UBATTERY®
Local Modular Energy

A Future Energy Solution

Introducing U-Battery

U-Battery is an advanced/small modular reactor, capable of providing a low-carbon, cost-effective, locally embedded and reliable source of power and heat for energy-intensive industries and remote locations. It has the potential to drive significant economic benefits through commercialisation and deployment in global markets.

The conceptual design was developed by the Universities of Manchester (UK) and Delft (Netherlands) after the project was initiated by Urenco, a global leader in the nuclear industry.

U-Battery has always been a commercially-focussed, market-led development, intended to compete with other non-nuclear options. U-Battery's unique concept enables a shorter development timeframe, and a low-cost, low-risk design and licensing process. Its modular design allows quality assurance and testing to occur during the manufacturing stage, while minimising civil construction times, reducing construction risk and financing costs, and easing transportation to global customers.

With the combined support of Urenco and other consortium partners, U-Battery presents a unique blend of economic, industrial and environmental opportunities, and a viable energy solution for the low-carbon economy.

The strategic goal is to have a first-of-a-kind U-Battery operating by 2028.

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Moving forward

The momentum around U-Battery is building rapidly following some key developments:

- The completion of the first phase of the UK government's Advanced Modular Reactor (AMR) programme.
- The release of the Canadian Small Modular Reactor Roadmap, outlining priority recommendations to enable the future deployment of small modular reactor (SMR) technologies.
- Research commissioned by U-Battery into market demand, including industrial applications in the UK as well as mining operations and remote communities in Canada.
- Discussions with government and sector stakeholders around siting first-of-a-kind facilities in the UK and Canada.
- Completion of the first stage of the Canadian Nuclear Laboratories' invitation for siting an SMR demonstration facility.

On the technology development side, continued progress with licensing and design work have confirmed and refined the conceptual U-Battery model toward the next phase of investment opportunities. Advancements include an improved nuclear island (reactor pressure vessel, core design, intermediate heat exchanger, helium pump) and refined conventional equipment including turbine/ generator sets.

The strengthened design has also enabled the next phase of capital cost projections for engineering, licensing, procurement and manufacturing. Engagement with suppliers has elevated confidence in proposed capital cost estimates for U-Battery.

Further engagement with governments, industry organisations, supply chain and licensing authorities in Canada and the UK has confirmed early phase deployment targets. As a result, U-Battery has now begun expanding its design and licensing team in preparation for the next stage of development.

Recent progress:
U-Battery in the UK

In December 2017, the UK Government reassessed the direction of its small modular reactor (SMR) competition and developed a new framework for the advanced modular reactor (AMR) programme, part of the Energy Innovation Portfolio.

Under the revised AMR programme, the Department for Business, Energy and Industrial Strategy (BEIS) committed to investing up to £44 million into a feasibility and development project, which would help take AMR designs closer to commercialisation.

AMRs are categorised within a broad group of advanced nuclear reactors, distinct from conventional reactors, which use pressurised or boiling water for primary cooling.

By design, AMRs can:

- Maximise the use of modular manufacturing and off-site factory fabrication;
- Generate low cost electricity;
- Increase flexibility in delivering electricity to the grid;
- Increase functionality, such as the provision of heat output for domestic or industrial purposes, or facilitating the production of hydrogen;
- Be capable of delivering alternative applications that may generate additional revenue or economic growth.

The AMR programme has two phases:

- **Phase 1** – funding (up to £4 million in available total funding) to undertake a series of feasibility studies for AMR designs. Contracts are worth up to £300,000.
- **Phase 2** – subject to phase 1 demonstrating clear value for money and government approval, a share of up to £40 million could be available for selected projects from phase 1 to undertake development activities. A further sum of up to £5 million may be made available to regulators to support the delivery of these projects.

In the second half of 2018, U-Battery was one of eight vendors selected to participate in phase 1 of the AMR programme. U-Battery developed a feasibility study, which made the technical and commercial case for its design. This study was submitted to the UK government on schedule in December 2018 and January 2019.

