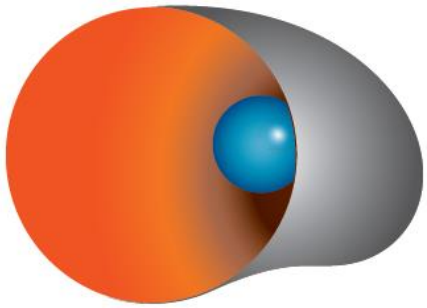


Kyoto Fusioneering

Models for funding fusion enabling technology development

Perspectives from Kyoto Fusioneering

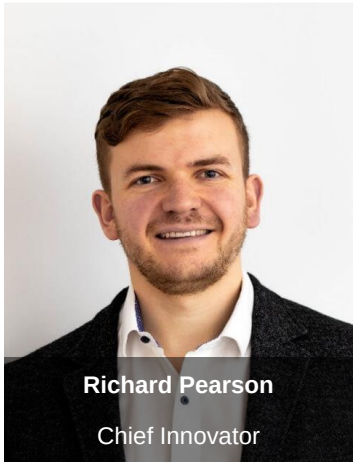
Dr. Richard Pearson – Chief Innovator, Kyoto Fusioneering Ltd

U.S. Department of Energy Virtual ARPA-E GAMOW Program Kick-off

Friday January 22, 2021

Kyoto Fusioneering: Company Overview

- Founded in **2019** in **Kyoto, Japan**
- Japan's *first* fusion start-up!
- Spun-out from **Kyoto University (*Konishi lab*)**
- Funding from **private investors** & **public grants**
  - **Total: $3.3M** (Jan 2021)
- Focused on **commercial development** of key **fusion reactor technologies** (principally in **fuel cycle** & **power generation**)
- Focused on developing **high-performance**, **cost-effective** solutions



Kyoto Fusioneering & GAMOW awardees

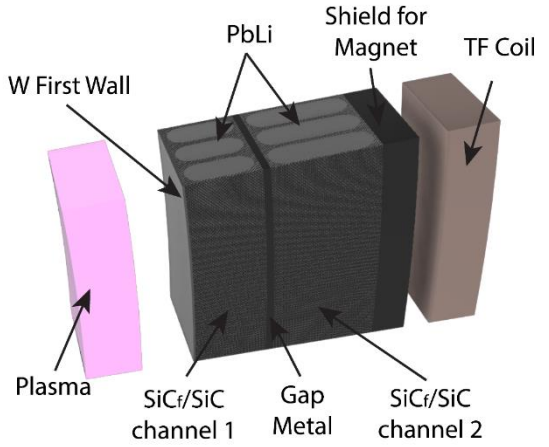
Similar in scope:

- Developing **enabling technologies** for **fusion industry**
  - A "*rising tide lifts all ships*" approach
- Taking **technologies** (typically) originating from **public sector R&D**
- Focused only on technologies with **transformative** potential & with **commercial attractiveness** (low-cost & high-performance)

Occupy space between ***start-ups*** and ***R&D institutions***:

- Whilst <u>not</u> developing a fusion reactor, still pursuing development of **advanced**, **unproven** – and thus **risky** – technologies
- Unlike public sector programs, there is a **high risk of failure**
  - *If they don't succeed, the business (or endeavor) will cease!*

Must develop a robust **business model** & **innovation strategy**



KF's SCYLLA© (Self-Cooled "Yuryo" Lithium-Lead Advanced) blanket concept

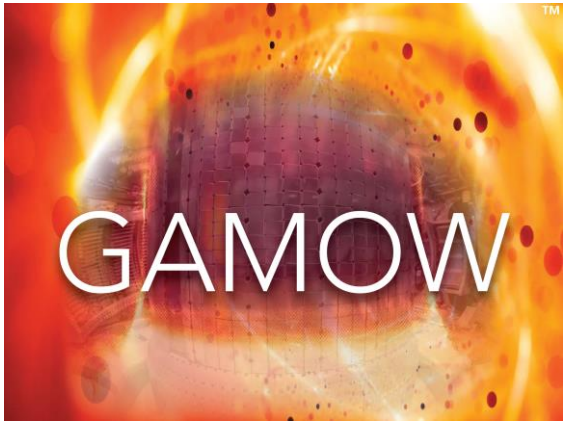


Image source: ARPA-E (public domain)

Business Models

What is a business model?

