 Tool-Kit must include a full suite of non-proprietary subsystem and component models that will allow users to model partial or full CCS chains.

F08 The non-proprietary subsystem and component models must include default relevant engineering information such as, e.g. representative performance maps, parameters or other characteristics.

1.5. Suite of non-proprietary models must have capability to match each other on operating characteristics and size

Since stakeholders want to be able to assemble CCS chain system models that include subsystems for which they are not experts, the Tool-Kit will need to have some capability to "match" subsystems in the chain to each other. What we mean by this is that for instance, a power plant operator wanting to model a CO_2 capture plant, a compression station and some transmission lines downstream of their power plant will need to select an appropriately sized

capture plant, compression station and transmission line capable of handling the volume of flue gas produced by the power plant. This capability is often described as the ability to carry out a *sizing* calculation.

F09 The Tool-Kit must have some capability to functionally match the non-proprietary subsystem and component models to each other and to proprietary subsystem models in terms of operating characteristics and size.

F10 Ideally, the Tool-Kit non-proprietary subsystem and component models will be fully scalable and will have the ability to carry out sizing calculations.

1.6. Unsteady modelling is a priority

A significant majority of stakeholder concerns relate to the effect of transient events – for example trip of downstream injection compression, performance of the system on ramp-up and ramp-down of the power plant, sizing of buffer capacity for system disturbances, verification of control structures, and so on.

The Tool-Kit should have the ability to predict sub-system instability through the use of pre-defined sub-system stability boundaries (for instance, a compressor surge line built in to a compressor performance map). While individual proprietary sub-system models might include the ability to predict the growth of instabilities within that sub-system, predicting instability events triggered by the interaction of sub-systems would require coupling of the sub-system models down to the pressure wave time scale which was determined to be outside the Tool-Kit scope specified by the ETI.

It will be necessary to demonstrate that the Tool-Kit is capable of dealing with system material and energy holdup (accumulation), definition and solution of transient behaviour (for example, cyclic operation of power plants), modelling of process control, and handling of time-based events such as trips and outages.

F11 The Tool-Kit must have the capability to deal with system dynamics at various time-scales ranging from seconds to steady-state.

1.7. Composition of the CO_2 stream is a major concern

Many stakeholders identified the CO_2 stream composition throughout the system, and the impact that this has on stream physical properties, as major risk items that they wish to gain insight in to through system modelling. Indeed, it was established that it is important to track composition from the start to the end of the chain (i.e. source to sink).

F12 The Tool-Kit must be able to capture effects related to the composition of the fluid stream.

F13 The Tool-Kit must be able to track the fluid stream composition throughout the chain.

1.8. Consistent physical property models will be a key enabler for model integration

While some stakeholders have sophisticated physical property models (e.g., industrial gas companies) others identified physical property models as an area where they were lacking in capability. This implies that the Tool-Kit must include a set of relevant physical property models. Differences in physical property models can make model integration very challenging (for instance, physical properties are a significant element of the CAPE-OPEN interoperability standards effort). Given the need to interface to a wide range of models identified above (**F03**, **F04**) the Tool-Kit implementation of physical property models must not restrict interoperability in that it should not restrict the ability of different tools to be interfaced with the toolkit when undertaking studies.

F14 The Tool-Kit must include a set of suitable physical property models.

F15 The Tool-Kit implementation of physical property models must not restrict interoperability.

1.9. System behaviour close to the critical point of the CO_2 stream is considered a key risk

Many stakeholders identified the general area of physical properties and in particular phase boundaries close to the critical point as a major risk area for both CCS technologies as well as for modelling.

F16 The Tool-Kit physical properties must be able to provide robust, stable physical property values close to the critical point for a range of CO_2 mixtures.

1.10. The Tool-Kit is not intended to capture details of multi-phase flow behaviour

Stakeholders were clear that while the processes that would be modelled would include phase change (e.g., compression and liquefaction of CO_2), the intent is not for the Tool-Kit to capture details of multi-phase flow behaviour (e.g. slugging and two-phase pipe or column flow). Another example of a phase-change related process that would be of interest would be the knock-out of water in a compression station inter-cooler. The stakeholders indicated that simple knock-out fractions should be sufficient fidelity for this type of process. In addition, the Tool-Kit should issue warnings if, for instance, a pipe flow is approach a phase boundary.

F17 The Tool-Kit is not intended to capture details of multi-phase flow behaviour, but should include the capability to issue warnings if a phase boundary is being approached.

1.11. Tool-Kit must allow user-defined calculations and integration of external data

Several stakeholders expressed a need for the ability to carry out user-defined calculations within the Tool-Kit. An example of this is that specific users may wish to make some operating cost estimates even though economic issues are not the primary focus of the Tool-Kit. A corollary need to this is the need to import external data (e.g. utility rate or fuel cost information).

F18 The Tool-Kit must be able to include user-defined calculations at the component, subsystem and system level.

F19 The Tool-Kit must be able to import data from external sources such as data files or websites.

1.12. Model validation is a key concern of many stakeholders

Stakeholders expressed significant concerns about the validity of potential results of system studies carried out with the Tool-Kit, in particular if the Tool-Kit models are to be used to make strategic and technology decisions. Thus validation of the models was seen as a critical step in ensuring that the Tool-Kit is seen as a resource for evaluating and reducing CCS related risks. Collaboration with domain expert stakeholders during the development of the suite of non-proprietary models (**F07**, **F08**) was seen as a way to ensure that those models took full advantage of the existing industry expertise.

F20 The Tool-Kit models must be validated and/or fitted to experimental data where relevant experimental data is available.

F21 The Tool-Kit should include the capability to facilitate users validating and/or fitting the non-proprietary model suite to their own proprietary data (parameter estimation).

F22 The Tool-Kit non-proprietary subsystem and component models should be developed in close collaboration with the domain expert stakeholders where possible.

1.13. Tool-kit must include capabilities for modelling and definition of time-based events

Understanding operational issues arising from having subsystems inter-connected on a CCS chain was seen as a key objective of the Tool-Kit. In light of this, the Tool-Kit must have significant capabilities to define and model operational strategies and other time-based events.

F23 Tool-kit must include capabilities for rich definition and modelling of operational strategies and procedures and other time-based events.

1.14. The ETI will likely not assume technical responsibility for future Tool-Kit development and support

During discussions it became clear that the ETI would likely not be interested in providing on-going, in-house, technical support to Tool-Kit users nor would the ETI want to assume in-house responsibility for future development of the Tool-Kit. Thus the Tool-Kit developers should be able to assume these roles.

F24 The Tool-Kit developers should be in a position to assume technical responsibility for on-going and future development and support of the Tool-Kit

2. Tool-Kit Requirements

2.1. Use Cases

There are two broad categories of use cases for the Tool-Kit. The first category describes the types of system model that the Tool-Kit will be used to assemble. The second category describes the types of event that the Tool-Kit will need to be able to model. Each category of use case is described separately below. Events that are specific to certain subsystems are described in the section on that subsystem.

2.1.1 Types of system model

As described in the findings above (**F01**, **F02**) two broad groups of potential users were identified: those with deep expertise in (at least) one subsystem, and those without. It is expected that these two user groups would have needs for different types of system models. In addition, during the stakeholder engagement it was clear that there was a general expectation that the detail and complexity of system studies undertaken would evolve over time both as CCS technology and the Tool-Kit matured and as the user experience base with the Tool-Kit increased. Because of this the Tool-Kit must be able to handle a range of complexity in the system models that it will use.

The Tool-Kit must be able to model systems that have any of the following high-level characteristics:

1) System model consisting of one or more non-proprietary subsystems;
2) System model consisting of one or more stakeholder subsystem model;
3) System model consisting of one or more non-proprietary subsystems and one or stakeholder subsystem models;
4) Simple network model with more than one instance of at least one subsystem, where those subsystem instances effectively operate in parallel but are also interconnected at at least one point. Specifically the model must be able to handle multiple CO2 sources and multiple CO2 sinks.

The delivered Tool-Kit must include at least one example of each type of system model listed above and appropriate test functions to exercise each system model to demonstrate this capability.

2.1.2 List of events

The primary objective of the Tool-Kit is to gain insight and understanding into operational issues surrounding CCS systems. Discussions with the stakeholders identified a significant number of events that would be of interest to them in the context of analysing a CCS system. There are however, a range of events that are common to most if not all the subsystems. These are discussed below.

The Tool-Kit must be able to model events including all of the following:

1) Steady-state operation
2) Cold start-up
3) Warm start-up
4) Ramp-up
5) Ramp-down
6) Planned shutdown
7) Trip shutdown
8) Extreme weather conditions or events (e.g., high or low ambient temperature)

This list of events should be understood as representative and not exhaustive. The Tool-Kit must be able to apply the listed events to any of the relevant subsystems or components in a given system model. To demonstrate this capability, the delivered Tool-Kit must include an appropriate system model of one of the types described in Section 2.1.1, with appropriate test functions to exercise the system model and recreate examples of each of the events listed above.

The Tool-Kit event modelling and representation capability must be flexible enough to represent and model all the types of events listed above as well as other similar events that may become of interest to users. The list of events should be understood as representative and not exhaustive. To demonstrate this capability the Tool-Kit must include functionality to define time-based events for any key subsystem or component model parameter for time periods spanning from seconds to days.

