ACADEMIC COUNCIL REPORT

SESSION:

Public ☒

ACTION REQUESTED:

Decision ☒
Discussion/Direction ☐
Information ☐

Financial Impact ☐ **Yes** ☒ **No** **Included in Budget** ☐ **Yes** ☒ **No**

TO: Academic Council

DATE: February 20, 2020

PRESENTED BY: Les Jacobs, Vice-President, Research and Innovation

SUBJECT: Establishment of the Centre for Small Modular Reactors at Ontario Tech University

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COMMITTEE/BOARD MANDATE:
In accordance with Article 1.4(b) of By-law No. 2 and the Procedures for the Creation of Research Entities, Academic Council makes recommendations to the Board on matters including the establishment of research centres.

Recommendation: The Research Board, at its February 6, 2020 meeting, reviewed the proposal by Dr. Kirk Atkinson from the Faculty of Energy Systems and Nuclear Science to establish the Centre for Small Modular Reactors and unanimously approved the motion of a recommendation that it go forward to Academic Council.

We request that Academic Council review the Centre for Small Modular Reactors proposal and find it appropriate to recommend to the Board of Governors for approval.

BACKGROUND/CONTEXT & RATIONALE:
Ontario has traditionally had a thriving nuclear industry and has relied on electricity generated by its three Nuclear Generating Stations (NGS) to power its homes and businesses. In the 1970's, Canadian engineers and scientists successfully designed the Canadian Deuterium Uranium (CANDU) reactor, the first of which produced 1744 Megawatts of heat and 515 Megawatts of electricity. The CANDU design was improved in the following decades and has been exported to Argentina, China, India, Pakistan, Romania and South Korea. There are currently 18 CANDU reactors operating in Ontario, along with one in New Brunswick. In 2025, one quarter of the nuclear generating capacity in Ontario will be lost through the planned closure of the six reactors at the Pickering NGS in Durham Region. This loss of generating capacity will need to be replaced in the near-term by fossil-fuels, as evidenced by Ontario Power Generation's (OPG) recent acquisition of gas-fueled power stations, and will reduce Ontario's ability to meet its climate change targets and in so doing diminish its green credentials. Whilst in the medium-term construction of new

CANDU units would be an option, experience from around the world has shown that building Gigawatt-scale reactors is too great an economic risk.

Recognizing the benefits of diversified power generation, and taking advantage of modern manufacturing techniques whilst understanding the need to comply with more stringent safety regulations; for the past decade a number of vendors have proposed Small Modular Reactor (SMR) designs that are 10-100 times smaller than the existing power reactors. Capable of being built in a factory where they can benefit from improved quality control and economies of scale, they can be transported to and from site using road, rail, or water-based transport. These transportation options facilitate deployment in remote, often indigenous, communities where energy supply is a limiting factor in quality of life and economic development, or to support energy-intensive extractive industries such as mining. The potential of SMRs has led to many nations racing ahead to realize the fiscal and employment benefits gained through being an early adopter. As well as being capable of meeting base-load and surge electricity demands, SMRs could potentially be manufactured quickly enough to provide the province, and Canada, with a major source of near-zero-carbon energy within the next ten years. To date, eleven SMR designs have been submitted to the regulator, the Canadian Nuclear Safety Commission (CNSC), for consideration.

Following the methodology developed by Rolls-Royce, the UK technical authority for small pressurized water reactors (PWR's) used on-board nuclear submarines, the SMR life cycle has six stages: Assessment, Concept, Development, Manufacture, Use, and Disposal. The first three stages are collectively referred to as `design'. All eleven SMR vendors have done some initial market analysis and requirements capture, and all have successfully completed concept designs. All vendors are currently at the development (detailed design) stage. None of the eleven proposed SMRs has been manufactured and the first is unlikely to be operational until at least the mid-to-late 2020s. OPG has not yet selected a preferred vendor, or vendors, for commercial deployment.

Many of the eleven proposed SMR designs are based on, or adapted from, feasible concepts last investigated in the 1960's. Whilst a number of prototype reactors were built and operated during this period; the scientific understanding, technical capabilities, and regulatory oversight of today was not there. As a consequence, despite some of the early prototypes, or their underpinning technologies, showing great promise; all SMR vendors must undertake significant research and development (R&D) before they will be able to build and operate first-of-a-kind (FOAK) systems. Moreover, responsibility for the environment now requires that proposed SMRs undergo extensive environmental impact assessment, including their whole life carbon footprint, and be `designed for disposal', a complicated endeavor given its socio-political dimensions. The speed at which R&D work can be completed will largely determine which design is first to market. Some vendors have indicated a commitment to manufacture all, or part, of their SMRs in Canada.

Nuclear engineering, like automotive engineering, is an application-focused field-of-study rather than a subject in its own right. Engineers and scientists, whether they be working on mechanics, electrics, controls, or human factors, along with professional colleagues working in such domains as ethics, business, and public relations, are all necessary to bring a new product to market. In the case of automobiles, Ontario Tech University has recognised the need for this multi-disciplinary approach through the establishment of the Automotive Centre of Excellence (ACE). All universities undertaking significant nuclear reactor-focused research across more than one domain have opted to establish a research centre to focus their efforts.

Despite strong interest nationally, no academic research centre focused exclusively on SMRs has, to date, been established and hence there exists the time-limited opportunity for Ontario Tech University to become the focal point for SMR research in Canada. Moreover, uniquely in Canada, Ontario Tech currently has the only two faculty members with real-world industrial experience of SMRs. Prior to joining the university in January 2019, for a decade, Dr. Atkinson worked in the UK

Naval Nuclear Propulsion Programme (NNPP), most notably as Technical Lead for Reactor Physics and High-Performance Computing, and later as Technical Lead for Radiation Physics and Criticality. Involved in multiple aspects of research, consultancy, education and training in support of light-water cooled pressurised water reactors (PWRs), Dr. Atkinson has deep experience in the design, manufacture, operation, and decommissioning of these canonical SMRs. Dr. Tokuhiro joined Ontario Tech in 2017 after several years as Senior Principal Engineer at NuScale Power, a PWR-based SMR start-up in Oregon, and leading vendor in North America. Prior to this, Dr. Tokuhiro worked on small fast reactors. According to Ontario Power Generation (OPG), subject to financial and regulatory approval, it is likely that installation of Canada's first grid-scale SMR will commence in Durham Region (at the Darlington new-build site) mid-decade, first power being intended for 2028. Given the short timescale it makes a light-water cooled reactor (i.e. a PWR) the only near term viable option.