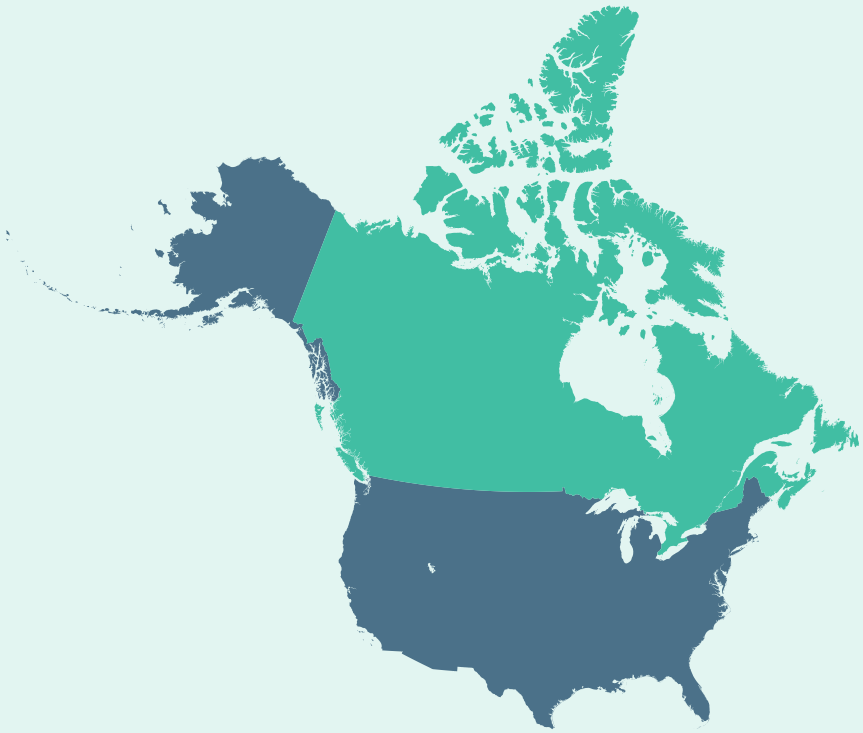
In July 2020 it was announced that U-Battery had progressed through to Phase 2 of the AMR programme and had been awarded almost £10m to conduct design and development work, the next step in bringing the new nuclear technology to market. U-Battery received additional funding from BEIS to design and build mock-ups of the two main vessels for the reactor and the connecting duct. The investment was awarded under the 'Call for Advanced Manufacturing and Materials Phase 2B'.

Recent progress:
U-Battery in Canada

In July 2019, U-Battery completed the first stage of the evaluation process in Canadian Nuclear Laboratories' (CNL) invitation to site a first-of-a-kind small SMR in Chalk River, Ontario. The U-Battery demonstration project will advance CNL's mandate to be recognised globally as a leader in SMR prototype testing and science and technology support.

The Government of Canada's SMR policy document, A Call to Action: A Canadian Roadmap for Small Modular Reactors, was released in late 2018 and identified the need to establish a demonstration site for SMRs at one or more locations in Canada. The roadmap recommended that Canada should be making strategic investments to capitalise on SMR opportunities, as "early-mover advantage will be critical to capturing global market share."

U-Battery has established a service agreement with the Canadian Nuclear Safety Commission for pre-licensing Phase 1 vendor design review, as well as a memorandum of understating (MoU) with Bruce Power for design review and feasibility services. Combined, these agreements will help ensure that U-Battery's design is well-positioned to meet regulatory and feasibility requirements as well as Canadian codes and standards as it works towards commercial deployment.



The U-Battery design

Why U-Battery?

Affordable: Factory manufacturing process. U-Battery's estimated capital cost will be £40-£70 million ($66-$115 million CAD). In the markets and applications intended, it will be competitive or leading in the cost of heat and power, and support Net Zero.

Flexible: Deployed locally to demand, significantly reducing grid and infrastructure costs.

Simple construction: Two-year construction period. Adaptable configuration to meet local needs. It can be installed above or below ground level, in single or in multiple units.

Inherently safe:

- Gas cooled - helium in primary circuit, nitrogen in secondary circuit.
- High integrity TRISO Fuel.