2.2. General Tool-Kit Capabilities

2.2.1 Model solution and convergence

The Tool-Kit should be able to solve flowsheets of models connected in the combinations described in Section 2.1.1 within acceptable engineering tolerances (typically 10E-5 or less on mass balance). A solved model flowsheet should exhibit mass and energy balances at the component, subsystem and system levels as well as matched interfaces between components and subsystems, all within acceptable engineering tolerances. It should also provide capabilities for aiding solution of networks of interconnected streams and/or systems with large recycles.

The Tool-Kit needs to provide capabilities for structural checks to aid consistent specification of the problem and provide guidance in case of incorrect specifications.

Attention needs to be given to ensuring that interfaced models and external software (e.g. physical properties calculations) are solved to a suitable tolerance to allow convergence of the main flowsheet.

The Tool-Kit must be able to converge flowsheets in times comparable with current commercially-available flowsheeting tools (e.g. Aspen Plus) for systems of similar complexity.

2.2.2 Multi-component fluid representation

As discussed above in the findings **F12** and **F13** it is critical that the Tool-Kit has a multi-component fluid representation.

The Tool-Kit must be able to represent the working fluid in the system as a mixture of all or any of the following components:

1) Carbon dioxide, CO_2
2) Water, H_2O
3) Nitrogen, N_2

4) Oxygen, O_2

5) Carbon monoxide, CO

6) Hydrogen, H_2

7) Methane, CH_4

8) Nitrogen oxides, NO and NO_2

9) Sulphur oxides, (principally SO_2)

This list of components should be understood as representative rather than exhaustive.

To demonstrate this capability, at least one of the example system models listed in Section 2.1.1 must include all the fluid components listed above.

The Tool-Kit must be capable of including all the species listed above as components in the fluid representation. Further, the Tool-Kit structure must not in any way preclude the addition of further components not listed in Sections 2.2.2 or 2.4.1 to the fluid representation. To demonstrate this capability, the Tool-Kit must include capability to add a previously undefined fluid component to the fluid representation.

The Tool-Kit must conserve the mass of each fluid component at the component, subsystem and system model levels. Further, the Tool-Kit must include functionality to calculate the mass and energy balance at the component, subsystem and system model level. To demonstrate this capability, all the example system models listed in Section 2.1.1 must report the mass balance for each fluid component for each component and subsystem in the model, as well as for the overall system.

2.2.3 Fluid stream definition

Equipment items within the flowsheet will be connected by fluid streams. These streams should support the passing of multicomponent and/or solids stream information between units.

The following stream types are required as a minimum:

1. Standard liquid-gas process stream, comprising:
    - component flowrates and/or total flow and stream composition
    - pressure
    - enthalpy (preferably) or temperature

    or appropriate equivalents (throughout the flowsheet)

2. Solids streams where appropriate:
    - particle size distributions of solids (for example, coal solid-handling) and/or
    - entrained solids in the case of flue gas streams.

It should be possible to:

- use different stream types – for example, solids and standard liquid/gas within the same flowsheet (even within individual units);
- use streams containing different components within the same flowsheet (for example, a heat exchanger may contain a process stream and a steam or water-only stream), and use different physical properties models for different component streams where appropriate.

In certain cases – for example, transient performance – it will be necessary for streams to cater for reverse flow.

2.2.4 Integration capability

The Tool-Kit should include an integration capability capable of incorporating external models and connecting these with the non-proprietary models within the Tool-Kit.

These include:

- models from other process modelling environments (PMEs)
- process model components from commercial component modelling software (PMCs)
- information from specialist modelling environments – for example Computational Fluid Dynamics (CFD) software
- process model components from in-house and legacy models in languages such as Fortran, C, C++

Ideally the interface will allow all of the following:

- embedding of external software within the Tool-Kit (along the lines of CAPE-OPEN socket-and-plug implementation)
- translation of input into an acceptable equivalent for native execution within the Tool-Kit environment
- 'co-simulation', where two software models execute in parallel.

Where possible the integration capability should use established standards such as CAPE-OPEN.

2.3. Subsystem, Unit and Component Models

2.3.1 Subsystem Models

The subsystem models represent the major constituent parts of the overall systems. The CCS system is defined as a series of subsystems typically including emitter, capture, transportation and injection subsystems. There are seven main sub-systems to be considered:

1) Pulverised Coal Fired
2) Integrated Gasification Combined Cycle (IGCC)
3) Combined Cycle Gas Turbine (CCGT)
4) Oxy-fuel Pulverised Coal Fired
5) Transmission
6) Injection and Storage
7) Support Systems/Utilities

The subsystems are subsequently divided into units and in some cases components. The units represent the major parts of the subsystem, while the components correspond to the functional parts of units. For example, in considering an IGCC, one of the units is the gasification which in turn has two components a gasifier and a gas shift reactor.

The Tool-Kit will be used to model future systems, probably in the 2020 to 2050 time horizon. Hence unit and subsystem models should capable of representing performance improvement which is likely to made through 'technology stretch' of current technologies. Furthermore, the Tool-Kit should be capable of incorporating models of novel technologies, at a component, unit or possibly even subsystem level.

2.3.2 Unit and Component Models

These models are the subsets within the subsystem set that enable the scheme to be modelled. They represent, for the most part, the fixed minimum requirements. The units and components must be robust enough to provide sound engineering answers. The models should be further broken down to provide the necessary control and responses to scenario requirements.

The models should contain enough predetermined information that, in the absence of an appropriate user input, the model can make a default assumption based on the critical sizing

information. For example the peak grid demand requirement on a power station defines the overall boiler size, and the model should be able select a default configuration.

2.3.3 General

Each of the unit and component models should be capable of handling the following range of input and parameter changes:

1) The user must be able to change the model parameters and the model operating state within a meaningful range of values around the defaults
2) Each model must be able to respond to the impact of upstream and downstream components
3) Each model should be able to provide representative default parameter values and performance characteristics for a range of sizes of the given component
4) Users should be able to substitute the default values with suitable parameters and performance characteristics from other sources

2.3.4 Component Models

The component models are shown in Figure 1 to Figure 21 showing the primary input and output requirements. In addition key variables are also listed. Where user data is not provided, the variables listed should default to predetermined values, patterns or performance maps relevant to the equipment in question. The listed inputs, outputs and variables are the minimum requirement for each model. The model should be expanded with extra inputs and outputs as required, to provide the level of accuracy and performance desired from the Tool-Kit.

Design parameters are criteria that can optionally be used to constrain choices in the subsystem configuration. For example a design parameter for a boiler is the unit size. In a case where the overall boiler requirement may, for instance, be 2400 MW, the unit size parameter can be used to decide the best fit of standard unit sizes of boiler as a plant of this overall capacity would consist of multiple trains. For example the design parameter would select from say three 800MW units, four 600MW units or six 400MW units. Similarly, the warm rate is essentially a bespoke rate at which a boiler can cycle from cold or warm to hot operation and would be in terms of a performance curve. Design parameters should be predefined based on existing information. However the ability to edit those parameters with proprietary or preferred data should be available to the user.

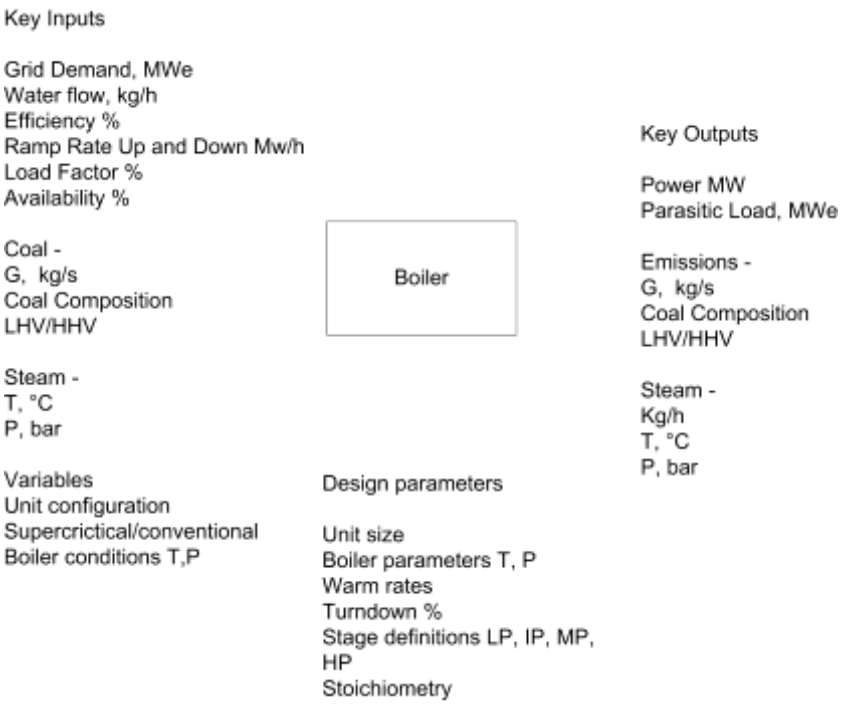

Figure 1 Key inputs, outputs, variables and design parameters for boiler component model

2.3.4.1 Boiler

The boiler model must be capable of modelling both conventional and supercritical combustion and steam raising, including the expected enhancement of boiler conditions which will be implemented over the next 10 – 30 years. Boiler selection should also be based on standard or typical sizes. Consideration must be given to the warm up, shut down and ramp rates for boiler configurations.

Models should allow for oxy-firing of boilers.

2.3.4.2 Heat Recovery Steam Generator & Cooling

The HRSG system is the steam raising section for CCGT and IGCC plants. The model should consider the typical design parameters for a large multi stage heat exchanger and allow for the selection of multiple steam generation pressures and targets. Cooling systems should consider general models for cooling water, chilled water and air cooling that can be applied as a unit or component model in a number of subsystems.