Branching out of the Faculty of Energy Systems and Nuclear Science (FESNS), the Centre for Small Modular Reactors (hereafter referred to as "CMSR" or "the centre") will become a major focal point and single point-of-contact for SMR research, consultancy, education and training within the university, in Canada, and Worldwide. At its heart is the principle that the whole is better than the sum of its parts. CSMR will bring together the diverse capabilities of individual university academics and research groups, leveraging their combined expertise towards SMR-specific problems, setting the narrative for Canada's burgeoning SMR industry, and allowing more significant funding opportunities to be exploited. Requiring large and often World-leading teams, such opportunities include Ontario Research Fund Research Excellence campaigns and New Frontiers Research Fund Transformation grants, each of which potentially offers funding circa $1M per annum. In this regard, Dr. Atkinson has received an encouraging level of support from Ontario Power Generation (OPG), SNC-Lavalin Group, Kinectrics, U-Battery Canada, Westinghouse Electric Canada, Terrestrial Energy, Promation Nuclear and Ecometrix. Initially, for the purposes of this proposal, membership of CSMR has been drawn from a quorum of persons within FESNS that have significant SMR-related experience. It is intended that, through the centre, any Ontario Tech faculty member (or indeed any Canadian academic) with serious interest in SMRs can become 'SMR-ready' by working with more experienced colleagues, as well as gaining increased credibility through membership.

RESOURCES REQUIRED:

Physical Requirements

Due to the virtual nature of the centre, where the capabilities and facilities of individual faculty members' research groups are leveraged towards the collective effort; **no additional office or laboratory space is currently required**. If a project manager is hired (e.g. as required by a large Ontario Research Fund submission), they would co-locate with the Graduate Program Manager in ERC 4026. It is also proposed that the large graduate student office, ERC 4100, be subdivided such that one half houses the graduate students who are employed on centre-based projects. There is sufficient free desk space in ERC 4100 to accommodate a twofold increase in graduate students if hot-desking is enforced. It is projected that a maximum twofold increase in cross-faculty graduate student enrollment could occur if all targeted grants were successful.

Staffing Requirements

Upon establishment, **no additional support staff are required**. Administration, advertising and website/social media maintenance will be undertaken by CSMR members in the first instance. Subject to sufficient funding being secured (e.g. from a large program grant), a project manager will be employed to co-ordinate work packages and undertake some of the other administrative functions. Additional staff support (e.g. technician time) will follow a pay-on-demand model, again reflecting the expand and contract model of operation. Graduate and undergraduate students will be employed in the normal way, and visiting scholars will be hosted on an ad-hoc basis in accordance with Ontario Tech University policy.

Budget and Financial Requirements

No start-up funding is requested. The Faculty of Energy Systems and Nuclear Science will underwrite the administrative (i.e. communications and advertising, and one, one-day on-site workshop per annum) costs of the centre from its operating budget unless and until external funding is secured. These costs are not expected to exceed $7500 per annum. Given that many of the initial meetings required to establish the centre and build-up partnerships will either be in the GTA, or can happen at major events which faculty already attend (e.g. the Canadian Nuclear Association conference), costs of travel will be borne initially by individual faculty members. As one of the aims is to be a force-multiplier for existing strengths; it is intended that the centre be able to be adaptable to funding, yet be able to successfully operate with a limited budget. The limited budget is the planning assumption, although larger revenues and hence larger budgets are expected (e.g. the Ontario Research Fund submission requested a cash budget of $3,162,686 over five years). **No unsecured funding has been assumed** for budget planning purposes. Given FESNS has control over, and experience of delivering training courses, a conservative estimate of revenue from such courses **has** been assumed. Profits will be shared between the centre, the faculty and the University following existing precedent. In addition to this Prof. Atkinson has recently conditionally secured five [5] years of SMR-relevant funding through a UNENE/NSERC Industrial Research Chair and, in 2019, Prof. Tokuhiro secured six [6] years of NSERC CREATE funding for up to four graduate students. SMR-focused Alliance and CREATE grants are planned for submission in 2020. It is anticipated that additional opportunities will stem from NRCan and the Canada-UK dialogue if CSMR is established.

IMPLICATIONS:

Ontario Tech has exceptional individual expertise in SMR or SMR-related topics, as well as growing infrastructure and equipment capabilities. Most recently, in addition to its health physics dose response facility, its design lab, and its materials and chemistry labs, FESNS has commissioned a two-storey (9 m) thermal-hydraulics loop, a unique facility in Canada and ideal for validation and verification (V&V) work that SMR vendors must undertake in order to get regulatory approval. Currently, FESNS is in the process of acquiring a unique graphite-based subcritical reactor that industry has already expressed an interest in using for V&V activities. Given the diversity of disciplines (i.e. nuclear materials, reactor physics, thermal hydraulics, radiation protection, control and instrumentation, etc.) needed to support nuclear projects, the burgeoning SMR industry is looking for academic partners of sufficient size and, currently, despite being the only school in Canada with faculty member experts across the full range of disciplines, Ontario Tech does not effectively project that. SMR funding is starting to become available and, thus far, small amounts are going to our competitor universities. Worse still is the fact that, as these competitors do not have the full range of capabilities needed to complete larger projects, funding is being sent overseas (especially to the UK and US) where nuclear researchers have set up centres of excellence.

Ontario Tech is losing market share in what should be one of its key markets. This must cease immediately. There is currently a short window of time during which Ontario Tech can address this and hence take the lead before other have time to adapt. By bringing together its disparate existing capabilities under one umbrella, not just from FESNS, but from all faculties, Ontario Tech will be able to demonstrate it has the size and scale to undertake this important work. This is a one-time opportunity, SMRs will start being built in the next five years, and in ten years the first SMR will be connected to the grid. This is a Worldwide phenomenon and Ontario Tech is ideally placed to take advantage of this nexus in energy production. Moreover, by having an established SMR brand, we become the go-to place in Canada, which has the added benefit of public relations opportunities and increased visibility. There is currently no SMR centre in Canada, but if we delay there will be.

