Written Evidence Submitted by Professor Laura Diaz Anadon, Dr. Anna Goldstein, Professor Erin Baker and Professor Claudia Doblinger (RFA0065)

1. *Introduction*

This evidence submission is written by Professor Laura Diaz Anadon at the University of Cambridge, Dr. Anna Goldstein and Professor Erin Baker at the University of Massachusetts Amherst, and Professor Claudia Doblinger at the Technical University of Munich.

We submit this comment in our personal capacity because our latest empirical study on the U.S. ARPA-E program, which is currently in press in the peer-reviewed journal *Nature Energy,* is very relevant to the Inquiry on "A new research funding agency" launched by the U.K. Science and Technology Committee in the House of Commons.

In this study entitled "Patenting and business outcomes for cleantech startups funded by ARPA-E," we investigated whether the U.S. ARPA-E had translated its unique approach into real-world success for startup companies (Goldstein et al. 2020). The creation of an ARPA for energy (ARPA-E) was recommended by the U.S. National Academies 2007 report, "Rising Above the Gathering Storm," to tackle environmental, competitiveness and security challenges in the energy sector. Since being first funded in 2009, ARPA-E has allocated $3.38 bn 2015USD (Gallagher & Anadon, 2020).

Our study compares ARPA-E funded startups to similar cleantech companies by constructing a dataset of 1,287 U.S. cleantech startups and using patents as a proxy for innovation. We found that companies funded by a fledgling ARPA-E in 2010 went on to file patents at an average of twice the rate of other similar cleantech companies in the years that followed, even when taking into account the differences in patenting activity and private finance prior to 2010.

In this submission, we provide input addressing the questions posed by the Committee based on these empirical insights and our extensive professional experience on these topics, including: (a) consulting for the U.S. National Academies review of the ARPA-E program and 5 years of research into the effectiveness of energy research, development and demonstration (RD&D) approaches (Dr. Goldstein); (b) 12 years of research on the U.S. energy innovation ecosystem, including RD&D programs and national labs (Prof. Anadon); (c) the international RD&D funding landscape, with a particular focus on China (Prof. Anadon); (d) many years of research on government-funded energy R&D portfolios (Profs. Anadon and Baker); and (e) 5 years of research on the cleantech business environment and public-private partnerships (Profs. Anadon and Doblinger).

2. *What gaps in the current UK research and development system might be addressed by an ARPA style approach?*

Similar to the ARPA-type agencies developed in the U.S., the U.K. ARPA should aim at funding "high risk, high reward" research with the goal of fostering major breakthroughs, often by providing greater freedom to take on highly ambitious technical challenges. ARPA-type agencies are enabled by their ability to nimbly hire top program managers (given differentiated contracting requirements) and to quickly tackle new research directions with significant funding amounts (a single program can fund 3-10 projects, each worth around $2-3 million dollars on average.) The current UK funding programs in the energy sector (i.e., various UKRI programs, the energy-related Catapults, and the Faraday Institution) to the best of our knowledge, do not provide such a mechanism in a consistent manner.

One role of U.S. ARPA-E has been to bridge the divide between so-called basic and applied research activities. The other R&D funding offices in the U.S. Department of Energy are categorized as either basic or applied; prior research has found that ARPA-E grants were more likely to publish scientific discoveries as well as patent new inventions (Goldstein & Narayanamurti, 2018) compared to grants of a similar size from those more siloed offices.

If a new ARPA in the UK were targeted at innovation in green technologies to enable the transition to net zero carbon, this would help to counteract the underinvestment in these technologies from the private sector. Technologies such as clean power generation and energy storage can generate large environmental and/or societal value but are out of favour with private investors (e.g., Venture Capitalists) who tend to prefer funding digital innovations with shorter development cycles and higher initial returns (Bumpus & Comello, 2017; Gaddy, et al., 2017).