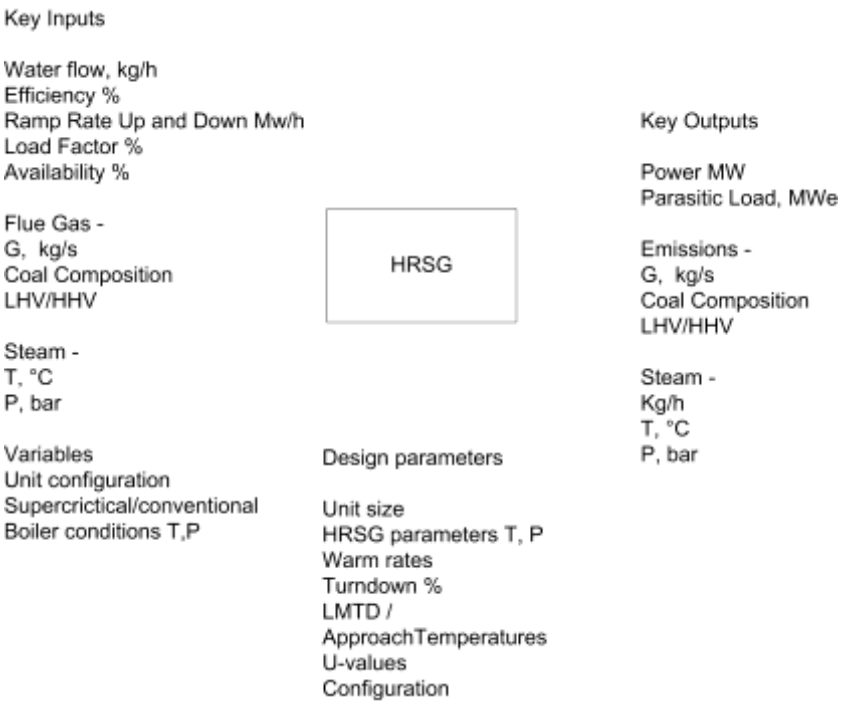

Figure 2 Key inputs, outputs, variables and design parameters for heat recovery steam generator (HRSG) component model

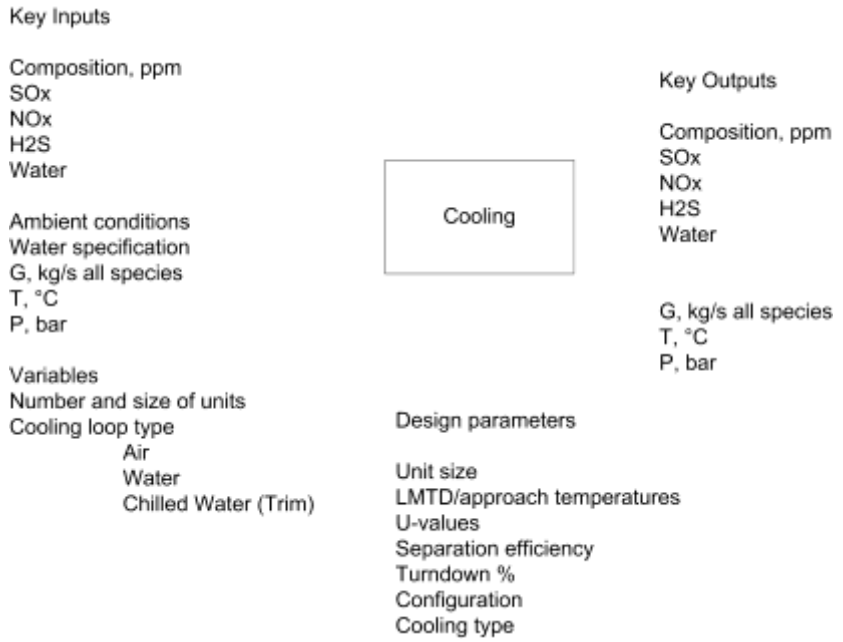

Figure 3 Key inputs, outputs, variables and design parameters for cooling component model

2.3.4.3 Steam Turbine

The steam turbine model is used in coal fired, IGCC and CCGT subsystems and should be flexible enough to accommodate the requirements of each type. The model should consider steam configurations at a variety of pressures and configurations in multiple stages.

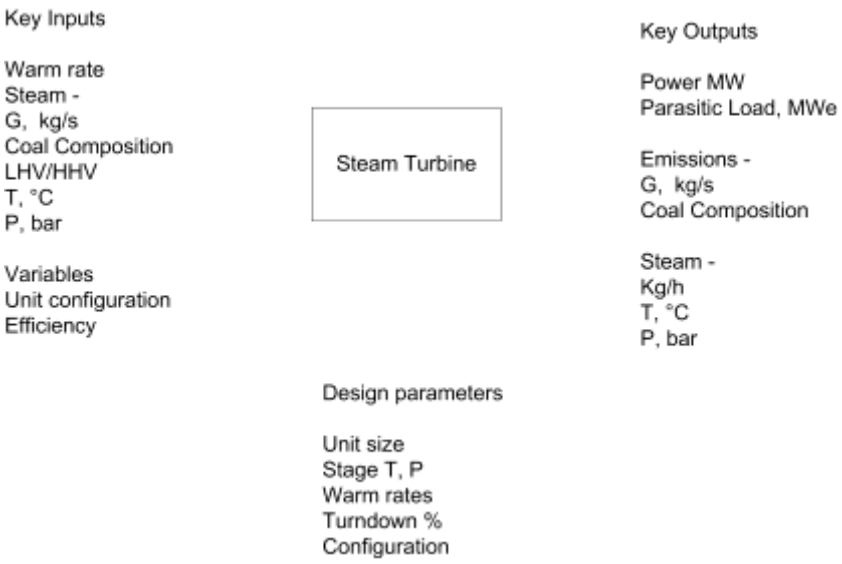

Figure 4 Key inputs, outputs, variables and design parameters for boiler steam turbine model

2.3.4.4 Generator

The generator is assumed to be a simple mechanical to electrical power conversion. The associated systems such as hydrogen cooling need not be considered. The inputs are generally derived from other models. The design parameters should be predefined with current available information.

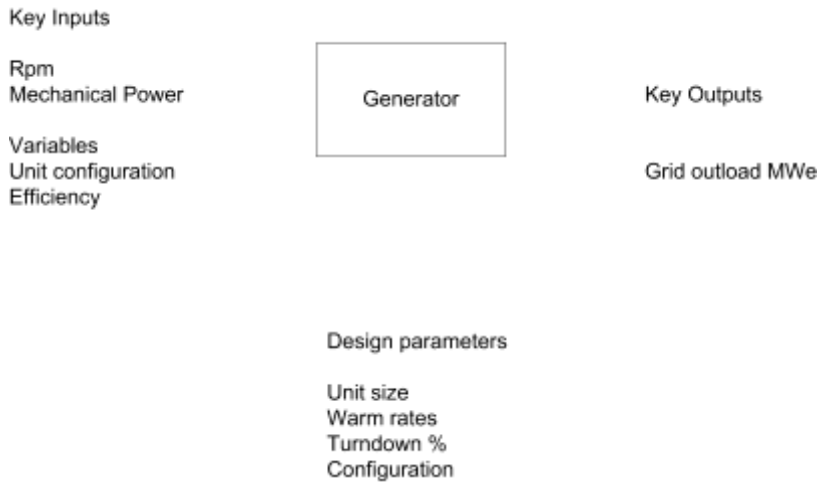

Figure 5 Key inputs, outputs, variables and design parameters for generator component model

2.3.4.5 Air Quality Control Systems

The removal of contaminants from the flue gas is required to comply with national regulations and the addition of a capture plant does not change this. The default criteria for particulates, SOx and NOx control will remain those imposed by the regulations in case venting prior to capture has to occur. The models should consider the technical options that are available for each model, allow the user to select an appropriate technology type, and include representative performance characteristics or curves for each technology type.