In terms of timeliness, this proposal reflects several external factors, the most important being the SMR timeline described above. In addition to this the forthcoming Canadian Nuclear Association (CNA) conference in Ottawa is an ideal forum at which to publicise the centre, especially since

Prof. Atkinson is joining the CEO of Canadian Nuclear Laboratories (CNL) and the CTO of Westinghouse, on a panel discussing 'SMRs as a disruptive technology', and because several strategic meetings on the way forward for SMRs in Canada are being held. Following on from the 2019 meeting, contracts were signed with competitor universities for a number of work packages. Through CSMR, Ontario Tech will be better able to challenge for this work. Furthermore, Prof. Atkinson has been asked by Natural Resources Canada to join the Canadian government delegation to the UK (led by the Associate Deputy Minister, Shawn Tupper) in March 2020. During this dialogue, SMR collaboration at the industry and academic levels are key agenda items, the outcome of the meeting being a harmonization of efforts between the two countries. From this, it is expected that opportunities funding will result. As UK centres above will be in attendance, through the vehicle of CMSR, Ontario Tech can challenge for a key role in this international development. Once again, this is a one-time opportunity for Ontario Tech to demonstrate it is a leader in the SMR field.

ALIGNMENT WITH MISSION, VISION, VALUES & STRATEGIC PLAN:

Given its industrial partners (i.e. OPG) and the threat posed by climate change; energy was one of the cornerstone themes in UOIT's 2013-2020 Strategic Research Plan, and remains as such in the Ontario Tech 2020-2025 research plan currently under review. Moreover, the President of the university is currently pursuing an energy initiative which may culminate in Ontario Tech becoming a regional hub or larger institute. Together with the Clean Energy Research Laboratory (CERL), and the extensive work undertaken on hydrogen-based fuel, CSMR would fit under this umbrella and be a distinct part of this endeavour. More broadly, the 2019 Ontario Economic Outlook and Fiscal Review had a number of themes (e.g. Make life more affordable: Lowering the cost of living in the north) for which energy provision is a key part. The cost and supply security of energy in Canada's north is one quality-life challenges facing our Northern and remote indigenous communities. SMRs, especially very small SMRs (vSMRs) are a potential solution to this that is under active investigation at a Federal level. The Canadian SMR Roadmap (https://smrroadmap.ca/), the development of which was led by the Nuclear Energy Division of Natural Resources Canada (NRCan), outlines the plan for SMRs within the country. OPG is actively looking at building an SMR plant in Darlington within this decade and CSMR would place Ontario Tech at the forefront in terms of both R&D and provision of the, as-yet, untrained SMR workforce.

ALTERNATIVES CONSIDERED:

- Do nothing – does not meet the objective, coordination of activities is not enhanced, no increase in status of Ontario Tech, contrary to the university's stated position in terms of energy initiatives, no advantage in applications for large-scale funding.
- Delay establishing a centre – would partially meet the objective in the longer term, but would do so at significant strategic cost. By not being first, we would cede advantage and influence to competitor universities.
- Join an established centre – given that existing centre's with a nuclear power-related focus currently lack significant SMR-specific expertise, Ontario Tech would be losing advantage, increase in status of Ontario Tech would be diminished through the subordinate role, contrary to the university's stated position in terms of energy initiatives.

CONSULTATION:

- *Office of Research Services*: Concept shared May 26, 2019.
- *VPRI*: Discussed at length October 2, 2019.
- *Partnership/advancement teams*: Concept shared May 14, 2019 and June 27, 2019, respectively.

- *Internal researchers*: March 29 – September 20, 2019.
- *External researchers/industry partners*: Summer 2019.
- *FESNS Faculty council*: Concept introduced in Spring 2019, update on progress provided February 20, 2020.
- *Research Board*: Motion passed February 6, 2020.

COMPLIANCE WITH POLICY/LEGISLATION:
The Centre for Small Modular Reactors proposal was developed in conjunction with the Office of Research Services to align with the University's Procedure for the Creation of Research Units, Centres and Institutes (see Appendix 1).

NEXT STEPS:
Send proposal to the Board of Governors for approval.

MOTION FOR CONSIDERATION:

That pursuant to the recommendation of the Research Board, Academic Council hereby recommends the Centre for Small Modular Reactors proposal to the Board of Governors for approval, as presented.

SUPPORTING REFERENCE MATERIALS:

1. Proposal for the Creation of the Centre for Small Modular Reactors at Ontario Tech University
2. Centre for Small Modular Reactors Budget

Proposal for the establishment of the Centre for Small Modular Reactors (CSMR) at Ontario Tech University

1. Name of the Entity:

Centre for Small Modular Reactors (CSMR)

2. Proposers:

2.1. Director:

Kirk D. Atkinson, PhD
Associate Professor, Faculty of Energy Systems and Nuclear Science
kirk.atkinson@ontariotechu.ca

2.2. Co-Proposers:

Akira Tokuhiro, PhD
Dean and Professor, Faculty of Energy Systems and Nuclear Science
akira.tokuhiro@ontariotechu.ca

Markus Piro, PhD
Assistant Professor and Canada Research Chair (Tier II) in Nuclear Fuels and Materials, Faculty of Energy Systems and Nuclear Science
markus.piro@ontariotechu.ca

Eleodor Nichita, PhD
Associate Professor, Faculty of Energy Systems and Nuclear Science
eleodor.nichita@ontariotechu.ca

Daniel Hoornweg, PhD
Associate Dean, Associate Professor and Richard Marceau Chair, Faculty of Energy Systems and Nuclear Science
daniel.hoornweg@ontariotechu.ca

Glenn Harvel, PhD
Associate Professor, Faculty of Energy Systems and Nuclear Science
glenn.harvel@ontariotechu.ca

Filippo Genco, PhD
Associate Teaching Professor, Faculty of Energy Systems and Nuclear Science
filippo.genco@ontariotechu.ca

3. Background, Description and Justification

3.1. Background

Ontario has traditionally had a thriving nuclear industry and has relied on electricity generated by its three Nuclear Generating Stations (NGS) to power its homes and businesses. In the 1970's, Canadian engineers and scientists successfully designed the Canadian Deuterium Uranium (CANDU) reactor, the first of which produced 1744 Megawatts of heat and 515 Megawatts of electricity. The CANDU design was improved in the following decades and has been exported to Argentina, China, India, Pakistan, Romania and South Korea. There are currently 18 CANDU reactors operating in Ontario, along with one in New Brunswick. In 2025, one quarter of the nuclear generating capacity in Ontario will be lost through the planned closure of the six reactors at the Pickering NGS in Durham Region. This loss of generating capacity will need to be replaced in the near-term by fossil-fuels, as evidenced by Ontario Power Generation's (OPG) recent acquisition of gas-fueled power stations, and will reduce Ontario's ability to meet its climate change targets and in so doing diminish its green credentials. Whilst in the medium-term construction of new CANDU units would be an option, experience from around the world has shown that building Gigawatt-scale reactors is too great an economic risk.