*"A plan for the **successful operation** of a **business**, identifying **sources of revenue**, the intended **customer base**, **products**, and details of **financing**."*

- Oxford English Dictionary definition

Why are business models important here?

*"getting the **business model** and the **technology strategy** right is necessary to achieve **commercial viability** if sustainable competitive advantage is to be built and **innovators are to profit from their innovations**."*

- Teece, "*Business Models, Business Strategy and Innovation*", (2010)

Levi Strauss & Co.

Image source: Wikimedia Commons.
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Image source: Wikimedia Commons. (Public Domain).

Manufactured durable clothing (jeans) for miners in the Gold Rush, rather than focusing on the *moon-shot* of the gold itself.

SpaceX

Image source: NASA, Wikimedia Commons. (Public Domain).

Founded to develop **advanced** & **low-cost** rocket technology, to *provide a service* to the public and private space transportation sector.

Image source: Bruno Sanchez-Andrade Nuño, Wikimedia Commons. Reproduced under a CC BY 2.0 license.

Rolls Royce

Image source: Julian Herzog, Wikimedia Commons.
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Leading manufacturer of **advanced** & **reliable** jet engine *technology for aerospace companies*

(including via its “TotalCare” service model)

Image source: Matti Blume, Wikimedia Commons.
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ALD Vacuum Technologies GmbH

The **only supplier** with the **required know-how** and **technology** for the job (vacuum metallurgy).

Operates an "*own & operate*" model, whereby the company owns part of the final product, meaning the customer does not need to purchase or provide its own personnel.

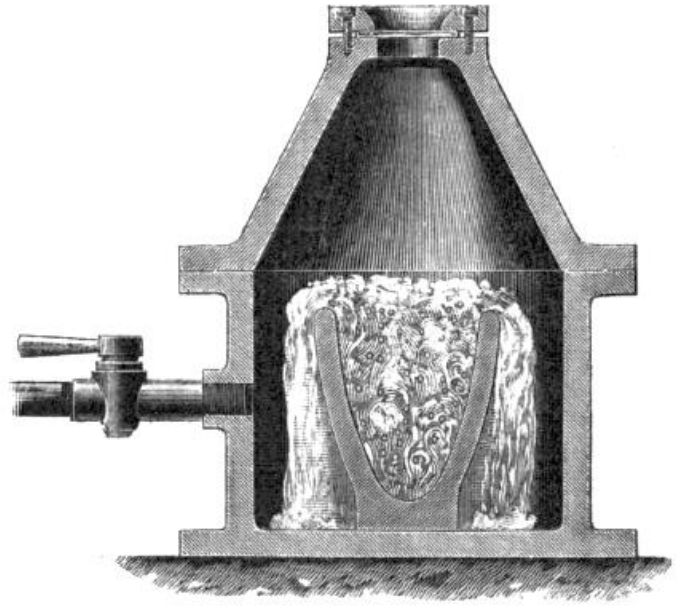


FIG. 76. EXPERIMENTAL APPARATUS FOR EXPOSING MOLTEN STEEL TO THE ACTION OF A VACUUM

Image source: Sir Henry Bessimer, Wikimedia Commons. (Public Domain).

GAMOW awardees *could* follow these models to...

Develop the **engineering & technologies required for overall industry success**, rather than the development of the fusion reactor itself ...

... like *Levi Strauss & Co.*

Develop **advanced, low-cost solutions** that enable fusion developers to commercialise on an **accelerated timescale** ...

... like *SpaceX*

Become **leaders** in different areas of fusion reactor engineering, **providing high-quality components for the industry** ...

... like *Rolls Royce*

Become **experts** in specific fusion reactor technologies, either **becoming the go-to manufacturer for the industry** or to **license their technology** out ...