Beneficial to local economies:

- Sustaining foundation industry jobs.
- £2.8 billion direct gross value added.
- £1.8 billion indirect gross value added.

Heat and power generation: 10MWt thermal that can be delivered in a cogeneration configuration with up to 4MWt electricity (MWe) and 710° process heat.

Low-carbon: An alternative to other fossil fuel based energy sources, benefiting the environment and enabling a low carbon economy and hydrogen economy.

Complementary: It complements other low emission technologies in support of Net Zero.

Adaptable:

- Hydrogen production
- Off-grid locations.
- Back-up energy supply.
- Potential linkage to energy storage systems.

About TRISO fuel

U-Battery is powered by accident tolerant TRISO fuel, which prevents the release of radioactive material, minimising the need for back-up shutdown systems.

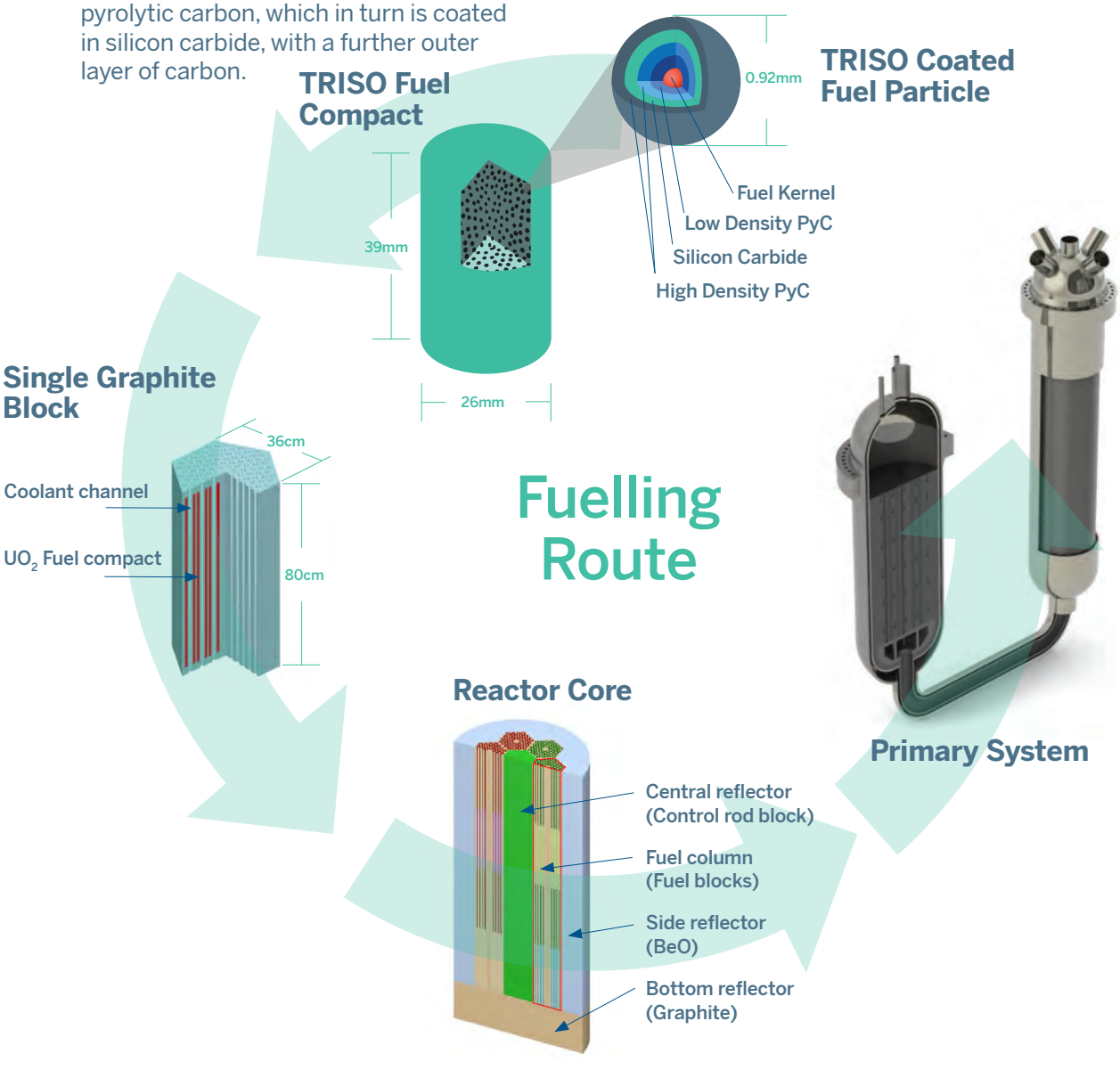
The reactor size and design, when combined with robust fuel, delivers inherent safety and reduces the size of any emergency planning zone allowing the energy source to be located directly adjacent to the point of use.