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Many of the eleven proposed SMR designs are based on, or adapted from, feasible concepts last investigated in the 1960's. Whilst a number of prototype reactors were built and operated during this period; the scientific understanding, technical capabilities, and regulatory oversight of today was not there. As a consequence, despite some of the early prototypes, or their underpinning technologies, showing great promise; all SMR vendors must undertake significant research and development (R&D) before they will be able to build and operate first-of-a-kind (FOAK) systems. Moreover, responsibility for the environment now requires that proposed SMRs undergo extensive environmental impact assessment, including their whole life carbon footprint, and be `designed for disposal', a complicated endeavor given its socio-political dimensions. The speed at which R&D work can be completed will largely determine which design is first to market. Some vendors have indicated a commitment to manufacture all, or part, of their SMRs in Canada.

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In Canada, there are three such nuclear reactor research centres of note. Established in 1992, the Centre of Nuclear Energy Research (CNER) at the University of New Brunswick (UNB), a small entity comprising four faculty members and six graduate students, undertakes applied research in chemistry and instrumentation for industry partners including NB Power, operator of the Point Lepreau Generating Station. Traditionally their work has focused on Canadian Deuterium Uranium (CANDU) reactors, however, backed by matched funding from the Province of New Brunswick, recent investment by ARC Nuclear and Moltex Energy, has led to investment of $10M in aspects of SMR research and development (R&D) of which CNER has, so far, received almost $1M. In 2009, the Centre for Advanced Nuclear Systems (CANS) was established at McMaster University with $24M of funding from the Canadian Fund for Innovation (CFI) and the Province of Ontario. This regional research centre focuses on behaviour of nuclear materials and thermal-hydraulics systems with no specific focus of either CANDU reactors or SMRs. Most recently, in 2019, backed by Bruce Power, the Nuclear Innovation Institute (NII) was established in Bruce County with the explicit purpose of improving Bruce Site operations and the local community.

Further afield, in the United Kingdom, a number of institutes and centres have been established at various universities. The Dalton Nuclear Institute was established by the University of Manchester in 2005. Initially pooling skills and facilities of individual research groups across the university under a single banner, it remained a virtual entity until funding allowed breakout expansion. In 2007, in a similar manner, Imperial College London established the Centre for Nuclear Engineering (CNE). With thirty-three faculty and staff members; CNE is managed via a management team responsible for strategy and administration, a management committee comprised of faculty members, and an advisory board drawn from industry. CNE has very

strong industry support and is a major participant in international consortia. At the University of Strathclyde, the Advanced Nuclear Research Centre (ANRC) was founded in 2015. Whilst the same virtual structure is employed, it differs by having tier 1 (large enterprise) and tier 2 (small-and-medium enterprise) industry members that pay membership dues to the centre. The dues, separately to any grants awarded to academic faculty members, allows a project manager to be employed. This project manager is responsible for assessing those cross-cutting issues pertinent to all industry members, and subsequently devising work packages to be undertaken by academics using the remaining funds available from membership dues. As the outcomes of these work packages are shared freely amongst all members, this approach provides industry partners with maximum value-for-money and minimum financial risk as contributions are leveraged. NII, due to its longstanding links with the University of Strathclyde, has emulated aspects of ANRC's operating model. Subsequent to Dr. Atkinson's visit to the University of Strathclyde in February 2019, ANRC members visited Ontario Tech University for exploratory discussions in May 2019.

Despite strong interest nationally, no academic research centre focused exclusively on SMRs has, to date, been established and hence there exists the time-limited opportunity for Ontario Tech University to become the focal point for SMR research in Canada. Moreover, uniquely in Canada, Ontario Tech currently has the only two faculty members with real-world industrial experience of SMRs. Prior to joining the university in January 2019, for a decade, Dr. Atkinson worked in the UK Naval Nuclear Propulsion Programme (NNPP), most notably as Technical Lead for Reactor Physics and High Performance Computing, and later as Technical Lead for Radiation Physics and Criticality. Involved in multiple aspects of research, consultancy, education and training in support of light-water cooled pressurised water reactors (PWRs), Dr. Atkinson has deep experience in the design, manufacture, operation, and decommissioning of these canonical SMRs. Dr. Tokuhiro joined Ontario Tech in 2017 after several years as Senior Principal Engineer at NuScale Power, a PWR-based SMR start-up in Oregon, and leading vendor in North America. Prior to this, Dr. Tokuhiro worked on small fast reactors. According to Ontario Power Generation (OPG), subject to financial and regulatory approval, it is likely that installation of Canada's first grid-scale SMR will commence in Durham Region (at the Darlington new-build site) mid-decade, first power being intended for 2028. Given the short timescale it makes a light-water cooled reactor (i.e. a PWR) the only near term viable option.

3.2. Description

Branching out of the Faculty of Energy Systems and Nuclear Science (FESNS), the Centre for Small Modular Reactors (hereafter referred to as "CMSR" or "the centre") will become a major focal point and single point-of-contact for SMR research, consultancy, education and training within the university, in Canada, and Worldwide. At its heart is the principle that the whole is better than the sum of its parts. CSMR will bring together the diverse capabilities of individual university academics and research groups, leveraging their combined expertise towards SMR-specific problems, setting the narrative for Canada's burgeoning SMR industry, and allowing more significant funding opportunities to be exploited. Requiring large and often World-leading teams, such opportunities include Ontario Research Fund Research Excellence campaigns and New Frontiers Research Fund Transformation grants, each of which potentially offers funding circa $1M per annum. In this regard, Dr. Atkinson has received an encouraging

level of support from Ontario Power Generation (OPG), SNC-Lavalin Group, Kinectrics, U-Battery Canada, Westinghouse Electric Canada, Terrestrial Energy, Promation Nuclear and Ecometrix. Initially, for the purposes of this proposal, membership of CSMR has been drawn from a quorum of persons within FESNS that have significant SMR-related experience. It is intended that, through the centre, any Ontario Tech faculty member (or indeed any Canadian academic) with serious interest in SMRs can become 'SMR-ready' by working with more experienced colleagues, as well as gaining increased credibility through membership. Whilst it is expected that members participate in the centre's larger, SMR-focused grant proposals and contribute to industry-funded work packages where agreed, all members remain free to pursue their own external funding.