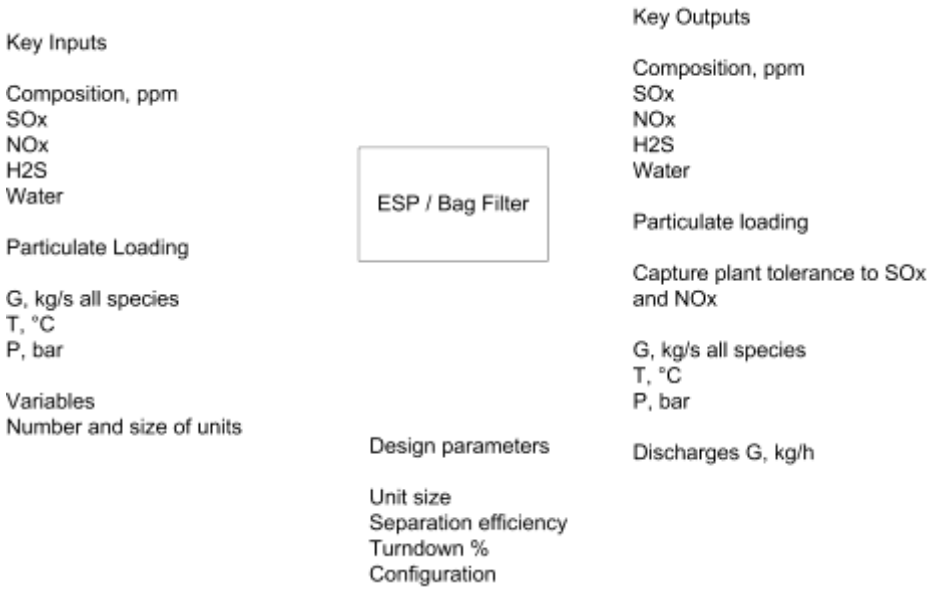

Figure 6 Key inputs, outputs, variables and design parameters for electrostatic precipitator (ESP) or bag filter component model

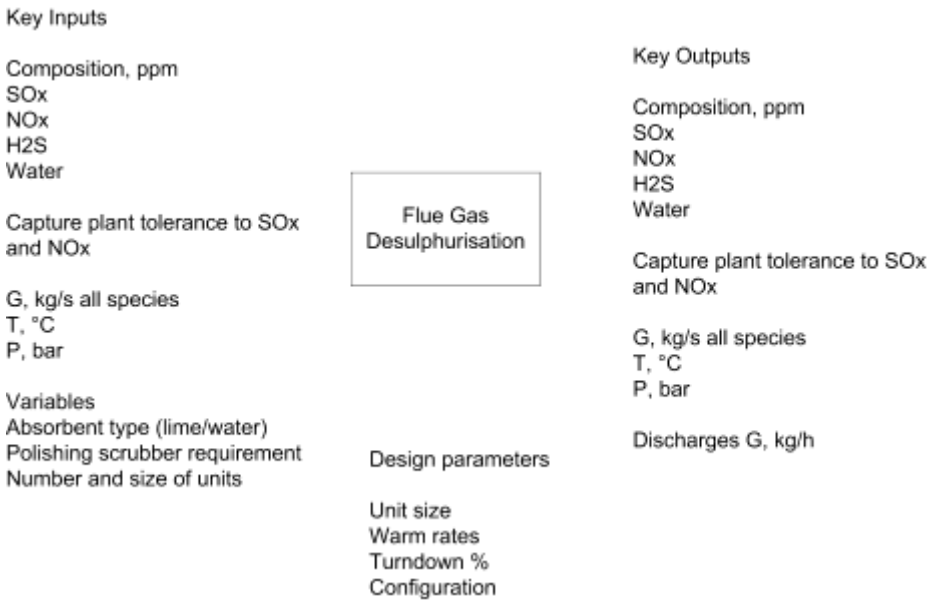

Figure 7 Key inputs, outputs, variables and design parameters for flue gas desulphurisation (FGD) component model

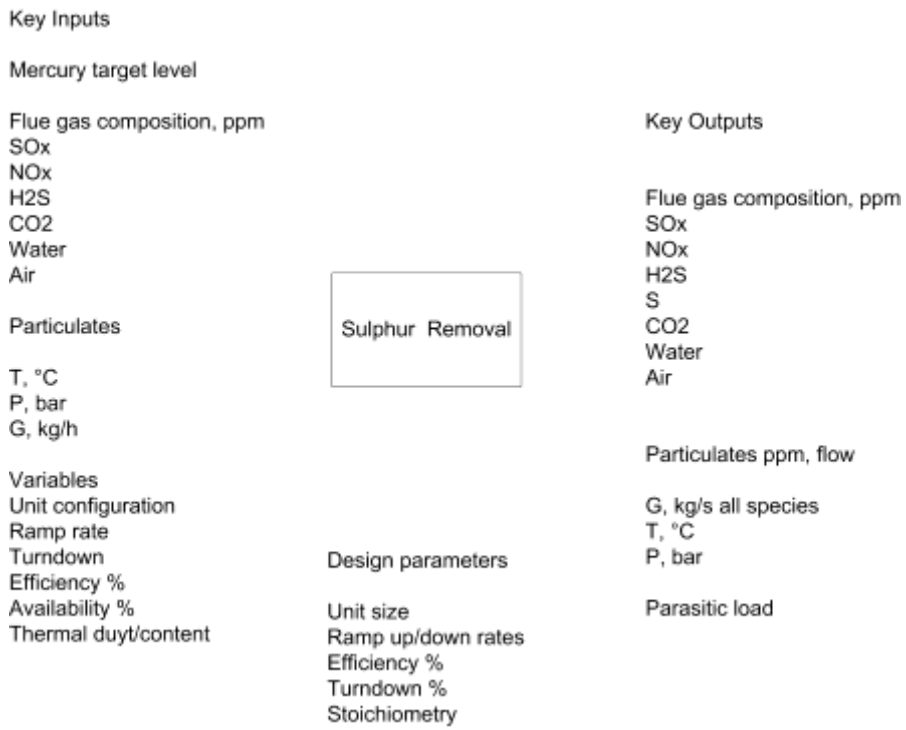

Figure 8 Key inputs, outputs, variables and design parameters for sulphur removal component model

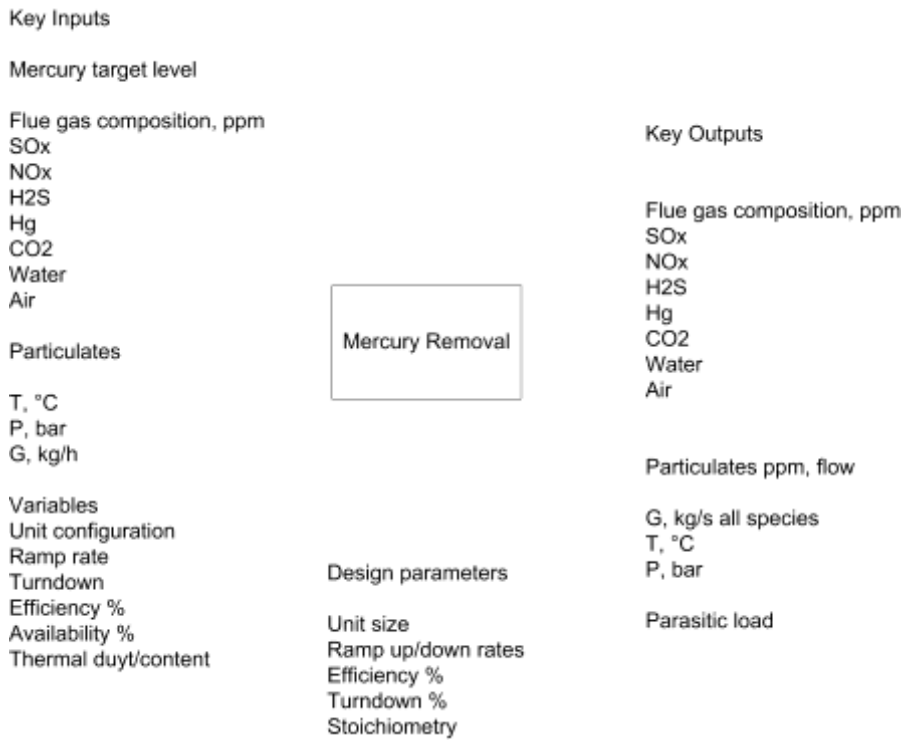

Figure 9 Key inputs, outputs, variables and design parameters for mercury removal component model

2.3.4.6 Capture plant

The capture plant should consider two elements, namely capture and post capture conditioning. The model should allow the selection of technology for capture including current amine technology, advanced amine technology and ammonia systems. Amine absorber and

regenerator models should include rate-based techniques or similar appropriately high-fidelity approaches for modelling of amine-CO_2 reaction and thermodynamics. The post capture conditioning is the dehydration step of the process to ensure the required outlet water concentration is met. Technology selection here should consider glycol based systems, absorption and molecular sieve processes.

For pre-combustion capture (IGCC), the model should include units for acid gas removal (ie H2S, SOx and CO2), including physical solvents (eg Selexol).

For oxy-fuel, the 'capture' unit comprises cryogenic separation of CO2, water and other components and recycle of CO2, and may be integrated with the compression system.

The Tool-Kit should allow for the integration of novel capture technologies (eg solid adsorbents, enzyme enhanced carbonates, ionic liquids) although modules for such technologies would not be developed initially.