TRISO fuel is constructed by triple-coating spherical particles of uranium fuel.

A uranium centre is coated in a layer of pyrolytic carbon, which in turn is coated in silicon carbide, with a further outer layer of carbon.

The structure and spherical shape of TRISO fuel means that it maintains its integrity under extreme conditions.

TRISO fuel is proven technology. It was originally developed in the 1960s and has been manufactured recently in the USA by BWXT. The fuel has been developed and tested, in applications that far exceed what is needed for U-Battery, under a programme funded by the US Department of Energy (Advanced Gas Reactor Fuel Development and Qualification Program).



Markets

- Conservative estimates value the global SMR market at £92 billion ($150 CAD billion) between 2025 and 2040. U-Battery's cogeneration capabilities provide a key advantage as many markets possess a need for both heat and power generation. Further, a co-generative deployment is notably cost-effective as it eliminates the need to further develop and connect to an electricity grid. A fleet approach would be adopted, using the same design at different locations.
- In the UK, some industries require high temperature process heat for their operations and currently operate by either using electricity from the grid and converting it to heat or by burning fossil fuel. In 2018, the UK industrial sector consumed approximately 14% of all energy used and 73% of the coal[1].
- U-Battery has conducted an analysis of the potential market size for heavy and energy intensive industrial sites that are seeking to decarbonise. Six industries were found to be technically suitable for deploying a U-Battery, and there was a high level of interest amongst energy managers for these industries, with a market size of potentially 200 sites.
- In Canada, there are many remote communities and mining operations that rely on diesel generation for power and heat, since they are not connected to a centralised electricity grid. The average local energy cost is two or three times the national average.
- There are also remote locations globally and parts of the developing world where deployment would alleviate the need and cost of building a national grid.
- In the nuclear industry, U-Battery could double as an always-on emergency generator for larger nuclear power plants.
- Desalination is a further application. Currently there are 18,000 desalination plants around the world with an annual demand of an additional 1,000 units.
- The burgeoning hydrogen economy is a further potential market where the process heat of the U-Battery could be a valuable asset and repurposed.
- U-Battery is best operated at full capacity and other uses for excess power include greenhouses and district heating.
- U-Battery can also be used as part of a hybrid energy system integrating multiple energy sources to increase efficiency and reliability.

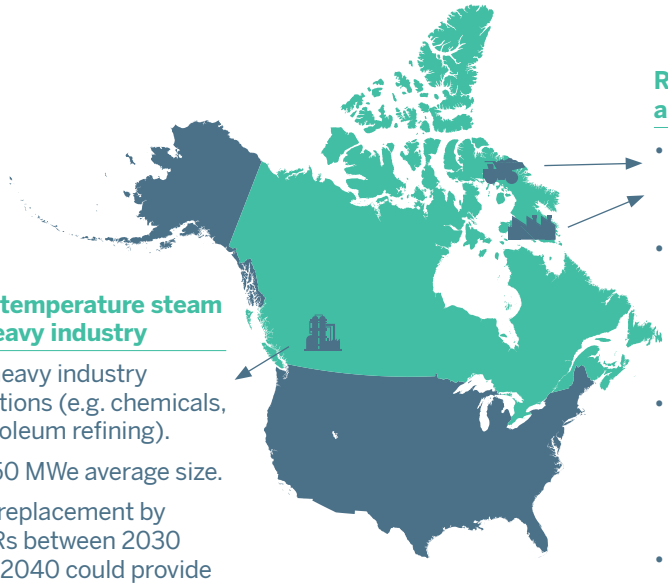
[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data file/820243/DUKES_2019_MASTER_COPY.pdf