3. *What are the implications of the new funding agency for existing funding bodies and their approach?*

The ARPA program is not a substitute for existing funding bodies or their approaches. Similar to the U.S.-based model, it would complement the existing funding schemes with a focus on promoting high-risk, high-reward green energy technologies through financial, technical and managerial assistance. The success of U.S. ARPA-E hinges on its ability to attract top managers on time-limited contracts by giving them discretion to craft programs and to actively manage grants through targeted milestones (Goldstein & Kearney, 2020). Adopting this model in the UK would provide a new and valuable mechanism that was, to some extent, present in the (now privatized) Carbon Trust (Anadon, 2012).

In addition to a new ARPA-type agency, complementary innovation policies are also needed to allow scale-up beyond the R&D phase and to ensure that innovations can leverage additional private finance and become commercial products. These policies include increased funding for demonstration and commercialization (Anadon et al., 2014), support for private actors for R&D in the form of user facilities or expertise, which are provided in the U.S. largely from the national laboratories (Doblinger et al., 2019), targeted procurement programs, and niche and early markets to buy down technology costs through learning by doing and economies of scale (Nemet, 2019). Scale-up activities are particularly important in the energy sector given its large infrastructure, interconnectedness and (in many cases) its nature as a commodity.

4. *What should be the focus be of the new research funding agency and how should it be structured?*

We recommend trialling a UK version of ARPA-E. The focus of the U.K. ARPA should be meeting the UK's ambitious net zero carbon target. This would involve supporting next-generation technologies for clean electricity and fuels, energy storage, buildings, transport, industry, agriculture, greenhouse gas removal and nature-based climate solutions. Innovation in these areas can boost productivity and deliver large benefits to society in the long-term, particularly in areas that are difficult to decarbonize such as shipping, aviation, and heavy industry.

Our recommendation is driven by evidence from the U.S. ARPA programs, which shows that ARPA is not a one-size-fits-all solution (Azoulay et al., 2019; Bonvillian, 2018; Fuchs, 2010). ARPA agencies are mission-focused, and there is no evidence to suggest this model would work well as a fund for general science and technology.

The UK ARPA could ramp up innovation in areas key for UK decarbonization and support selected projects through to the demonstration phase. R&D investments in energy transition would be a relatively inexpensive but essential and high impact component of a Covid-19 recovery package (Anadon, 2020). A recent study of expert opinion further supports this view: clean R&D funding is expected to have a positive economic multiplier and the second largest potential climate impact from 25 policy measures considered (Hepburn et al. 2020).

The U.S. ARPA-E was designed in the model of the U.S. defence agency DARPA, with organizational flexibility (reporting directly to the Cabinet Secretary) and with short-term expert program staff who are empowered to pursue the “white space” between existing R&D activities. Based on DARPA’s long track record of accomplishments and recent research in energy, including our latest study (Goldstein et al. 2020), this funding model is expected to produce breakthrough innovations with the potential to transform technology markets.

ARPA-E also adapted the DARPA model in several ways. They created an annual summit to convene researchers, entrepreneurs and other stakeholders and build a strong community around energy innovation. They also created a “tech to market” program, which allows awardees to develop commercialization plans and meet with investors to pursue follow-on innovation funding. Finally, they have also focused on funding teams that include partnerships across different types of organizations, including university labs, startups, and established firms. These adaptations reflect the fact that, unlike in defence where the government itself is the customer for the products resulting from DARPA innovations, energy innovations must transition to private sector customers and end-users.

5. *What funding should ARPA receive, and how should it distribute this funding to maximise effectiveness?*

The U.S. ARPA-E program was established in the U.S. Department of Energy under President Obama, using a portion of the economic stimulus package that followed the 2009 financial crisis. It has been allocated $3.38 billion 2015USD so far (Gallagher & Anadon, 2020). Since 2013 ARPA-E has received over $250 million 2015USD a year, but the agency has been growing slowly over time. Over the past three years it has received an average of $350 million 2015USD. Most of these funds go directly to external research activities rather than to the agency itself; in 2020 ARPA-E had $390 million 2020USD R&D projects and $35 million 2020USD for program direction (Gallagher & Anadon, 2020).