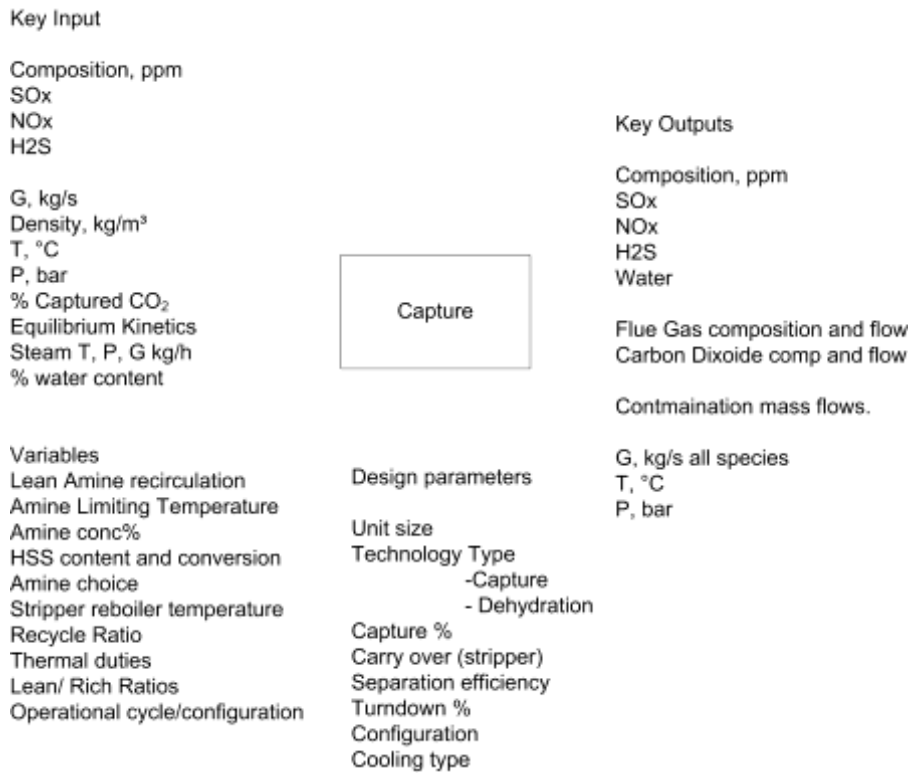

Figure 10 Key inputs, outputs, variables and design parameters for CO_2 capture component model (amines)

2.3.4.7 Compression, Liquefaction and Pumping

The transportation of the CO_2 stream can occur in either gas or liquid (dense) phase. To achieve this, the compressor model should be robust enough to address gas and phase change compression. The alternative of liquefaction typically requires the stream to be compressed and then cooled to induce the phase change. Once in liquid form it can be driven simply by the pressure provided by the compressor; however there can also be additional pumping stations. In considering either, the models must consider the phase characteristics of the fluid and the associated operating issues.

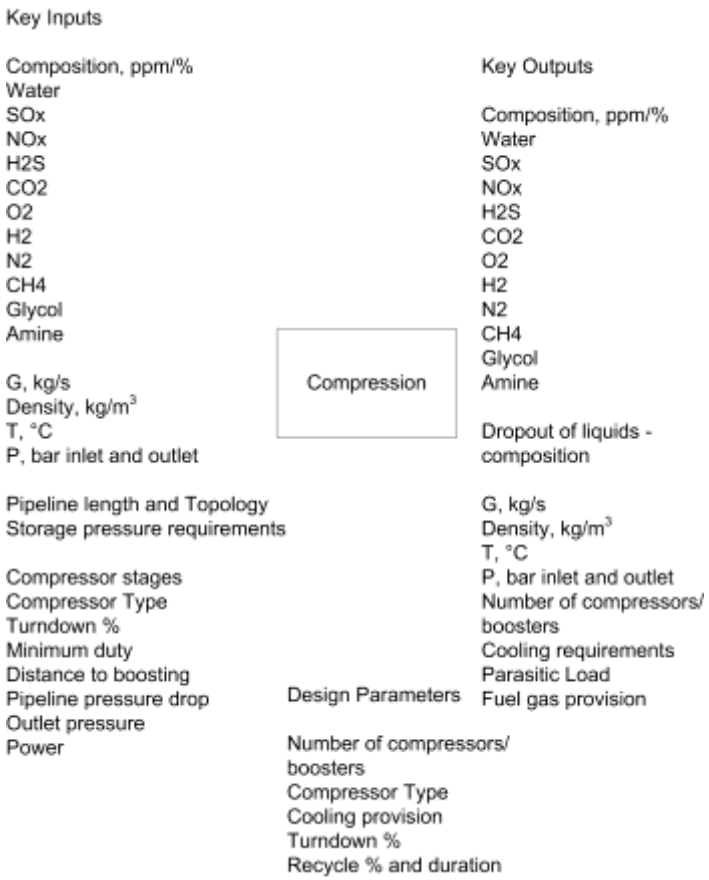

Figure 11 Key inputs, outputs, variables and design parameters for compression component model

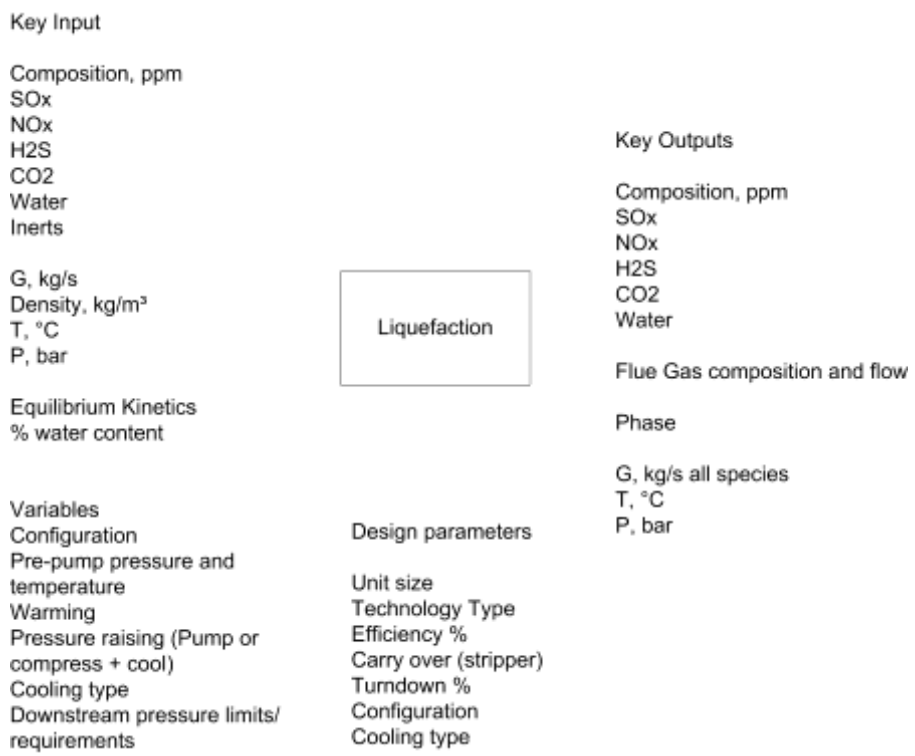

Figure 12 Key inputs, outputs, variables and design parameters for liquefaction component model

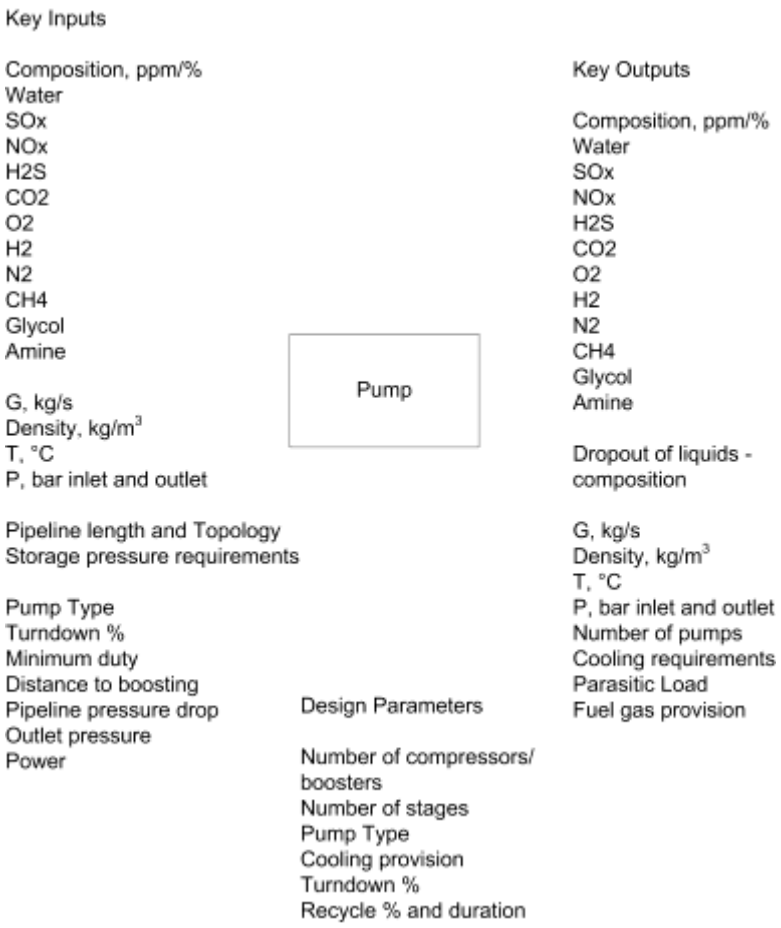

Figure 13 Key inputs, outputs, variables and design parameters for pump component model

2.3.4.8 Pipelines

The pipeline element of any transport infrastructure is not a static system. The pipeline model must be able to accommodate gaseous, liquid and dense phase carbon dioxide streams. The model should also consider the issues around phase transition and allow users to set limits on temperature and pressure but also provide a default condition that prohibits (but warns about approaching) transition from gas to liquid and vice versa. However, multi-phase flow would not be modelled. The pipeline should consider issues such as line pack, as a potential buffer store, but would not include rapid transient events (eg pressure surge). The model should also allow users to define spacing to compressor or pump booster stations, or automatically select an appropriate distance.