In terms of research management; individual investigators will have autonomy to manage their individual work packages, although weekly meetings will be encouraged. More formally, three working groups will be struck up; a technical working group, a management working group, and a stakeholder advisory group. The Technical Working Group (TWG) will meet monthly and will comprise of faculty and staff members. The function of the TWG is to agree on strategy, consider funding opportunities, and to communicate technical progress amongst investigators. The Management Working Group (MWG) will meet quarterly and will comprise the Director, the Dean of FESNS (the supporting faculty), and, initially, representatives from Ontario Tech's Office of Research Services (ORS), Research Partnerships and Research Accounting teams. The function of this is group is the reporting of progress relative to the stakeholder expectations and milestones, and to assure that funding is be appropriately spent. As additional public or private revenue becomes available, over time, additional administrative staff will be employed to take over some of those management functions initially delegated to central services. The Stakeholder Advisory Group (SAG) will meet soon after the centre is established (a kick off meeting) and then annually at the start of each subsequent year. It will be comprised of industry supporters (support has been secured from SNC-Lavalin, Kinectrics, U-Battery Canada, Westinghouse Electric Canada, Terrestrial Energy and Promation Nuclear), SMR end-users (support has been secured from OPG and COG), the Director, and two peers from academia. Observers are welcome, where appropriate. The function of the SAG is to provide high level direction, and will be a forum for the centre to be responsive to industry need. The Ontario Tech Research Board and SAG members will be provided with an annual report at the end of each full year.

The aim of the CSMR is to be an umbrella entity that operates on a **low operating cost model** (initially via faculty support) yet can **expand and contract** as funding permits. As external research contract funding is received, it is expected that the centre would receive back its 25% share of the indirect costs charged (as stated in university policy). This 5% (in real terms) of any eligible research contract secured (e.g. $50k from a $1M award), would be directed towards the centre's operating budget to pay for additional promotional activities and human support. In due course, industry membership will be explored. Here, member companies would pay a predetermined amount per annum into a research fund from which mutually beneficial research – adjudicated by the SAG – is funded. This approach maximises leverage and reduces individual risk. This model, used by ANRC, is not appropriate from day one because we start from a different baseline.

3.3. Justification

Ontario Tech has exceptional individual expertise in SMR or SMR-related topics, as well as growing infrastructure and equipment capabilities. Most recently, in addition to its health physics dose response facility, its design lab, and its materials and chemistry labs, FESNS has commissioned a two-storey (9 m) thermal-hydraulics loop, a unique facility in Canada and ideal for validation and verification (V&V) work that SMR vendors must undertake in order to get regulatory approval. Currently, FESNS is in the process of acquiring a unique graphite-based subcritical reactor that industry has already expressed an interest in using for V&V activities. Given the diversity of disciplines (i.e. nuclear materials, reactor physics, thermal hydraulics, radiation protection, control and instrumentation, etc.) needed to support nuclear projects, the burgeoning SMR industry is looking for academic partners of sufficient size and, currently, despite being the only school in Canada with faculty member experts across the full range of disciplines, Ontario Tech does not effectively project that. SMR funding is starting to become available and, thus far, small amounts are going to our competitor universities. Worse still is the fact that, as these competitors do not have the full range of capabilities needed to complete larger projects, funding is being sent overseas (especially to the UK and US) where nuclear researchers have set up centres of excellence (e.g. the Dalton Nuclear Institute at the University of Manchester and the ANRC at the University of Strathclyde).

Ontario Tech is losing market share in what should be one of its key markets. This must cease immediately. There is currently a short window of time during which Ontario Tech can address this and hence take the lead before other have time to adapt. By bringing together its disparate existing capabilities under one umbrella, not just from FESNS, but from all faculties, Ontario Tech will be able to demonstrate it has the size and scale to undertake this important work. This is a one-time opportunity, SMRs will start being built in the next five years, and in ten years the first SMR will be connected to the grid. This is a Worldwide phenomenon and Ontario Tech is ideally placed to take advantage of this nexus in energy production. Moreover, by having an established SMR brand, we become the go-to place in Canada, which has the added benefit of public relations opportunities and increased visibility. There is currently no SMR centre in Canada, but if we delay there will be.

In terms of timeliness, this proposal reflects several external factors, the most important being the SMR timeline described above. In addition to this the forthcoming Canadian Nuclear Association (CNA) conference in Ottawa is an ideal forum at which to publicise the centre, especially since Prof. Atkinson is joining the CEO of Canadian Nuclear Laboratories (CNL) and the CTO of Westinghouse, on a panel discussing ‘SMRs as a disruptive technology’, and because several strategic meetings on the way forward for SMRs in Canada are being held. Following on from the 2019 meeting, contracts were signed with competitor universities for a number of work packages. Through CSMR, Ontario Tech will be better able to challenge for this work. Furthermore, Prof. Atkinson has been asked by Natural Resources Canada to join the Canadian government delegation to the UK (led by the Associate Deputy Minister, Shawn Tupper) in March 2020. During this dialogue, SMR collaboration at the industry and academic levels are key agenda items, the outcome of the meeting being a harmonization of efforts between the two countries. From this, it is expected that opportunities funding will result. As UK centres above will be in attendance, through the vehicle of CMSR, Ontario Tech can

challenge for a key role in this international development. Once again, this is a one-time opportunity for Ontario Tech to demonstrate it is a leader in the SMR field.

4. Research Mandate

4.1. Scope

Small Modular Reactors present a viable way of both meeting our societal need for energy whilst protecting our climate. Unlike large nuclear generating stations, SMR's are designed to be super safe, yet it is known that trust comes by demonstration. As such, working with the leading nuclear supply chain companies, and supported by SMR vendors and end-users, the centre will address those key research needs required to gain public trust. Conscious of work done elsewhere, CSMR will seek to address aspects of SMR manufacture and use that are uniquely novel, or unique to Canada. Initial discussions with the aforementioned SAG industry partners identified four key research themes, each of which has specific focus areas:

- SMR manufacture:
    - Economic analysis demonstrating reduction in capital costs.
    - Additive manufacturing techniques.
    - Design and characterisation of specialised heat exchangers.
- SMR fuel considerations:
    - Accident tolerant fuels for SMRs.
    - Molten salt reactor fuels and materials modeling and characterisation.
- SMR end user applications:
    - Use of SMRs to manufacture medical isotopes.
    - impact of SMR construction on carbon dioxide emissions.
- SMR safety and security:
    - Probabilistic risk metrics for SMR selection.
    - Source term, environmental impact and emergency zone modeling.
    - Physical security and protection factors for SMRs.
    - Bio-dosimetry to determine the radiological impact of low dose radiation.
    - Remote reactor ambient radiation monitoring.