... like *ALD Vacuum Technologies GmbH*

Innovation

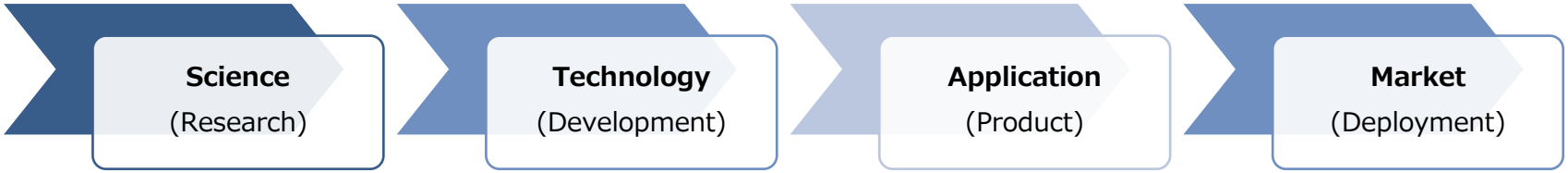
Innovation 101 (*recap from BETHE*)

Innovation is the **application** of **invention**

Key points:

- An invention, in and of itself, does not constitute an innovation.
- There is a major difference between technological innovation & commercialisation.

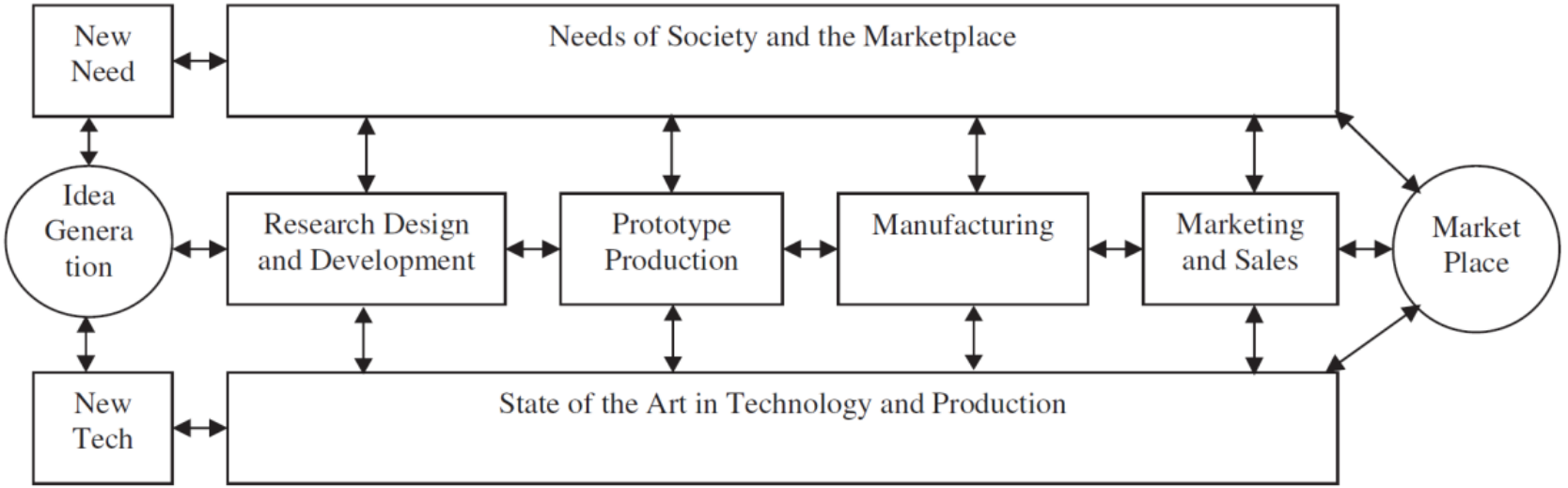
and innovation is a process ...



See BETHE launch presentation slides: https://arpa-e.energy.gov/bethe-kickoff-meeting

… a *dynamic* process

Innovation should NOT be viewed as **linear**, but instead as a **dynamic system**, with feedback between all stages.



Innovation as a system, showing the feedback between stages (Galanakis, 2006)

Need to understand and account for the **requirements**, **actors** and **processes** in both the **front-end** (*technical: R&D*) and **back-end** (*commercial: product for market*) of the system.