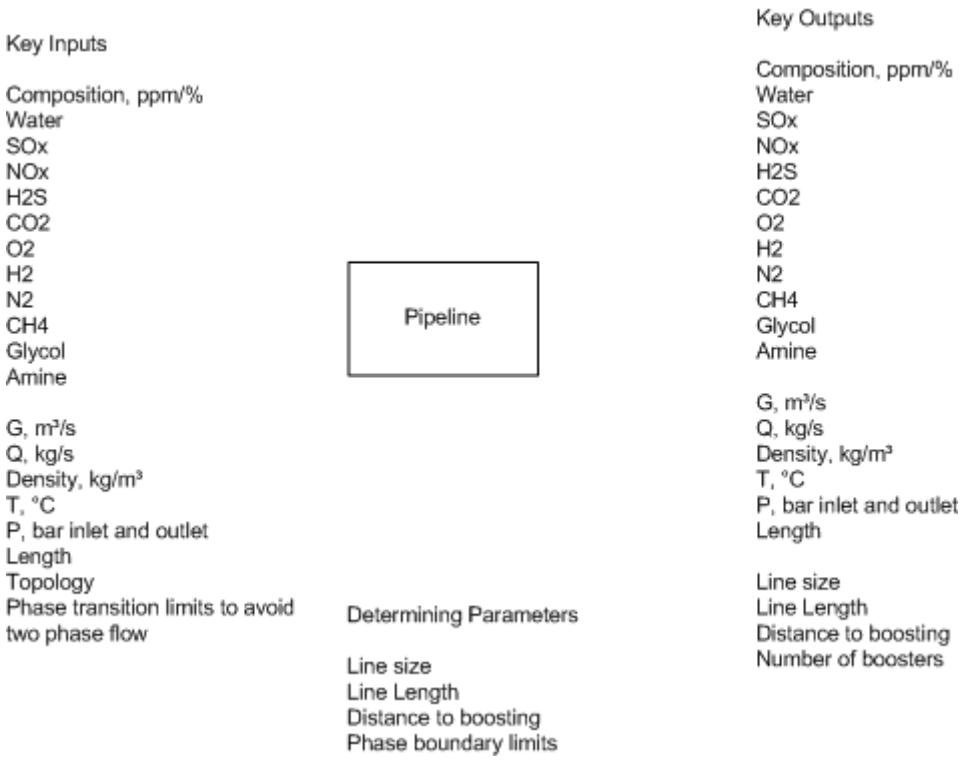

Figure 14 Key inputs, outputs, variables and design parameters for pipeline component model

2.3.4.9 Buffer Storage

The concept of buffer storage is to provide an intermediate store that allows accommodation of plant flexibility or upsets conditions within the system. The store can be both large scale pressurised vessel storage or a geological formation such as salt cavern or depleted hydrocarbon field. Use of line pack for buffer storage is considered within the pipeline model. The buffer storage model must consider the same issues as permanent storage however a default configuration for each type will be required as well as the ability of the user to modify each criterion.

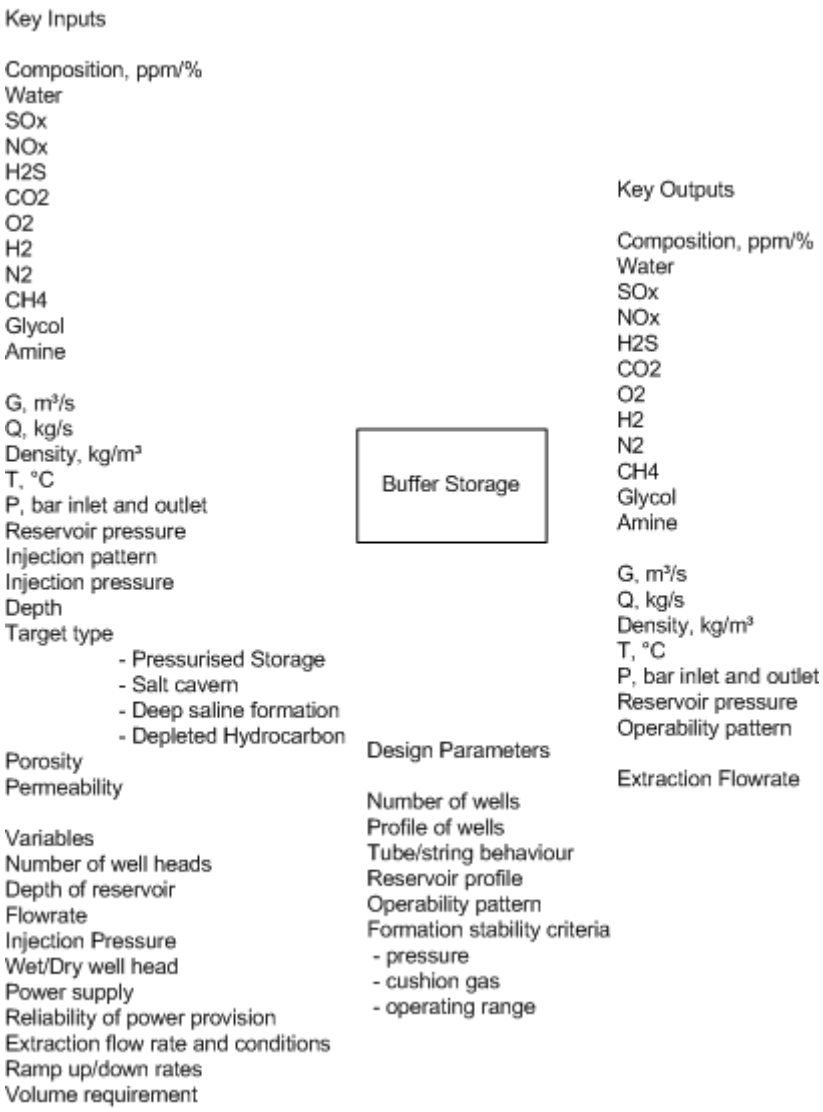

Figure 15 Key inputs, outputs, variables and design parameters for buffer storage component model

2.3.4.10 Gas Turbine

The gas turbine model should be capable of modelling stand-alone gas turbines as well as be suitable for integration into a CCGT or an IGCC subsystem model. The model should be able to predict flue gas conditions and composition for firing on both natural gas as well as syngas, and should include performance data representative of current gas turbine performance as well as the ability to include performance enhancements expected in the next 10–30 years.

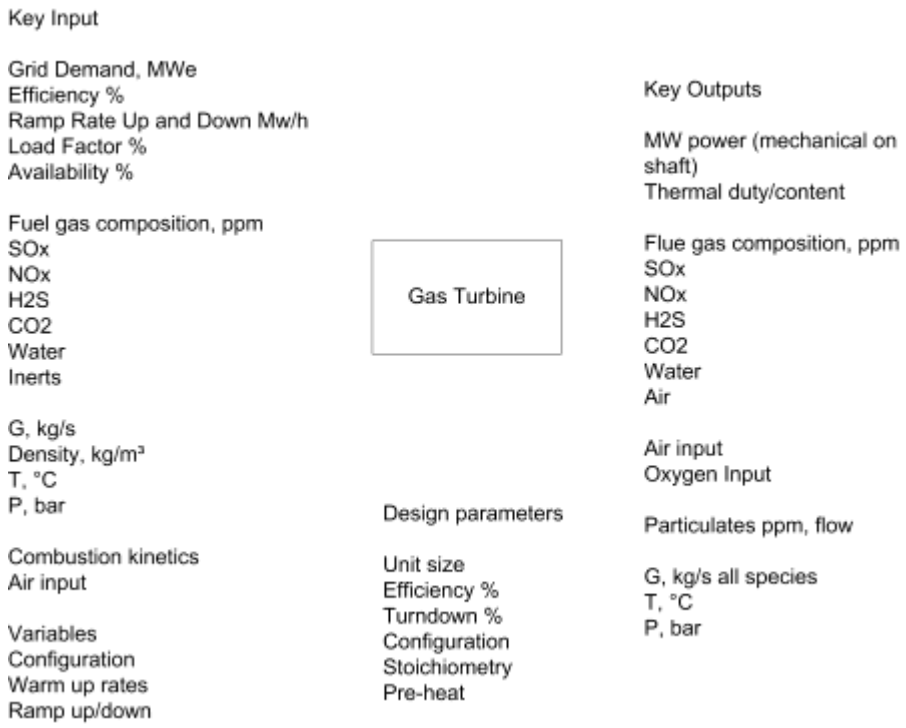

Figure 16 Key inputs, outputs, variables and design parameters for gas turbine component model

2.3.4.11 Gasification

Gasification subsystems such as IGCC replace the traditional boiler with a number of units. The gasifier essentially fires the fuel producing an incomplete combustion flue gas. The flue gas is then reacted with water at high temperature to generate a syngas which is hydrogen rich. Inputs to the gas shift reactor are the outputs from the gasifier and the two are linked. The variables are based on the reactor technical expectations rather than the feedstock stream.