Markets

UK's energy intensive industries and market potential

Sector	No. of U-Batteries	Use
Glass	14	Heating raw materials and annealing
Paper	20	Drying paper
Steel	20	Less likely - very sensitive to price
Ceramics	50	Process heat need 220-650°C for drying and spray drying
Minerals	10	Cement production
Chemicals	Large and varied	Heating fluids at 450°C

Canada's heavy industry, remote communities and mines



High-temperature steam for heavy industry

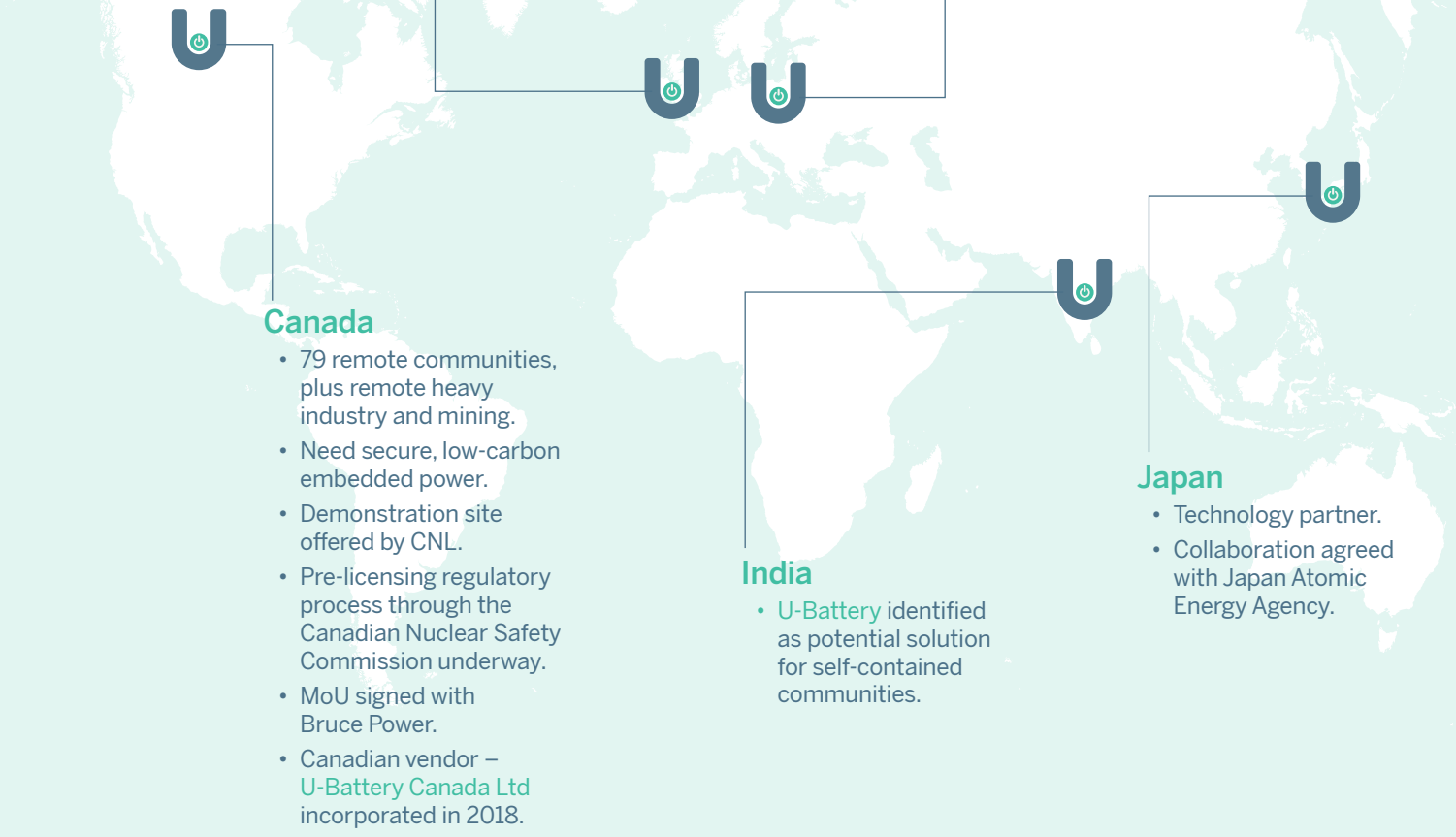
- 85 heavy industry locations (e.g. chemicals, petroleum refining).
- 25-50 MWe average size.
- 5% replacement by SMRs between 2030 and 2040 could provide $46 million in value annually.