'Manufacture' in this case specifically considers the exploitation and justification of advanced manufacturing techniques (e.g. additive manufacture) to reduce cost of SMRs, as well as SMR fuel considerations (as no SMR design uses natural uranium, the traditional CANDU fuel). 'Use' in this case includes both SMR end user applications (e.g. electricity generation, hydrogen co-generation, desalination, district heating and healthcare) and SMR safety and security considerations (e.g. probabilistic risk, environmental impact, emergency preparedness, remote monitoring and operation, and physical security).

To support SMR manufacturing research, faculty members of FEAS would be encouraged to join CSMR to provide additional technical expertise, whereas faculty members from FBIT could contribute to the economics-based activities. SMR end user applications would benefit from the inclusion of FSSH faculty members, especially on activities related to social license, whilst faculty members from the Faculty of Education could contribute to advanced training

methodologies. As human factors are important to SMR safety and security, as well as end user applications, faculty members from FHS could add additional insight, and, lastly, faculty members from the Faculty of Science could provide additional rigour in the exploration of mathematical modeling (e.g. risk metrics) and bio-dosimetry. In short, **there is a place in CSMR for faculty members from all faculties at Ontario Tech**.

4.2. Alignment

Given its industrial partners (i.e. OPG) and the threat posed by climate change; energy was one of the cornerstone themes in UOIT's 2013-2020 Strategic Research Plan, and remains as such in the Ontario Tech 2020-2025 research plan currently under review. Moreover, the President of the university is currently pursuing an energy initiative which may culminate in Ontario Tech becoming a regional hub or larger institute. Together with the Clean Energy Research Laboratory (CERL), and the extensive work undertaken on hydrogen-based fuel, CSMR would fit under this umbrella and be a distinct part of this endeavour. More broadly, the 2019 Ontario Economic Outlook and Fiscal Review had a number of themes (e.g. Make life more affordable: Lowering the cost of living in the north) for which energy provision is a key part. The cost and supply security of energy in Canada's north is one quality-life challenges facing our Northern and remote indigenous communities. SMRs, especially very small SMRs (vSMRs) are a potential solution to this that is under active investigation at a Federal level. The Canadian SMR Roadmap (https://smrroadmap.ca/), the development of which was led by the Nuclear Energy Division of Natural Resources Canada (NRCan), outlines the plan for SMRs within the country. OPG is actively looking at building an SMR plant in Darlington within this decade and CSMR would place Ontario Tech at the forefront in terms of both R&D and provision of the, as-yet, untrained SMR workforce.

4.3. Sustainability

Not wanting to delay, an opportunistic Ontario Research Fund proposal was submitted in late 2019 and a New Frontiers Research Fund Transformation is in preparation. In addition to this, Prof. Atkinson is under consideration for a five [5] year NSERC Industrial Research Chair which has a 50% focus on SMRs, and Prof. Tokuhiro secured six [6] years of SMR-related funding from NSERC in 2019. An SMR-focused Alliance grant, and an NSERC CREATE grant, are planned for 2020. The latter will focus on modeling and simulation and will seek to align with the existing graduate program in modeling and computational science in the Faculty of Science. NRCan is currently in discussion with its counterparts in the United Kingdom with regards to nuclear energy collaboration. Professor Atkinson has been asked by NRCan to join the Canadian government delegation to the UK (led by the Associate Deputy Minister, Shawn Tupper) at start-March 2020. During this dialogue, SMR collaboration is one of the key agenda items, the desire being a harmonization of efforts between the two countries. From this, additional opportunities for cross-border funding will result.

5. Student Involvement and Training

Graduate students, both MASc and PhD, will be essential to generate research outcomes. In the aforementioned Ontario Research Fund RE-10 submission, funding for sixteen [16] MASc and eight [8] PhD students was requested over the five-year term of the award. In addition to this, Professor Tokuhiro has funding for four [4] PhD students via his CREATE funding. Additional grant proposals, if successful, will sustain further numbers of graduate students. Furthermore, as specific funding may be provided by industry partners under sub-contract, the opportunity for student involvement is clear (undergraduate involvement will be included where appropriate). It is proposed that, for industry funded work, we will award additional Research Assistantships. Due to the engagement of SMR industry partners, all involved Ontario Tech students would, by definition, become the SMR workforce the industry has stated it will need over the next decade.

CSMR will also play a leading role in SMR training and education. Firstly, engagement with SMR vendors allows FESNS faculty members to enhance its undergraduate curriculum to benefit enrolment in the existing undergraduate Nuclear Engineering, and Health Physics and Radiation Science, programs. Emulating what CSI did for Forensic Science; SMR is a major driver of enthusiasm for these disciplines in a climate change-conscious World. Secondly, via its recently awarded NSERC funding and its position within UNENE, Ontario Tech is already developing SMR-focused graduate courses, the first being titled 'Next generation Reactor Concepts and Design Engineering.' Finally, emulating the success of the AOOM course delivered by FESNS, CSMR will develop four specialised training courses to address industry needs for upskilling. The first of these courses, addressing light-water reactor technology, is slated to run in Summer 2020. It is expected that this become a revenue generator for the centre, and, by extension, FESNS and the University. Absorbing these courses within a new GDip in SMR Science and Technology will be investigated. The key aim is for Ontario Tech, via CSMR, to be the go-to place for SMR training and education in Canada.

6. Research Dissemination and Service Plan

Research findings will be rapidly published in the public domain (principally key, high-impact journals). Commercially-sensitive and security-sensitive findings will be rapidly shared with the respective sub-contracting partners in order to inform their development (detailed design) and decision-making. An annual one-day SMR workshop will be hosted at Ontario Tech. This workshop will present results and report progress during the year to a wider Canadian audience. A frequently-updated website will be maintained and a social media presence established. It is anticipated that additional media opportunities will be forthcoming. Via the outreach element included in the Ontario Research Fund RE-10 submission or otherwise (e.g. using NSERC Promo Science funding), outreach to potential SMR host communities will be undertaken. The latter is especially important with regards to indigenous communities who are often overlooked and to whom SMRs could provide improved quality of life and economic opportunities.

