



Polymer Fuel Cells Challenge

Information Document

www.carbontrust.co.uk/fuelcells

Updated January 2010

Summary

As part of our mission to accelerate the move to a low carbon economy, the Carbon Trust develops commercially viable low carbon technologies, through partnerships, funding, expert advice, technology demonstration and the development of new, low carbon technology businesses.

The objective of the **Polymer Fuel Cells Challenge** (PFCC) is to develop, prove and commercialise novel polymer fuel cell technologies that have the potential to deliver a step-change in overall system cost – a reduction of at least one third at large production volumes – without sacrificing durability and performance characteristics. We believe that the UK has the capability to develop innovative cell-level technologies that could meet this Challenge, which if successful has the potential to accelerate access to new markets for fuel cell products, saving carbon whilst generating economic value for the UK.

Following the successes of the Advanced Photovoltaic and Advanced Bioenergy Accelerators, the Carbon Trust is running a public competition to select partners to carry out a further Directed Research initiative. Over the next 4-5 years, we intend to invest around £8m to create or develop a world-class UK business and help it capture a substantial part of the potential multi-billion pound polymer fuel cell market.

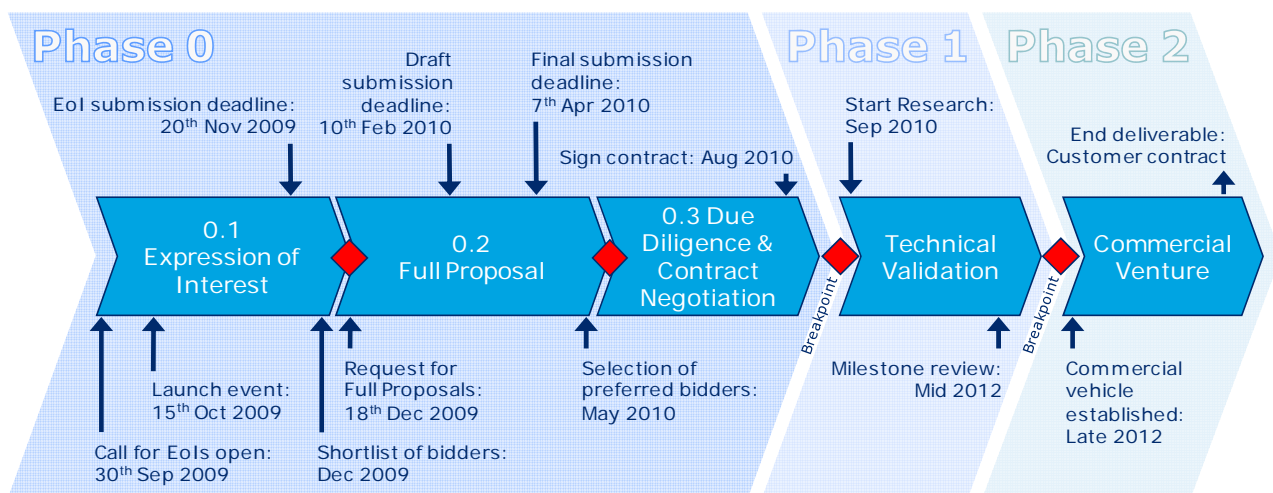


Figure 1: Key dates for Phases 0, 1 and 2 of the PFCC

Having closed the Request for Expressions of Interest on 20th November 2009, we are currently reviewing these proposals, with a shortlist of consortia to be selected in December 2009.

Rationale for supporting polymer fuel cell R&D

During 2008-2009, we carried out a detailed analysis through direct consultation of fuel cell stakeholders (including a workshop and a series of interviews), but also through modelling of fuel cell system costs and market research on potential applications. This analysis, supporting the present Polymer Fuel Cells Challenge, is detailed below.

Successful fuel cell products, almost exclusively based on polymer technology, are emerging in specific markets such as back-up power for telecoms base stations, materials handling (fork-lift trucks) and auxiliary power units. Sales in these markets grew at an annual rate of ~60% from 2006-08, with growth forecast to continue. Ultimately, much larger markets – including transport and cogeneration – are being targeted by polymer fuel cell developers. Using fuel cells in these markets could significantly contribute to carbon reductions. Of all of the fuel cell types, our analysis suggested that the greatest crossover benefits could be achieved by a directed investment in polymer fuel cells¹.