Many scholars and observers have recommended that U.S. ARPA-E should be expanded significantly. The original suggestion in the U.S. National Academies report “Rising Above the Gathering Storm” (NASEM, 2007) was for $1 billion USD per year. DARPA is currently funded at USD $3.5 billion USD per year. Of course, the U.K. has a smaller economy; if $1 billion USD were optimal in the U.S. for ARPA-E, then a smaller amount would likely be optimal for a U.K.-based “Net Zero” or “Climate” ARPA.

In trialling a U.K. ARPA, it will be important to share data with independent researchers and conduct evaluations of the program on a regular basis, similar to the National Academies report “An Assessment of ARPA-E” (NASEM, 2017). That committee noted the difficulties of assessing a long-term innovation effort at such an early stage, yet they found "clear indicators that ARPA-E is making progress toward achieving its statutory mission and goals." Evaluation of a U.K. ARPA may point to opportunities to further adapt the ARPA model for the UK context.

6. *What can be learned from ARPA equivalents in other countries?*

Many histories have been written describing the breakthroughs resulting from DARPA-funded research, although data on DARPA's operations have not been made available due to military secrecy. U.S. ARPA-E on the other hand has been the subject of several recent empirical studies, in addition to the assessment by the U.S. National Academies (NASEM, 2017). One study found that ARPA-E projects frequently produce both a scientific paper and a patent, which suggests ARPA-E's positive influence on innovation at the interface between science and technology (Goldstein and Narayanamurti, 2018). Another study showed that ARPA-E staff actively manage projects and frequently adjust project terms, most often to extend or expand them, but they also cut short or cancel projects based on poor performance, thus mitigating the high-risk nature of the projects they take on (Goldstein and Kearney, 2020).

Most recently, in our study of U.S. ARPA-E funding for cleantech startups, we found that startups funded by the program file patents at twice the rate of similar cleantech firms (Goldstein et al. 2020). The "innovation advantage" bestowed by ARPA-E was not shared by startups funded via other U.S. government programs such as the Office of Energy Efficiency and Renewable Energy (EERE).

Hence, our U.S.-based research points to the value of ARPA agencies in advancing mission-oriented innovation. The UK may well benefit from such an approach in a post-pandemic world, given the technological capital within its universities and private sector.

However, we also found that the ARPA-funded companies fared no better or worse than other similar cleantech startups in terms of business success. This suggests that U.S. ARPA-E has helped startups working on riskier but potentially more disruptive technologies to reach the same levels of success as other, less risky, cleantech firms.

Additional public support mechanisms beyond ARPA-E are needed to help new clean technologies to succeed in the market and fulfill their promise of environmental and societal benefits. U.S. ARPA-E has been an important contributor toward this goal, but this agency alone has not been sufficient to bridge the "valley of death": the phase between initial funding injection and revenue generation during which startups often fold.

7. *What benefits might be gained from basing UK ARPA outside of the 'Golden Triangle' (London, Oxford and Cambridge)?*

One of the key aspects of U.S. ARPA-E is the hiring of expert program staff who are given significant autonomy in creating programs and managing projects. Hence, the location of the UK ARPA agency needs to ensure that these experts have easy access to travel from headquarters to the locations of the awardees and other strategic partners in industry and government. Given the nature of the Golden Triangle as a UK transit hub, as well as the U.S. experience from locating of both ARPA-E and DARPA in the Washington D.C., we would recommend basing the agency there.

However, the research funds should not be limited to certain regions. Instead, ARPA grant-making should take advantage of research capabilities across the entire U.K. and also take the opportunity to strengthen local and regional innovation ecosystems. Many of the startups in the first cohort of U.S. ARPA-E awardees were located in established hubs such as Boston and Silicon Valley, but others were spread across the U.S. in Colorado, Florida, North Carolina, Ohio, Texas and Utah.

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