7. Membership List, CVs and Affiliations

The initial membership on day one will be:

Name:	Position, Faculty:	Expected contributions:
Kirk D. Atkinson, PhD	Associate Professor, Faculty of Energy Systems and Nuclear Science.	• Founding Director of CSMR. • (under consideration) NSERC/UNENE Industrial Research Chair in Health Physics and Environmental Safety. • Will lead projects on SMR environmental impact assessment, operations, methods development radiation physics, and diagnostics.
Akira Tokuhiro, PhD	Dean and Professor, Faculty of Energy Systems and Nuclear Science.	• Senior leadership support to CSMR. • Via FESNS, budget support. • Will lead projects on probabilistic design/risk assessment.
Markus Piro, PhD	Assistant Professor and Canada Research Chair (Tier II) in Nuclear Fuels and Materials, Faculty of Energy Systems and Nuclear Science	• Will lead projects on SMR fuels and materials, as well as some interest in advanced manufacturing approaches. (note: it is anticipated that FEAS faculty members would join CSMR and contribute to/lead advanced manufacturing projects).
Eleodor Nichita, PhD	Associate Professor, Faculty of Energy Systems and Nuclear Science.	• Will lead projects on modeling and simulation of SMR neutronics.
Daniel Hoornweg, PhD	Associate Dean, Associate Professor and Richard Marceau Chair, Faculty of Energy Systems and Nuclear Science	• Will lead projects on social license and sustainability of SMRs.
Glenn Harvel, PhD	Associate Professor, Faculty of Energy Systems and Nuclear Science	• Will lead projects on design, SMR thermal-hydraulics and decommissioning technologies.
Filippo Genco, PhD	Associate Teaching Professor, Faculty of Energy Systems and Nuclear Science.	• Will lead projects on gas-cooled reactor thermal-hydraulics and materials performance issues.
Hossam Gaber, PhD	Professor and Graduate Program Director, Faculty of Energy Systems and Nuclear Science.	• Will lead projects on SMR control systems and grid connectivity.

Liliana Trevani, PhD	Associate Professor, Faculty of Science	• Will lead projects on light-water coolant electrochemistry.

It is anticipated that additional faculty members from FESNS, FEAS and FS, and perhaps from FBIT, FED and FSSH, will join CSMR and hence provide it with enhanced capability. Faculty members with experience in education, psychology and human factors, microbiology, economics and advanced manufacturing techniques would be especially welcome on day one. It is anticipated that we can engage a suitable (external) associate member to assist with indigenous engagement activities. Further such associate members can be drawn from our national and international collaborator base. Interest from a faculty member from Queen Mary University of London has already been received. Upon approval of the centre, a targeted call for additional membership will be made.

8. Resource Requirements

8.1. Physical Requirements

Due to the virtual nature of the centre, where, like at ANRC, the capabilities and facilities of individual faculty members' research groups are leveraged towards the collective effort; **no additional office or laboratory space is currently required**. If a project manager is hired (e.g. as required by a large Ontario Research Fund submission), they would co-locate with the Graduate Program Manager in ERC 4026. It is also proposed that the large graduate student office, ERC 4100, be subdivided such that one half houses the graduate students who are employed on centre-based projects. There is sufficient free desk space in ERC 4100 to accommodate a twofold increase in graduate students if hot-desking is enforced. It is projected that a maximum twofold increase in cross-faculty graduate student enrollment could occur if all targeted grants were successful.

8.2. Staffing Requirements

Upon establishment, **no additional support staff are required**. Administration, advertising and website/social media maintenance will be undertaken by CSMR members in the first instance. Subject to sufficient funding being secured (e.g. from a large program grant), a project manager will be employed to co-ordinate work packages and undertake some of the other administrative functions. Additional staff support (e.g. technician time) will follow a pay-on-demand model, again reflecting the expand and contract model of operation. Graduate and undergraduate students will be employed in the normal way, and visiting scholars will be hosted on an ad-hoc basis in accordance with Ontario Tech University policy.

8.3. Budget and Financial Requirements

No start-up funding is requested. The Faculty of Energy Systems and Nuclear Science will underwrite the administrative (i.e. communications and advertising, and one, one-day on-site workshop per annum) costs of the centre from its operating budget unless and until external funding is secured. These costs are not expected to exceed $7500 per annum. Given that many of the initial meetings required to establish the centre and build-up partnerships will either be

in the GTA, or can happen at major events which faculty already attend (e.g. the Canadian Nuclear Association conference), costs of travel will be borne initially by individual faculty members. As one of the aims is to be a force-multiplier for existing strengths; it is intended that the centre be able to be adaptable to funding, yet be able to successfully operate with a limited budget. The limited budget is the planning assumption, although larger revenues and hence larger budgets are expected (e.g. the Ontario Research Fund submission requested a cash budget of $3,162,686 over five years, albeit the submission would have been strengthened had it been submitted by a centre). **No unsecured funding has been assumed** for budget planning purposes. Given FESNS has control over, and experience of delivering training courses, a conservative estimate of revenue from such courses **has** been assumed. Profits will be shared between the centre, the faculty and the University following existing precedent. In addition to this Prof. Atkinson is under consideration for five [5] years of SMR-relevant funding through a UNENE/NSERC Industrial Research Chair and, in 2019, Prof. Tokuhiro secured six [6] years of NSERC CREATE funding for up to four graduate students. SMR-focused Alliance and CREATE grants are planned for submission in 2020, albeit they would be strengthened if submitted by the centre. It is anticipated that additional opportunities will stem from NRCan and the Canada-UK dialogue if CSMR is established.

9. Intellectual Property and Commercialization

As the core membership of the centre will be Ontario Tech University faculty and students, notwithstanding any legal constraints (e.g. data that has been shared with the centre, or with its individual members, through non-disclosure agreements) or licensing agreements (e.g. to use necessary computer codes from third parties), ownership of intellectual property created or developed by the centre using public-derived funds will retained by faculty and/or students in accordance with Ontario Tech University policy. Ownership of, and the rights to exploit, intellectual property created or developed using private and/or industry funding, or where private and/or industry funding is leveraged to get public funding, will be established on a case-by-case basis with private and/or industry partners. Rights to publish non-commercially and non-security sensitive works will be sought during any negotiations.