In developing these early products, some of the engineering and supply chain problems impeding market access have been solved. These solutions have significantly reduced the risk of investment in R&D for mass market applications. However, polymer fuel cell system costs are still too high, and performance and durability not yet sufficient for many applications.

To understand the implications of fundamental technology developments on possible applications and market entry, the Carbon Trust commissioned a detailed cost and market study². The impact of three potential breakthrough technologies on overall product cost were modelled, to estimate the effects of these cost savings on market penetrations for certain key applications.

This analysis indicated that incremental improvements in current polymer fuel cell technology, even with projected economies of scale and learning effects, will be insufficient to achieve the cost levels necessary for significant penetration in the very large, carbon-saving markets of automotive and cogeneration. A significant step-change in polymer fuel cell technology will be required to access these markets and deliver the corresponding carbon

¹ In particular our analysis indicated that the SOFC industry is consolidating vertically around developing unique systems, and hence supporting innovative SOFC research would result in products with a much narrower range of applicability and value to the UK.

² More details on the cost model we developed can be found [on our website](#). If you would like information on the possibility of **accessing and using our costing model and methodology** (whether in relation to the PFCC or not), please contact directed.research@carbontrust.co.uk

savings. For this reason, the PFCC will only support innovative breakthroughs, rather than incremental improvements.

System cost reduction target

Our analysis indicated that overall system cost reductions of around one third versus costs of current technology projected at scale would be needed to materially accelerate the development of polymer fuel cell mass markets. If successful, these cost reductions could – in the UK alone – unlock a \$19bn market by 2050, saving 7MtCO₂e a year. It is expected that the route to these mass markets would be via a series of intermediate markets such as Diesel generator replacement, back-up and off grid power, and buses.

Such innovation could potentially be delivered by existing research programmes. However, UK fuel cell companies and research groups are currently significantly short of capital and find it difficult to access customers for their technology (many of whom are overseas). As previous accelerators demonstrate, a focused intervention bringing together the right mix of actors with a common goal can make a significant difference. **The overarching objective of the Challenge is therefore to accelerate the development of a novel polymer fuel cell technology that could deliver mass-manufactured system cost savings of at least a third over current state-of-the-art approaches.** An illustration of this cost target is given below in Figure 2.

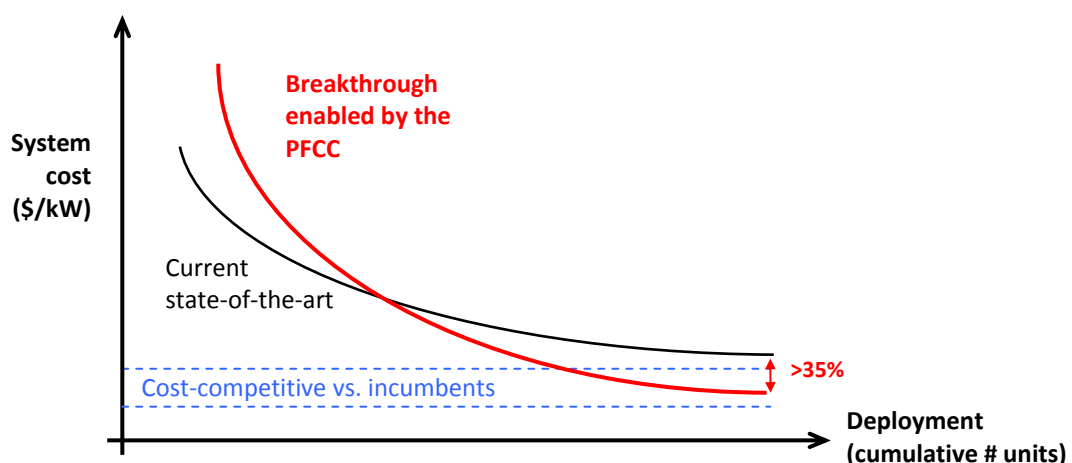


Figure 2: Indicative polymer fuel cell system cost curves

The technologies targeted through the PFCC are presently at an earlier stage of development, and more expensive, than current state-of-the-art technologies. The Polymer Fuel Cells Challenge's programme of technical and commercial validation and support is intended to accelerate the new technologies down the 'PFCC-enabled' red cost curve shown in Figure 2 above, bringing forward the time when novel technologies are fully competitive with current technologies. The Carbon Trust aims to bridge the cost gap in order to deliver this change.