See BETHE launch presentation slides: https://arpa-e.energy.gov/bethe-kickoff-meeting

Connecting the front-end & back-end

Actors at the **front-end** & **back-end** have different roles, typically:

- It is not the role of publicly-funded **laboratories** or **universities** to **develop a product for market**
- It is not the role of **private companies** to **conduct fundamental research** to advance scientific understanding

Despite differing roles, **cohesion** is needed:

- **Private sector** must **guide front-end R&D** (*market-pull*)
- **Public sector** must aid **product development at the back-end** (*technology-push*)

Real-world example of **Tesla, Inc.**:

- **Product development** is jurisdiction of Tesla.
- But **advanced batteries** developed with R&D support from **government-backed laboratories & universities**
  - Includes R&D into **manufacturing** and **charging infrastructure** – which, typically, relates to the **"deployment"** stage *(associated with the back-end of the innovation system)*

Image source: Ivan Radic, Wikimedia Commons. Reproduced under a CC BY 2.0 license.

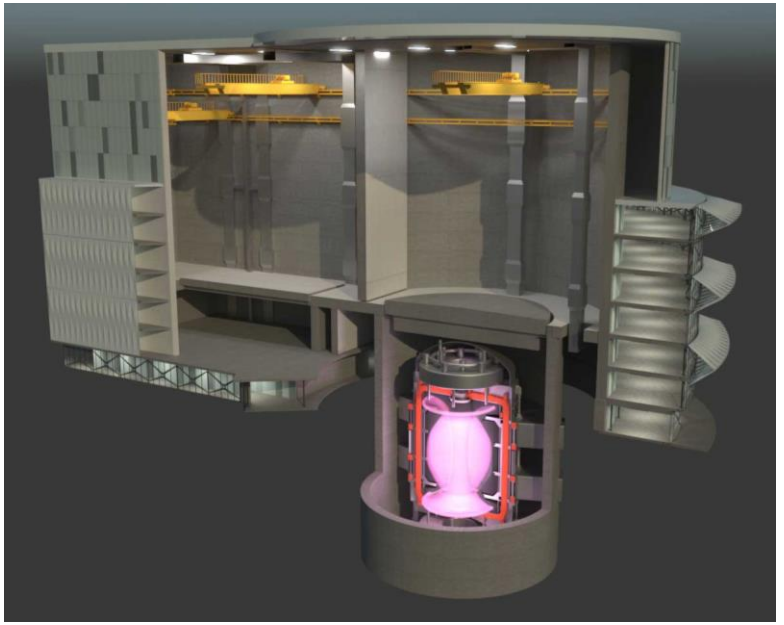
The state of play: fusion innovation

The vast majority of development in fusion has been in the **public sector**, which has had two impacts:

- **National laboratories & universities run** (almost) **all programmes**, with something of a monopoly on **experimental capabilities** and **expertise**.
- Focus has been almost entirely on the **front-end** of the innovation system, *i.e. on **technological innovation** and **not commercialisation**.*

Plans for **next-step demonstration reactors** (*e.g. STEP in the UK*) show **intent** for public sector institutions to **develop a product** for commercialisation

Private fusion developers are **upending** the current **paradigm** by trying to **commercialize** fusion within the **next decade or so...**



The "STEP" reactor concept

Image source: UKAEA. (Public Domain).

Fusion innovation in the public sector

The focus of development in the public sector can be separated into **two categories**, both of which mean that it has **very strong front-end capabilities**:

1. **Fundamental research** to **advance scientific understanding** (of fusion)
2. **Mission-led programs** to **demonstrate** fusion technology (towards the point at which it can be turned into a product).

These two categories are not always complementary. However, the two have become **muddled.** This is epitomized in the **ITER project**, which is intended to both **advance scientific understanding** and provide a **step towards commercial fusion**:

- **Extensive technology R&D** is carried out to **enhance scientific understanding** whilst also **reducing the risk of technological failure**
  - *for ITER, this involves trying to understand the technology whilst also building it into the machine.*
- Such predication with testing to reduce the technological risk **increases costs**, the chance of **delays**, and **technological obsolescence**.
- Somewhat ironically, this **predication on low technological risk increases risk of project failure**, and – at the very least – **limits innovation impact**.