Remote communities and mines

- 79 remote communities in Canada with energy needs >1 MWe.
- SMRs replacing costly diesel and heating oil could reduce energy costs to the province or territorial government.
- The high cost of energy from diesel is a barrier. SMRs could facilitate and enable new mining developments.
- 24 current and potential off-grid mines.

Source: National Resources Canada Roadmap. November 2018.

Focus areas



United Kingdom

- Export-focused technology, manufacturing and supply chain opportunity.
- High tech IP, advanced manufacturing facility and jobs.
- Decarbonise heavy industry.
- Global leadership in a new global energy technology sector.
- UK vendor – U-Battery Ltd incorporated 2017.

Poland

- Carbon intensive heavy industry.
- Seeking long-term energy independence.
- U-Battery identified by Polish authorities as potential solution.
- Letter of Intent to investigate early deployment.
- Task Force for high-temperature reactor development.

Canada

- 79 remote communities, plus remote heavy industry and mining.
- Need secure, low-carbon embedded power.
- Demonstration site offered by CNL.
- Pre-licensing regulatory process through the Canadian Nuclear Safety Commission underway.
- MoU signed with Bruce Power.
- Canadian vendor – U-Battery Canada Ltd incorporated in 2018.

India

- U-Battery identified as potential solution for self-contained communities.

Japan

- Technology partner.
- Collaboration agreed with Japan Atomic Energy Agency.

About us

Consortium

Organisation	Key capabilities	Overview
urenco The Energy to Succeed	Fuelling existing and advanced nuclear reactor technologies	A leading international supplier of uranium enrichment services and fuel cycle products.
Jacobs	Project management and nuclear engineering	Jacobs provides a full spectrum of professional services including consulting, technical, scientific and project delivery for the government and private sector. In the nuclear services sector, Jacobs has 60 years' experience of nuclear reactor design in the UK and has been responsible for the design and implementation of a significant element of the existing UK fleet of nuclear power plants.
KINECTRICS	Licensing support in Canada	An engineering, testing, inspection, certification and consulting company providing lifecycle management solutions for the electricity industry; from power generation to transmission and distribution.

Supporting organisations

NUCLEAR AMRC

NATIONAL NUCLEAR LABORATORY

cavendish nuclear

MANCHESTER 1824 The University of Manchester

TU Delft Delft University of Technology

Our team

Steve Threlfall
General Manager, U-Battery

Steve Threlfall is U-Battery's General Manager and leads its development. During his thirty-year career at Urenco, Steve's prior experience includes directing the company's uranium activities and the successful delivery of commercial projects.

Sean Donnelly
Team Lead - Canada, U-Battery

Sean Donnelly is a professional engineer and an experienced technical contributor and integrator in a wide variety of multi-disciplinary projects including new build programmes, nuclear safety assessment, and licensing. Sean is currently the Director of Innovation at Kinectrics and is responsible for the company's involvement in Small Modular Reactors as well as other innovative technologies across the electricity sector.

Chris White
Director of Government Affairs, U-Battery

Chris White has responsibilities covering government affairs across the UK, and supporting the Group's engagement in emerging markets. Chris' specific focus is leading on government engagement and outreach activities, to optimise the Group's standing and influence with external stakeholders, in support of the Group's strategic and commercial objectives.

David Fletcher
Head of Business Development, U-Battery

David Fletcher serves as Head of Business Development and a member of the Commercial Lead Team, with responsibilities that include the development of Urenco's front-end fuel cycle capability for the next generation of advanced reactors. David holds an Honours Degree in Civil Engineering from University of Surrey and an MBA from London Business School.