Key cost components

The polymer fuel cell industry and supply-chain is consolidating horizontally around component specialisation. There is therefore an opportunity to introduce innovations on core components at the MEA and cell level, in materials, novel architectures and electrochemical processes, which will then have the potential to be used in many different applications and markets. Therefore, the PFCC will support research at this level (MEA, cell and stack components) to maximise the commercial and carbon reduction value of any breakthroughs. The approach is intentionally technology-agnostic, to allow, for example, innovative approaches using both precious metal and non-precious metals.

Projects may focus on any one critical component or aspect of the polymer fuel cell stack assembly, or may be broader and include a number of sub-components. Whilst innovation is anticipated to be at the cell and perhaps stack level, **impacts will be considered at the system level.**

To illustrate the systems cost impact of different components when manufactured at volume, cost breakdowns for stack and system are shown below in Figures 3, 4 & 5³ for three families of polymer fuel cell applications – transport, stationary CHP⁴ and portable generators. These charts are based on specific parameters and system designs; and as such are only a guide to assessing whether a particular innovation is material in meeting the objectives of the Challenge.

The Carbon Trust is able to help project teams to quantify the system cost impacts of their research. This will be achieved by explaining the cost model methodology to applicants if requested, and at the later Full Proposal stage, we will ask for a set of key parameters from each team in order to run the detailed model and assess the impact of their proposed breakthrough.

³ Source: Austin Power Engineering & E4tech (2009)

⁴ Note that these CHP system costs do not include the cost of the reformer (this was considered separately in the lifecycle costs calculations)