See: BETHE slides & Pearson et al., 2020

Fusion innovation in the private sector

Private sector fusion developers are sharply focused on **commercialization:**

- Pursuing **concepts** that **originate** mostly from **publicly-funded institutions**
- Trying to **transform those technologies into products** suitable for the market
- Aiming to make a **return on investment** to shareholders.
- Often this means a **lack of scientific maturity** (either of the concept or of an **enabling technology**, *e.g. HTS magnets or low-cost lasers*)
- As such, they must **proceed with risk** (and **without understanding**)

Private developers are limited in their:

- **Experimental capabilities** for (mission-relevant) **focused R&D**
- Exploration of **broader technologies** (*e.g. blankets*) that they will one day require to develop a **commercial fusion reactor**.

The public sector has the capabilities to address these, but **how can they be leveraged** in line with the private sector innovation approach..?

... cue, **ARPA-E GAMOW!**

ARPA-E: bridging the gap

ARPA-E blends aspects of the **public** and **private** sector approaches, somewhat bridging:

- Targets **front-end technologies** with **disruptive potential** (for *societal* and *commercial* impact)
- Embraces technologies that are **low maturity** and thus **high risk**
- Mission scope **emphasizes demonstration** ("fail-fast, learn-fast")
- Spurs an **agile approach** by providing **limited resource** and **schedule**
- **Not overly focused on advancing scientific understanding**, but at the same time **does not require the realization of a market-ready product**
- **Avoids bureaucracy** typical of public sector grants

ARPA-E GAMOW (specifically):

- Specifically supports **enabling technologies** that can connect (**bridge**) the front-end and back-end of the fusion innovation system.
- Promotes birth of **specialist fusion engineering companies** to be:
  - **Key partners** to **provide technology** for developers in the **near-term**
  - **A catalyst** for the fusion industry in the **long-term**.

A business vision for GAMOW awardees

Question: *How can fusion engineering companies leverage the best of both public and private sector innovation, whilst operating a robust business model?*

(An) answer:

1. Using **private investment** *and* **ARPA-E** (or similar) grants, **fusion engineering companies** develop **mission-relevant products** for **fusion developers**.
   - *Missions carried out in an agile manner (iterative, rapid "build-test-learn" cycles).*

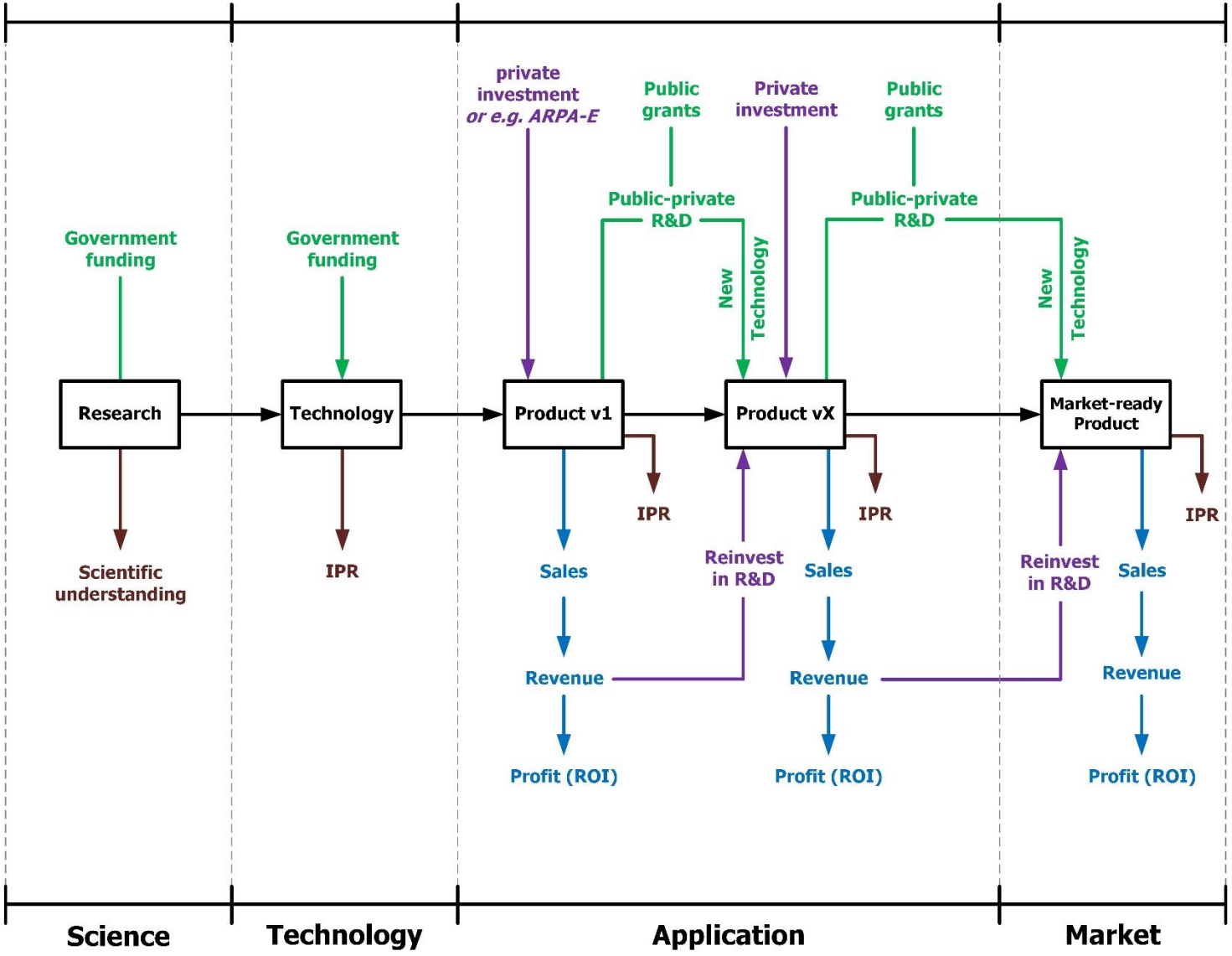
2. New **R&D challenges** arising **during product development** can be addressed by **public sector laboratories and universities** who have the **required capabilities and expertise**, via **targeted R&D programs**.
   - *Potential enabling technologies or new ideas that emerge over time (as a result of scientific exploration) can be "pushed" by laboratory programs.*