Professor Tim Abram

Chief Technologist, University of Manchester

Tim Abram is the Westinghouse Chair in Nuclear Fuel Technology at the University of Manchester. Prior to joining the University, Prof. Abram was the Senior Research Fellow for Fuels and Reactor Systems at the UK's National Nuclear Laboratory, where he retains the position of Associate Fellow.

John Eldridge

Engineering Consultant, U-Battery

John is a Chartered Engineer, Fellow of the Institution of Mechanical Engineers and Royal Academy of Engineering, and a Visiting Professor at the School of Engineering, University of Liverpool. He has over 40 years of experience in the nuclear industry including reactors, irradiated fuel processing, fuel storage and waste treatment plants.

Andrew Bailey

Director of Specialist Consultancy and Defence, Critical Mission Solutions-International, Jacobs.

Andrew is responsible for leading Jacobs SMR strategy and delivery for Gen III and Gen IV reactor power plants. He has a technical degree in Chemical Engineering plus a Masters degree and Diploma in Business, and has over 25 years' experience in providing technical engineering delivery into the Process Industry.

Andrew Johnstone

Technical and Licensing Lead - Canada, U-Battery

Andrew Johnstone has over 15 years of experience in the Canadian nuclear industry with multi-disciplinary projects in the areas of safety, licensing and operational support. Andrew has managed a number of technically complex projects for various clients, including Small Modular Reactor licensing, regulatory and design review support. Andrew was intimately involved in the review of vendor documentation for potential New Nuclear Build in Ontario, as well as licensing support and technical reviews of new reactor design options for Canadian licensees.

Greg Willetts

Vice President Technology & Consultancy, Critical Mission Solutions-International, Jacobs

Greg has 30 years' experience in the nuclear industry and has spent 20 years in business leadership positions. He is responsible for all aspects of Wood's 650 strong Technology & Consultancy business which is part of Jacobs Critical Mission Solutions business. This business combines the strength of the wider Jacobs global business with the Wood Nuclear expertise which it acquired in March 2020.

Mei Tamkei

Thermal Performance and Analysis Lead, Kinectrics

Mei Tamkei, P.Eng, has worked in the Canadian nuclear industry since 2003 specialising in thermal hydraulic analysis, thermal performance modeling, and safety analysis. She has developed various operational safety and licensing cases focused on the application of thermal hydraulic models for nuclear utilities, and is highly experienced in leading large, multi-disciplinary projects. Mei is currently leading the development of the U-Battery thermal performance assessments.

Richard Stainsby

Chief Technologist, Advanced Reactors Group, Critical Mission Solutions-International, Jacobs

Richard is a Chief Technologist within the Jacobs Advanced Reactor Group and a key member of the U-Battery project team responsible for developing the design of the reactor power plant to date and the consequent research and development programmes for the primary and secondary systems. Richard has 35 years of experience working on advanced reactor systems featuring gas and liquid metal coolants. He has served as the Co-ordinator of two Euratom projects on the development of high temperature gas-cooled fast spectrum reactors (GCFR STREP and GoFastR) and is a Visiting Professor for Nuclear Energy Systems at the University of Manchester.

Kellie Foster

Project Engineer - Canada, Kinectrics

Kellie Foster is an associate analyst in the Nuclear Safety and Licensing Division at Kinectrics, specialising in new nuclear developments including Small Modular Reactors and New Builds in Ontario. She has significant experience in the areas of operational nuclear safety, licensing and regulatory support for new and existing utilities, and project management.

Peter Bradley

Senior Commercial Manager, U-Battery

Peter Bradley is the lead for procurement, techno-commercial assessment and financial control. He has worked in the chemicals, energy and professional services sectors, including roles within engineering and design management, financial deal advisory, procurement management and industrial commercial management. He remains the Urenco procurement global lead for energy and utilities.