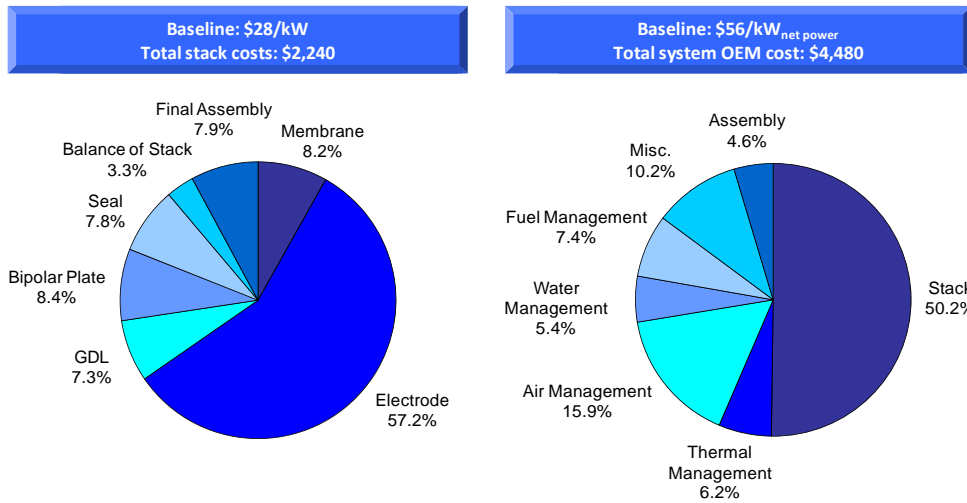


Figure 3: Indicative cost breakdown for an 80kW transport system

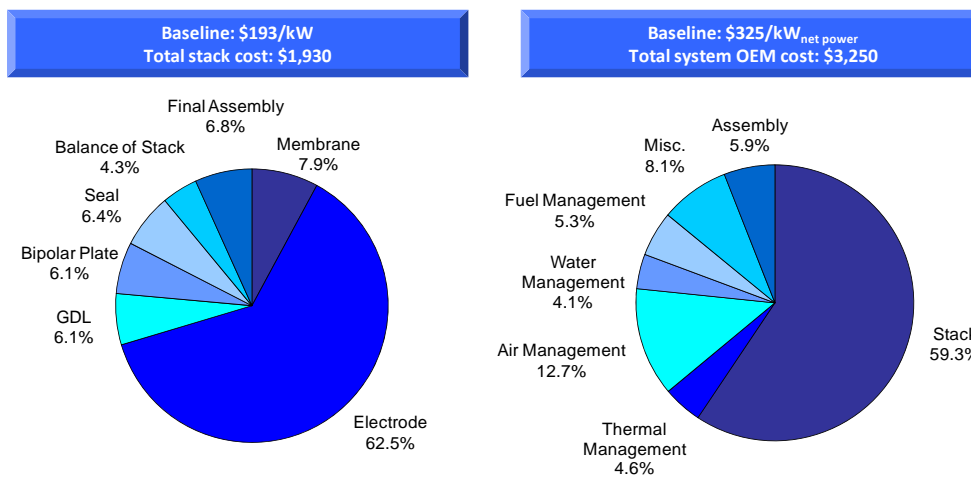


Figure 4: Indicative cost breakdown for a 10kW stationary CHP system

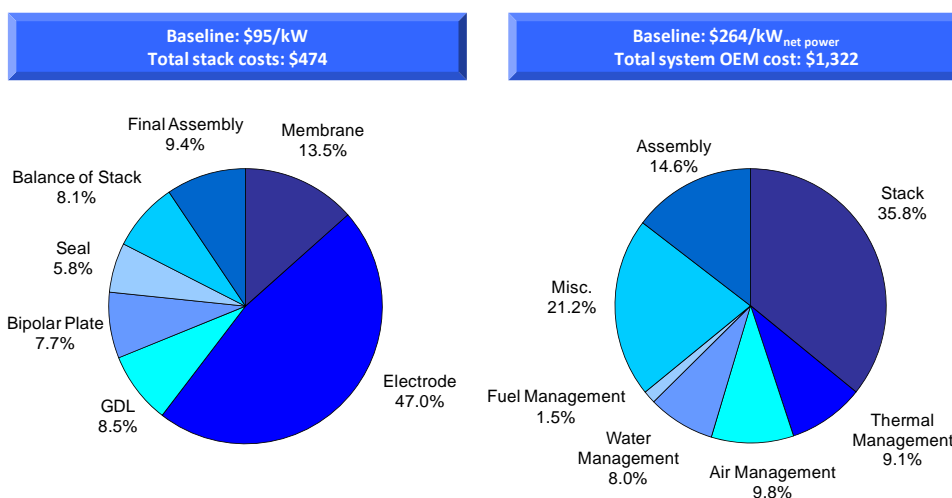


Figure 5: Indicative cost breakdown for a 5 kW portable generator system

UK R&D capabilities

The UK has strong R&D capabilities in materials science and chemistry, with a dozen large universities and research organisations, several start-up companies and major industrial players involved in polymer fuel cell research. Numerous research collaborations exist between all types of organisations. In particular, the UK is home to world-class research on catalyst thrifting, non-precious metal catalysts, membrane materials with improved conductivity & durability, MEA development for conventional polymer fuel cells, and alkaline anion-exchange membrane fuel cell research.

Many innovations in fuel cell research have occurred through researchers bringing in novel ideas from outside the existing fuel cell community. Some of these approaches offer direct savings in lower materials costs for cells and indirect savings through simplified systems configurations and lower-cost balance of plant.

This is therefore an opportune moment for UK polymer fuel cell technology – research is well placed to deliver a significant breakthrough, and markets are beginning to emerge – combined, these factors have created an opportunity to launch world-class products onto a massive global market. Recent UK innovations could move fuel cells down the cost curve illustrated in Figure 2, and so the Carbon Trust is looking to help create partnerships to convert research breakthroughs into proven concepts that attract substantial commercial investment.