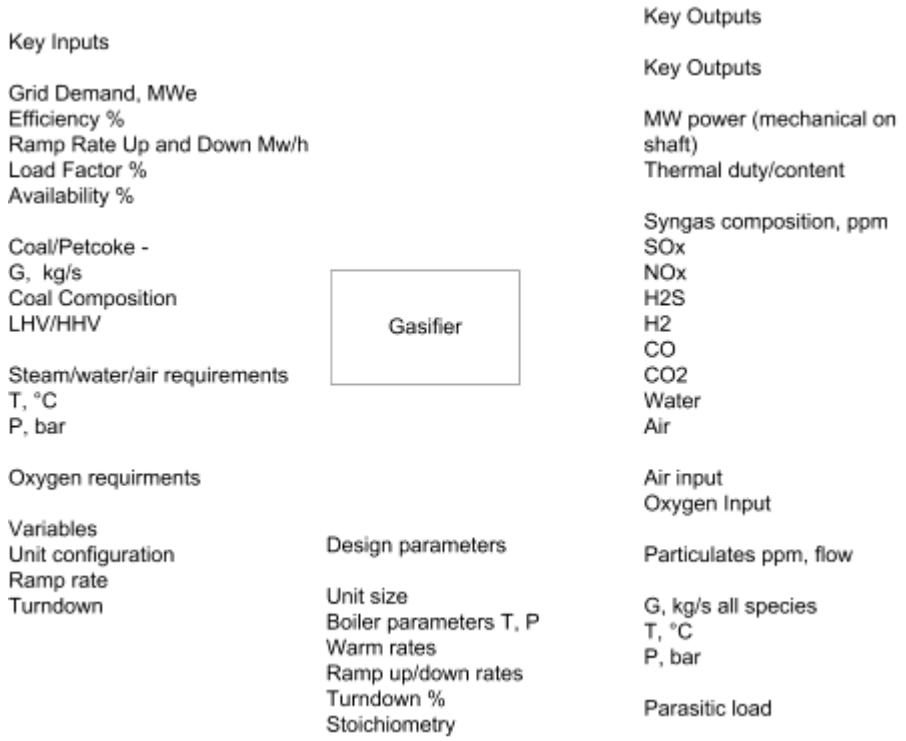

Figure 17 Key inputs, outputs, variables and design parameters for gasifier component model

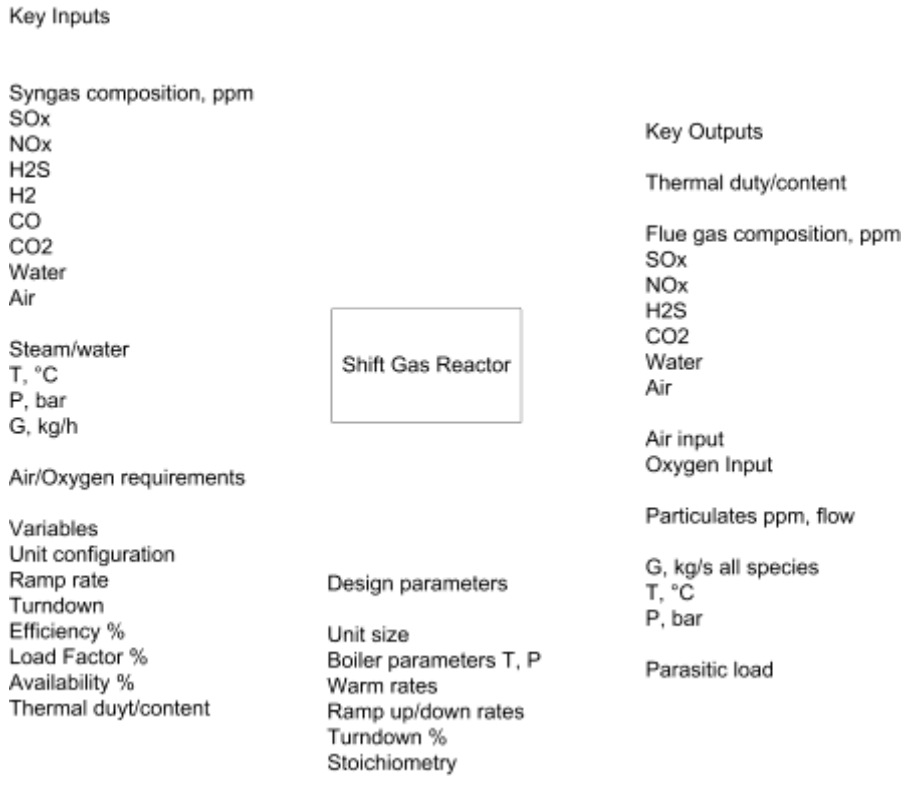

Figure 18 Key inputs, outputs, variables and design parameters for gas shift reactor component model

2.3.4.12 Air Separation Unit

The air separation unit must be capable of predicting the performance and output of a stand-alone cryogenic air separation processes both with and without product compression. In addition, for IGCC applications, it will be desirable for the air separation process to be integrated with the rest of the IGCC process for optimization purposes. Thus the air separation process product conditions and any heating and cooling requirements should be capable of being supplied externally to the model.

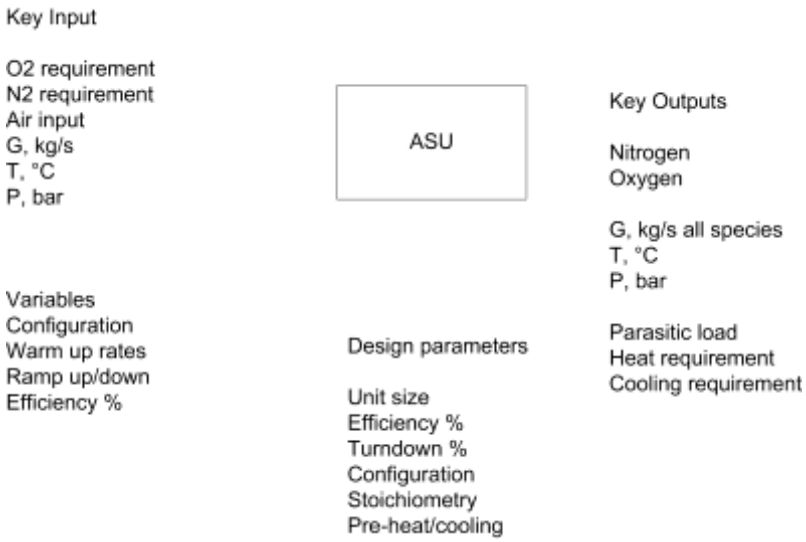

Figure 19 Key inputs, outputs, variables and design parameters for air separation unit (ASU) component model

2.3.4.13 Well head

The model will only consider offshore storage of CO2, as onshore storage is unlikely to be utilised in the UK. The well head and associated infrastructure can be wet (subsea) or dry (platformed) depending on water depth and the configuration of the storage site. The key operating criteria are that wholly subsea, wet completion will not be able to have associated compression or pumping and will have to rely on the transmission system onshore to provide motive force. Dry wells are those on platforms which can therefore have limited pressurisation and conditioning equipment on them. The driving force for a well head is also not the flow rate to it, but the ability of the well to respond to a storage site. Well flow should be related to both the injection pressure, the bottom-hole pressure of the storage site and the permeability (the latter two of which may also change with time) – i.e. the storage site should not be considered to be an infinite sink. Feedback from the wells will constrain the transportation system rather than provide an accommodation for variations.

Conditioning may be required to accommodate the expected well-specific requirements to inject at conditions other than those at which the fluid is received. For example some depleted hydrocarbon fields may require gas phase injection at first rather than liquid or dense phase.

Use of CO2 for Enhanced Oil Recovery (EOR) is not a priority.

Figure 20 Key inputs, outputs, variables and design parameters for well head component model

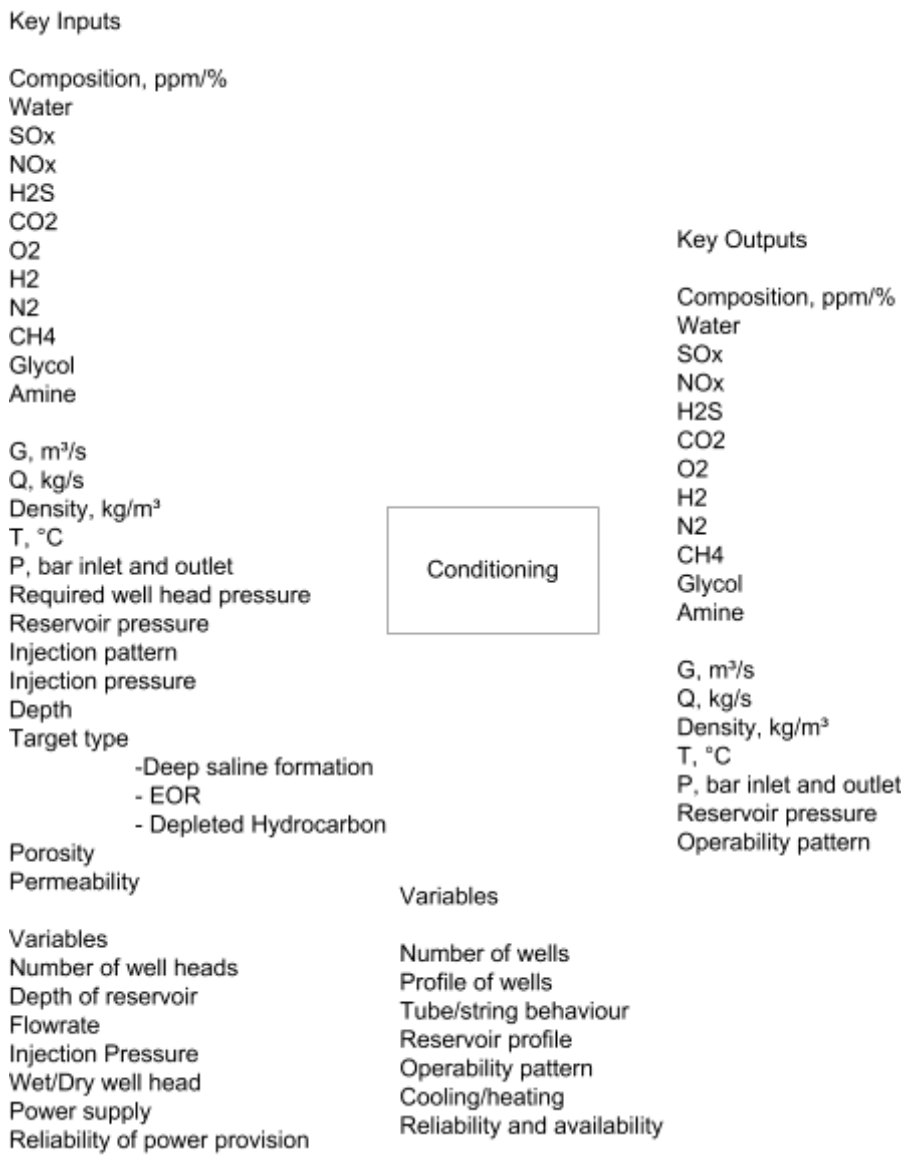

Figure 21 Key inputs, outputs, variables and design parameters for conditioning component model

2.3.4.14 Utility component models

In addition to the components described above, the Tool-Kit will need to include other simple components that are required to put together system models. These should include:

- Generic source: to initiate a stream of any kind covered in Section 2.2.3
- Generic sink: to terminate a stream
- Stream splitter: to split a stream flowing to more than one component
- Stream mixer: to mix multiple streams where they join.
- Control elements of various types, including a PID (or PI-) controller in order to provide process control.