Research Entity Budget

	Items	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Justification
1. Operatonal Budget								
1.1 Labour Costs - Staff								
	Administrative Assistant/Communications Off	$ -	$ -	$ -	$ -	$ -	$ -	Not needed (This could change, subject to demand. Any change would be funded from new revenue).
	Project Manager	$ -	$ -	$ -	$ -	$ -	$ -	Not needed (This could change, subject to demand. Any change would be funded from new revenue).
	Benefits (9%)	$ -	$ -	$ -	$ -	$ -	$ -	-
SUB-TOTAL Labour		**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	
1.2 Labour Costs - Director								
	Teaching Release	$ -	$ -	$ -	$ -	$ -	$ -	Not needed (This could change, subject to demand. Any change would be funded from new revenue. Costed at $8641 per course).
	Benefits (9%)	$ -	$ -	$ -	$ -	$ -	$ -	-
SUB-TOTAL LABOUR		**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	
1.3 Research Entity Operating Costs								
	Technical/Consulting Services	$ -	$ -	$ -	$ -	$ -	$ -	Not needed (This could change, subject to demand. Any change would be funded from new revenue).
	IT Support	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 5,000	Video production.
	Equipment	$ -	$ -	$ -	$ -	$ -	$ -	Not needed (This could change, subject to demand. Any change would be funded from new revenue).
	Office Supplies and Services	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 5,000	Paper, printing, etc.
	Staff and Director Travel	$ 3,500	$ 3,500	$ 3,500	$ 3,500	$ 3,500	$ 17,500	Attending business development meetings (Excludes any meetings held at conferences, etc, that faculty members are already attending from their own budget.
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	-
SUB-TOTAL-Research Entity Operating Costs		**$ 5,500**	**$ 5,500**	**$ 5,500**	**$ 5,500**	**$ 5,500**	**$ 27,500**	
2. Research Networking								
	Seminars and workshops	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 10,000	Annual workshop hosting costs (principally refreshments).
	Conference	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 10,000	Attending Canadian Nuclear Association conference (attending regardless)
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	
SUB-TOTAL-Research Networking		**$ 4,000**	**$ 4,000**	**$ 4,000**	**$ 4,000**	**$ 4,000**	**$ 20,000**	
3. Communications								
	Website	$ -	$ -	$ -	$ -	$ -	$ -	csmr.ontariotechu.ca will use Ontario Tech template and CMS at no cost. Initial development undertaken by FESNS, updates to be made by centre members as required.
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	
4. Knowledge Transfer and Dissemination								
	Publication Costs	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 5,000	Promotional materials (two-sided paphlets).
	Outreach	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 10,000	Outreach visits to indigenous communities.
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	
SUB-TOTAL		**$ 3,000**	**$ 3,000**	**$ 3,000**	**$ 3,000**	**$ 3,000**	**$ 15,000**	
TOTAL OPERATIONAL BUDGET		**$ 9,500**	**$ 9,500**	**$ 9,500**	**$ 9,500**	**$ 9,500**	**$ 62,500**	
REVENUE								
	FESNS underwriting	$ 7,500	$ 7,500	$ 7,500	$ 7,500	$ 7,500	$ 37,500	FESNS will support up to $7,500 per annum
	Directors' PD	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 10,000	Attending Canadian Nuclear Association conference (attending regardless)
	SMR training (summer term)	$ 14,000	$ 14,000	$ 14,000	$ 14,000	$ 14,000	$ 70,000	Expecting 24 students @ $1k per person per week (market rate). After the instructor is compensated, the residual is expected to be $14k. This range and frequecny of courses will be expanded subject to centre approval.
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
TOTAL REVENUE		**$ 23,500**	**$ 23,500**	**$ 23,500**	**$ 23,500**	**$ 23,500**	**$ 117,500**	
TOTAL OPERATIONAL BUDGET LESS REVENUE		**$ 14,000**	**$ 14,000**	**$ 14,000**	**$ 14,000**	**$ 14,000**	**$ 70,000**	

		Research Costs						
		Year 1	Year 2	Year 3	Year 4	Year 5	Total	
Student and Postdoc Salaries								
								Comments
	Research Assistants	$ -	$ -	$ -	$ -	$ -	$ -	None currently projected.
	Masters Students	$ 96,000	$ 114,000	$ 68,000	$ 18,000	$ -	$ 296,000	Leveraged from IRC, CRC, and CREATE funding.
	PhD Students	$ 20,000	$ 40,000	$ 40,000	$ 40,000	$ 20,000	$ 160,000	Leveraged from IRC, CRC, and CREATE funding.
	Post-Doctoral Students	$ 33,435	$ 33,435	$ 33,435	$ -	$ -	$ 100,305	Leveraged from IRC, CRC, and CREATE funding.
	Visiting Scholar	$ -	$ -	$ -	$ -	$ -	$ -	Self-funded.
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	None currently projected.
	Benefits (9%)	$ -	$ -	$ -	$ -	$ -	$ -	-
SUBTOTAL Trainees		**$ 149,435**	**$ 187,435**	**$ 141,435**	**$ 58,000**	**$ 20,000**	**$ 556,305**	
Research Operating Costs								
	Travel	$ 6,000	$ 8,000	$ 6,000	$ -	$ -	$ 20,000	Leveraged from IRC, CRC, and CREATE funding.
	Equipment	$ 22,000	$ 2,000	$ 1,000	$ -	$ -	$ 25,000	Leveraged from IRC, CRC, and CREATE funding.
	Other (explain)	$ -	$ -	$ -	$ -	$ -	$ -	-
SUBTOTAL Operating		**$ 28,000**	**$ 10,000**	**$ 7,000**	**$ -**	**$ -**	**$ 45,000**	
TOTAL RESEARCH COSTS		**$ 177,435**	**$ 197,435**	**$ 148,435**	**$ 58,000**	**$ 20,000**	**$ 601,305**	
REVENUE RESEARCH								
	IRC, CRC, and CREATE funding	$ 177,435	$ 197,435	$ 148,435	$ 58,000	$ 20,000	$ 601,305	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
		$ -	$ -	$ -	$ -	$ -	$ -	
	TOTAL REVENUE	**$ 177,435**	**$ 197,435**	**$ 148,435**	**$ 58,000**	**$ 20,000**	**$ 601,305**	
	TOTAL REVENUE LESS EXPENSES	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	