Structure of the Polymer Fuel Cells Challenge

The Challenge is designed as a two-phase programme to develop, prove and help bring to market core components enabling significantly lower cost polymer fuel cell systems. After an initial selection process, the first phase of the Challenge will combine innovative research with industry engagement to prove novel concepts enabling significant cost reductions. The second phase will look to commercialise the most promising results.

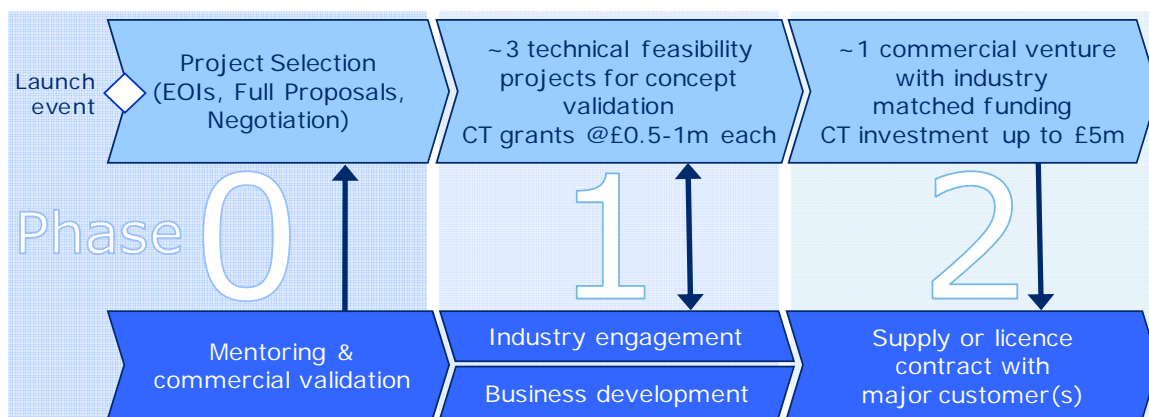


Figure 6: Outline structure of the Polymer Fuel Cells Challenge

Selection criteria

Throughout the Challenge, concepts will be evaluated on the criteria below:

- 1. the size of the potential system cost reduction enabled**
- 2. the originality of the approach**
- 3. the distinctiveness of applicants' existing proprietary technology**
- 4. the strength of the team, both individuals and organisations**
- 5. readiness of the technology in the 2010-2015 timescale**
- 6. level of technical and commercial risk**
- 7. cost effectiveness of the programme of work**

It is important to note that the launch of the Polymer Fuel Cells Challenge does not commit the Carbon Trust to future funding – having assessed the quantity and quality of the proposals received at each Phase (and sub-phase) of the PFCC, the Carbon Trust may not progress any projects. For more details, see the Contractual Commitment at the end of this document.

Phase 0: Project selection

Selection of the most promising projects for Phase 1 will be carried out using a three stage process: Expressions of Interest, Full Proposals and Due Diligence & Contract Negotiation. The key dates for Phase 0 are shown in Figure 7.