2.3.5 Requirements

The Tool-Kit should include predefined models (referred to as the “non-proprietary” models) for the units and components listed above The models should be based on open source literature,

or other sources where the originator is prepared to place the models in the public domain. Models should be fully scalable – i.e. a single model should be capable of being used to model operation at many different scales, simply by making the appropriate variable and parameter specifications. It is also desirable for the models in the Tool-Kit to have the additional capability to impose modular, integer sizing on components constrained by industry practice and capability. Thus, for instance, optional model design parameters could be used to select a process train configuration. However, this capability must be additional to the sizing capability and not substitutional.

Each predefined model should include performance maps such as compressor curves or ramp rates that are based on commercially available equipment, although the models should have the capability of exploring the effects of 'technology stretch', ie incremental improvements to represent future technology development. The Tool-Kit should also include predefined system models for the power station sub systems, a typical pipeline and network arrangement and a typical well head arrangement. The library of models and configurations shall include full descriptions of the system, theory and variables and provide worked examples. Sufficient detail in the models must be provided to ensure that dynamic modelling and sensitivity analysis can be done.

It should be possible to augment the Tool-Kit library of non-proprietary models by the addition of proprietary models in all cases. It should be possible to protect the intellectual property (IP) and data (e.g. parameter values) within proprietary models in order that they can be used securely outside the supplying organisation if required. In addition the Tool-Kit models will accept the input of data from proprietary sources. The user must also have the ability to enter user defined models or customise existing models to ensure development information can be added and evaluated.

The Tool-Kit models must allow for calculation of upstream and downstream effects - i.e. it should be possible to specify upstream variable values and see the calculated effect on downstream variable values and vice versa. Changes in one section must cascade through the system as appropriate in both steady state and dynamic modes.

In practice the Tool-Kit will need to provide the capability to export and import the models and full systems. The data transfer should be to multiple standards and platforms such as spreadsheets, Fortran or CAPE-OPEN. The transfer of data must not affect the security of proprietary data.

The Tool-Kit models must be fully scalable within the reasoned bounds of current technology. There must be demonstration of a cap that prohibits the size of a component or unit to step outside of normal bounds. For example a 2,400 MW power station is not a single steam turbine and generator. The models must also address and adapt to the upper range cap and down size accordingly duplicating the performance in another shared duty unit or component.

2.4. Property Model

2.4.1 Species list

The species and mixtures for which physical properties must be defined are listed in Sections 2.2.2.

2.4.2 Property model use cases

Rather than specify a particular physical property model or models we have phrased the requirements in terms of "usage scenarios". The intention is that the respondent is free to choose whichever physical properties system they feel is appropriate as long as it covers the envisaged scenarios adequately.

3. Tool-Kit Validation and Verification

3.1. Component and Subsystem Model Validation and Verification

The term validation is used here to mean “to make valid”, rather than “to verify” (which is indeed part of the process of validation).

Model validation typically involves fitting the parameters (for example the heat transfer coefficient) of a theoretical model to real-life data in order to make the model reflect observed behaviour. This acknowledges the fact that there is a degree of empiricism in even “first-principles” chemical-engineering models.

If the model is of suitable fidelity and the data are suitably accurate and free of extraneous (particularly scale-related) influences, such validation should provide a model that gives accurate results over a range of scales and operations.

Components and/or subsystems (whichever is the appropriate level of granularity given the available data) should be fitted to steady-state or dynamic plant or other observed (laboratory, pilot plant or test rig) data in order to adjust the key model system-specific parameters to reflect operation for that system.

Having obtained a fit, the predictions of the adjusted model should be *verified* against a second set of observed data.

For example, a boiler model can be validated against steady state boiler data for a standard operating state. The fitted model should be shown to be capable of predicting operation of a second steady-state to a suitable level of accuracy.

3.2. System Model Testing and Verification

Once individual sub-system models have been validated, the system models will need to demonstrate that they can function over a range of realistic operational conditions.

Providing validated sub-system and component models are used in the construction of the system models, verification of the latter will be aimed at ensuring that operation is directionally-(or qualitatively-) correct, particularly in the case of dynamics and that steady-state values are consistent with those observed during validation.

Validation (i.e. parameter adjustment) of system models should only be applied to parameters (for example, newly-added sections of pipe) that have not been fitted at a component level, unless good justification can be shown.

Appendix G Glossary

Term	Definition
Arising IP	Any intellectual property which is created by or for any Participant during the Project or for the purposes of the Project.
Background IP	Any intellectual property which existed prior to any Participant's commencement of the Project and which was created by or for the Participant.
CDM	Construction (Design and Management) Regulations 2007.
Client	As defined by CDM.
Consortium	The group of organisations described in Section 1.5 which may decide together to submit a Proposal to carry out the Project and be governed by a Consortium Agreement between themselves. This will not include the ETI itself or any Subcontractors.
Consortium Member	An organisation which forms part of the Consortium.
Consortium Agreement	The agreement to be entered into between the organisations together forming a Consortium, as described in Section 1.5, which governs the execution of the Project within the Consortium.
ETI	The Energy Technologies Institute LLP, a limited liability partnership (Company no. OC333553) whose registered office is at Holywell Building, Holywell Way, Loughborough, Leicestershire LE11 3UZ.
ETI Executive	The Executive Committee of the ETI.
Lead Coordinator	The organisation which is a Consortium Member, and which manages and coordinates the activities of all the Consortium Members, and which acts as the primary interface between the Consortium and the ETI, as described in Section 1.5.
Own Funds	Funding sourced by the Respondent's own resources and not dependent in any way on third party lending to either the Respondent or member of the Respondent's group.
Participant	Either the Prime Contractor or a Consortium Member.
Payment Milestone	A contract milestone with defined constituent deliverables, associated deliverable acceptance criteria, and milestone value (all to be detailed in the Respondent's Proposal and agreed in the Project Contract) which should be completed in order to reach the said milestone, and at which, subject to acceptance by the ETI that the milestone has in fact been reached, payment may be claimed from the ETI on the basis described in Section 3.2 and on the Terms in Appendix B.
Prime Contractor	A sole organisation which contracts with the ETI to manage the project. It may have Subcontractors.
Programme Manager	The individual appointed by the ETI to manage the overall ETI programme to which this Project is affiliated, and to whom the Project Manager is accountable.
Project	The project for which the purpose, scope of work and other details are described in this Request for Proposals.
Project Contract	The contract, as described in Section 6, to be entered into between the ETI and the Participants (whether between the Consortium Members or a Prime Contractor)
Project Detailing Stage	The stage of Project commissioning carried out by the ETI if and after it has decided to take forward a Proposal, during which full and final Project details are established and a Project Contract is agreed.
Project Manager	The individual who is appointed by the Lead Coordinator or Prime Contractor, or is otherwise agreed by the Project Participants, to carry out its responsibilities.
Project Organisation	The entity or group of entities / organisations, and the contracting and management structure which they adopt, as described in Section 1.7, which together will carry out the

	Project if commissioned by the ETI and includes any Consortium Members or Prime Contractor and any Subcontractors.
Proposal	The proposal for the Project submitted to the ETI, as described in Section 3.1, in response to this Request for Proposals.
Public Funding	Any funding provided by a public authority or agency.
Respondent	The organisations submitting a Proposal to the ETI, as described in Section 3.1.
Review Point	A Project review involving Project Participants and ETI representatives at which the overall progress in Project or a specific Work Package will be critically reviewed and following which a formal decision will made on the future Project programme.
Stage Gate	A major Project Review Point involving Project Participants and ETI representatives at which the overall performance and business case for the Project will be critically reviewed and following which a formal decision will be made whether to continue with the Project, based on whether agreed Stage Gate Criteria have been met.
Subcontract	A contractual arrangement between a Participant and another organisation to which work for the Project has been subcontracted.
Subcontractor	An organisation which has a Subcontract.
Submission	The components set out in Section 3.1, including the Respondent's Proposal submitted by the Respondent in response to this Request for Proposals.
Task	A significant activity or group of activities (within a Work Package) which results in completion of a deliverable or a significant part of one, or which represents a significant step in the process towards one.
Work Package (WP)	A major section of the Project scope of work, which may be identified in this Request for Proposals or in the Respondent's Proposal, in order to break up the scope of work into separate manageable parts. A Work Package will usually consist of a number of Tasks.