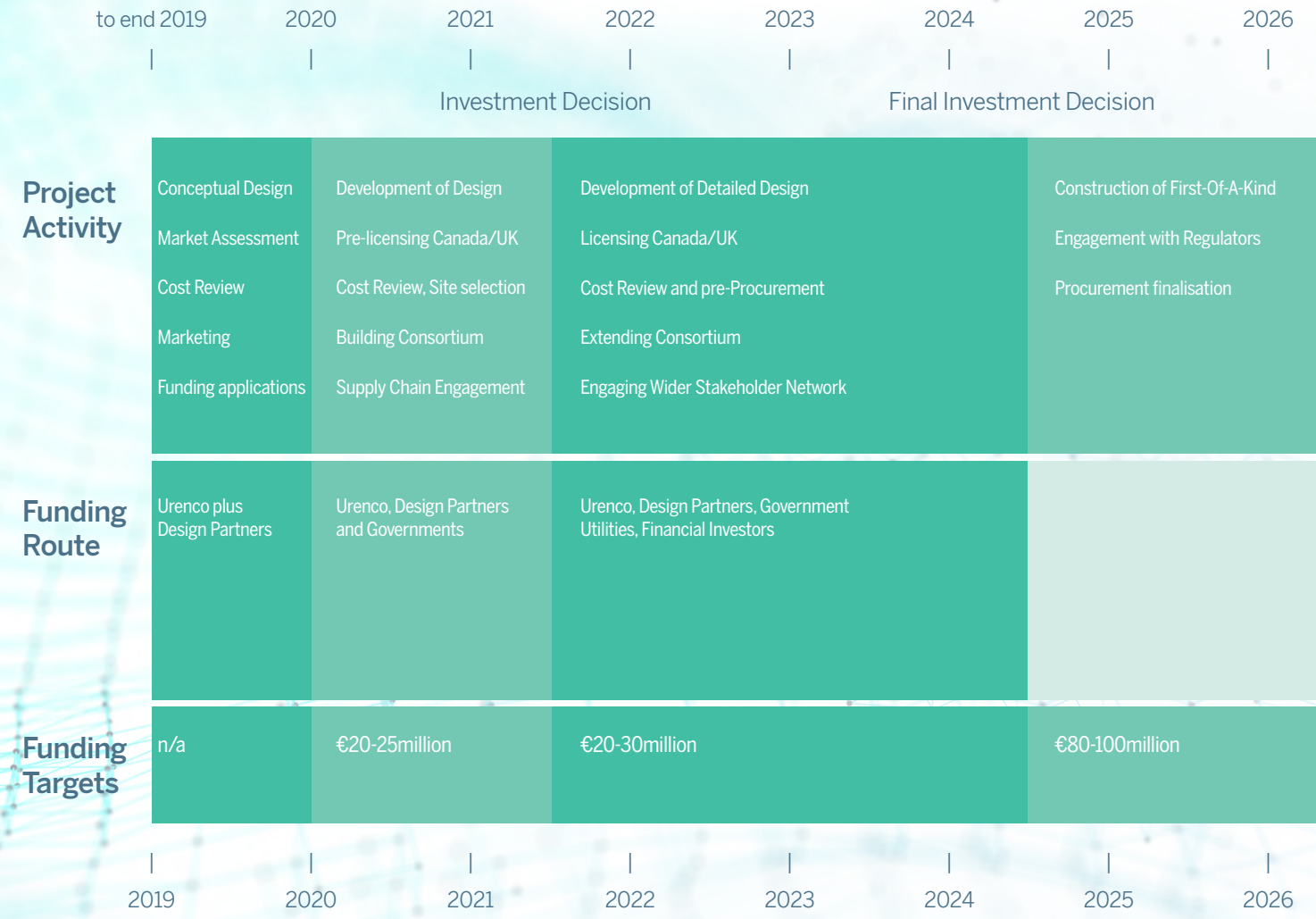
Paul Clarke

Project Director, Group Projects, Urenco

Paul is responsible for managing the delivery of the U-Battery activities and brings 37 years of experience in projects, operations and engineering from the nuclear, oil & gas and chemical sectors. He has worked for several multi-national companies, managing large teams to deliver work in complex environments, including nuclear power generation and nuclear new build.

Timeline

U-Battery enters development phase*



* As at December 2019

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