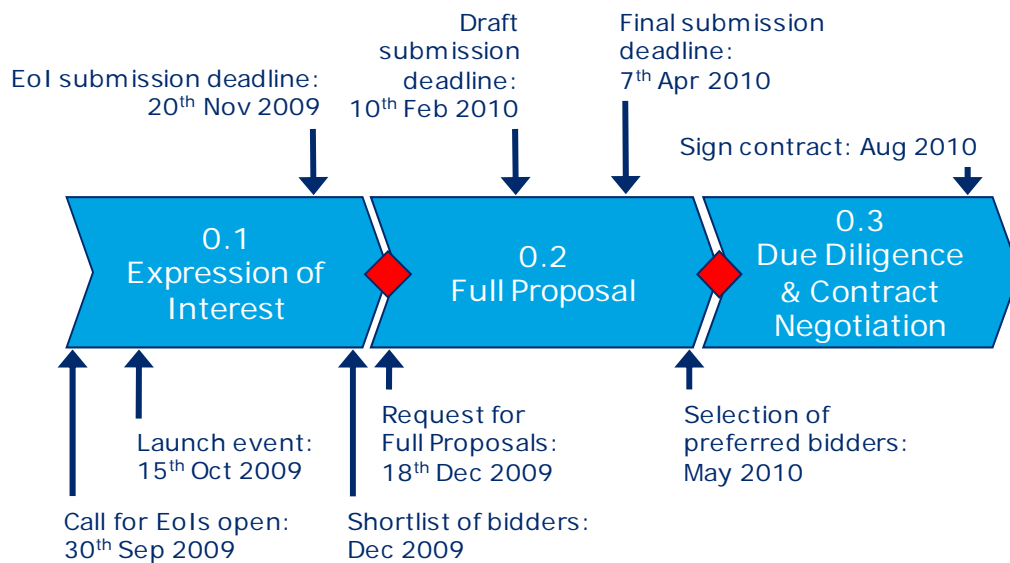


Figure 7: Key dates for Phase 0 of the PFCC

Phase 0.1 – Expressions of Interest

This first phase of project development called for the submission of Expressions of Interest (EoIs) from organisations or consortia, before 20th November 2009⁵. These EoIs were required to outline how the proposed technology route would address the system cost-reduction challenge; what the consortium will do to take their technology from its current state to proof of commercial viability, given up to £11m of funding (up to £6m from the Carbon Trust); and why the assembled team has the skills, experience and resources to carry out this challenging work

The role of the EoI stage was to identify the best teams and ideas, rather than solicit detailed project plans. The review process was therefore focused on the originality of the concepts and the competence of the teams, rather than on a fully formulated value proposition.

The EoIs received in this initial call have been reviewed by a panel comprising Carbon Trust as well as independent international assessors. Five consortia

⁵ Note that we cannot accept EoIs after this date.

have been selected to engage in the Full Proposal preparation phase; short summaries of their proposed projects can be found on our [website](#).

Phase 0.2 – Full Proposals

Following the submission of the EoIs and the review process, successful teams have been invited to submit a more detailed full application as part of a competitive tender.

Since the EoIs were only project outline documents, the details contained within them can and almost certainly will change during this stage – however, the principles must remain consistent. Full proposals need to describe in greater detail a proposed plan of work in order for the team’s research to lead to a validated technology breakthrough, enabling significant system-level cost reductions in identified products. This includes:

- a detailed technology development roadmap, laying out the key expected milestones and describing activities intended to achieve these. This should also give the approach to specific technical tasks, such as the screening of catalysts or the selection of a membrane monomer formulation. Intermediate technology milestones should be used to show progress against relevant metrics, and demonstrate whether the technology could reach the market sooner in niche applications
- a summary description of relevant background intellectual property and how this is intended to be used to progress the technical work
- an outline business plan for commercial exploitation of the proposed technology. Although a track record of commercial exploitation experience is not a pre-requisite for submitting a proposal to the PFCC, being able to identify a credible and sustainable market outlet for the proposed technology is important. We expect an approach that has significant challenge and risk, but could result in the creation of valuable intellectual property, and a commercial product within the next 5 years
- a techno-economic system analysis, with a breakdown of stack and system costs. There will be an opportunity to use the Carbon Trust’s model⁶ for this analysis.
- detailed biographies of key team members, along with summaries of how their skills will be utilised in the project and why this team would be best placed to develop low-cost polymer fuel cell technologies

⁶ Organisations wishing to inquire about the use the model independently of the PFCC process are invited to contact directed.research@carbontrust.co.uk

- treatment of both technical and commercial risks; teams will be expected to assess key commercial drivers, uncertainties and risks realistically, and lay out plans for mitigation of these

The Carbon Trust will be able to provide mentoring on draft applications and support throughout this stage. Project proposals will cover both Phases 1 and 2, but programmes of work must incorporate a stage gate after 18-24 months at the end of Phase 1, to allow for review against the project's technical milestones, and competitive selection for progression to Phase 2.

When appropriate during the EoI or Full Proposal process, the Carbon Trust reserves the right to facilitate the formation or re-structuring of consortia, in order to strengthen a proposed project. This may involve suggesting an additional partner or proposing a merger between two complementary projects.