3. Product **developed iteratively**, with **product prototypes** being **sold** to **fusion developers**.
   - *Generating IPR, revenue (and profit!)*

4. **Final product developed**, ready to **scale-up production** for the **fusion industry**.
   - *Having already been developed in conjunction with the budding fusion industry, should be focus on smoothing the initial rollout of commercial fusion.*

The biggest challenge might be that this necessitates a shift away from the view that public sector must lead development all the way through to a demonstration reactor...

A symbiotic model for innovation & revenue



Key

- Publicly funded R&D
- Private investment / ARPA-E funding / reinvesting revenue
- Scientific & IPR output
- Revenue generation

Recommendations (my view)

- **ARPA-E model** for **public-private innovation** should **become the norm** for **fusion engineering**.
- **Greater number** of (and **greater funding** for) targeted **ARPA-E fusion programmes**
- Smaller, targeted **"quick-release" funds** with **rapid application-to-award time** (*less than ~6 weeks*) to **address challenges** that could be solved via a **"super sprint"** *(~6 months to 1 year*)
  - Would enable a rapid burst forward (used with great success during the pandemic)
- **Lobby** for **ARPA-E type initiatives** to be launched **in other countries** (*Japan, UK, Canada, EU*)
- Be more aware of **innovation literature & theory**(!), in particular:
  - ***Scientific discovery*** *and* ***inventions*** *are not innovations in and of themselves; it is how we can turn them into something that can* ***tangibly improve the quality of human life (society) and generate economic impact*** *that is important.*

Summary

Business models are important – with a robust model to develop and sell a product, fusion engineering companies can take a good "*slice of the fusion pie*":

- Think about how you will **make a business out of your future product**.

The **public** and **private sector** have **different roles** to play in the **fusion innovation system**; *a shift in thinking is needed*.

ARPA-E GAMOW awardees are in a **strong position** to **bridge** the **public** and **private sectors**:

- Potential to **provide game-changing technologies** to **fusion developers**, giving them the best chance to succeed in their missions.
- Potential to **leverage capabilities and expertise** from **public sector laboratories and universities**, to take the ideas from R&D through to product.

Recommended reading

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Kyoto Fusioneering

Thank you for listening!

E: info@kyotofusioneering.com
W: www.kyotofusioneering.com