Phase 0.3 – Due Diligence & Contract Negotiation

Those teams who are successful in progressing beyond the full proposal stage will proceed to negotiate suitable terms under which their Phase 1 proposed research will be conducted, and the structure of the potential Phase 2 commercialisation⁷. This is still a competitive step where success is not guaranteed: consortia will be expected to make significant contributions of their own (e.g., effort in-kind, cash, Intellectual Property) to the project, in order to share risk – and potential upside – with the Carbon Trust. As part of the due diligence process, consortia will also need to provide evidence for, and answer, any remaining questions to the satisfaction of the Carbon Trust.

Phase 1: Research

The Carbon Trust may take forward up to 3 proposals in Phase 1, for concept validation and engagement with industrial stakeholders aimed at de-risking the technology and demonstrating technical feasibility. Up to £1m (subject to State Aid rules) will be made available to each of the selected project teams. This grant funding will be used to validate their technology concepts over the following 18-24 months, by delivering their proposed programme of work, and meeting agreed milestones.

During Phase 1, the engagement of the project teams with industry members and end users will aim to ensure that the technologies developed meet market needs. Customer specifications will help steer project milestone reviews. The

⁷ Potential applicants are invited to refer to our [Statement of Principles](#) concerning this phase

engagement with end users and investors will also be an opportunity to demonstrate to the Carbon Trust the level of commercial interest in their technology, and thus the most valuable breakthroughs. Existing relationships should be cited at the EoI stage.

The output of Phase 1 must be suitable for commercial exploitation. It should be noted that the Carbon Trust will provide additional business development support if necessary, to ensure the commercial impact of a project is fully realised. Phase 1 will terminate with a **competitive review of the achievements of all research teams**. Only the most promising project, with a clear route to market and the demonstrated potential to introduce a radically cheaper fuel cell system, will be selected for the further Phase 2 investment.

Phase 2: Commercialisation

Those polymer fuel cell innovations shown to best meet the selection criteria above will be taken to proof of commercial value in Phase 2, developing the new cell concept for specific application requirements and the establishment of a UK-based business to market the new technology. The final end deliverable of the PFCC is expected to be a development, license or supply contract with a major customer or manufacturer – the PFCC will therefore be supporting a technology all the way through to a customer.

Detailed commercial arrangements will be agreed between the partners and the Carbon Trust at the end of Phase 0 – which will vary considerably due to variety of organisations who could participate. However, the expectation is that the right to exploit the intellectual property (IP) assembled by the most successful project (or exceptionally two projects) in Phase 1 will be vested in a commercial vehicle (e.g., a company, joint venture, joint development agreement) dedicated to this purpose, which will own the project outcomes.

As shown in Figure 8 below, it is proposed that stakes in this commercial vehicle will be jointly taken by:

- the project partners (contributing in particular Background IP, cash and in-kind)
- the Carbon Trust (converting its grant funding from Phase 1 into equity and contributing up to £5m of additional finance)
- 3rd party private cash investors (VCs or industrial partners with an interest in the technology)

The commercial vehicle structure should be designed to allow the Carbon Trust to share the benefits as well as the costs of the project. The Carbon Trust will expect a share of value from exploitation of the Intellectual Property

generated, in exchange for providing a proportion of the costs of the programme to mitigate the associated technology risk. The proportion of each party's share will be established in advance, and will be intended to reflect the value of the contribution of each to the project. It should be noted, however, that the Carbon Trust has no intention of retaining any ownership of Intellectual Property in the long term, and our overall objective remains to enable new, low-carbon technologies to be deployed as quickly as possible.

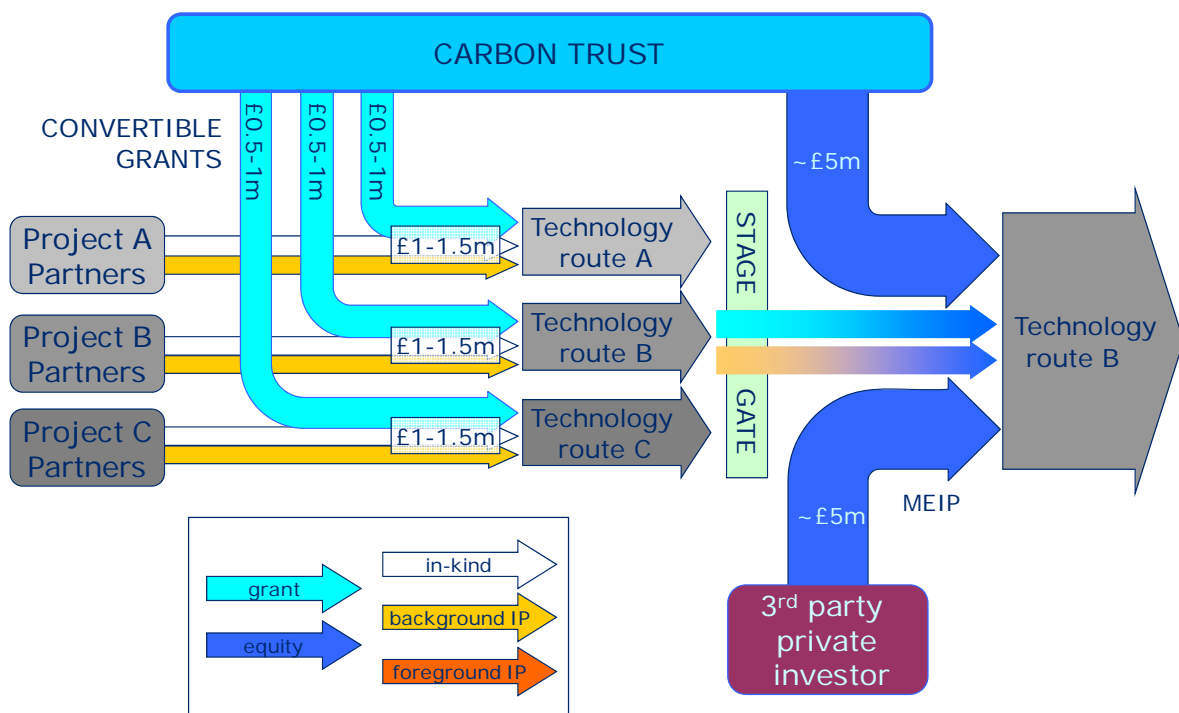


Figure 8: Proposed project R&D funding and commercial vehicle structure

The Carbon Trust's investment will be staged subject to approval by the Carbon Trust Investment Committee, requiring the successful achievement of technical milestones and the continued validity of the technological and business case for the programme. In order to reduce the investment risk of Phase 2, the further investment by the Carbon Trust is also contingent on a similar sized cash co-investment from an third party (e.g., a potential customer or commercial investor). It is therefore essential the project team engages with industry members, and creates a compelling commercial proposition.

Further details on the Carbon Trust's approach to the structure of this Phase 2 commercial vehicle can be found on our [website](#).

About the Carbon Trust

For general information about the Carbon Trust and its mission to accelerate the move to a low-carbon economy, please visit www.carbontrust.co.uk.

About Research Challenges

Research Challenges are distinctive from and complementary to our existing Applied Research programme. Key features of these challenges are the scale of projects and their focus on meeting specific research needs that are facing the most important low-carbon technologies. Within the Research Challenges structure, we typically aim to support the work with commercial investments (with an expectation of a return) rather than offer conventional grants.

Contractual Commitment of this Information Document

This Information document does not constitute an offer by the Carbon Trust to contract. It only represents a summary of the selection criteria for the various phases of the Polymer Fuel Cells Challenge, and an invitation for selected consortia to submit proposals addressing these criteria. Issuance of proposals (Expressions of Interest, Draft or Full Proposals) and the subsequent receipt and evaluation of a proposal by the Carbon Trust does not commit the Carbon Trust to enter into a contract with any bidder – having assessed the quantity and quality of the proposals received, the Carbon Trust may not progress any projects.

The onus is therefore on the research community to show the Carbon Trust that there are a number of sufficiently significant ideas, and as each stage of the PFCC progresses, and selection criteria are met, confirm that the most promising of these ideas have real commercial value, and an economic and carbon benefit to the UK.

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