SANDIA REPORT
SAND2019-14857
Printed Click to enter a date

Sandia National Laboratories

The Gulf Nuclear Energy Infrastructure Institute (GNEII): Origins, Objectives, and Operations—A Joint Report

Adam D. Williams, Alexander A. Solodov, Amir H. Mohagheghi
Sandia National Laboratories/Center for Global Security and Cooperation

Philip A. Beeley, Saeed Al-Ameri
Khalifa University of Science and Technology/Gulf Nuclear Energy Infrastructure Institute

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico
87185 and Livermore,
California 94550

Issued by Sandia National Laboratories, operated for the United States Department of Energy by National Technology & Engineering Solutions of Sandia, LLC.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@osti.gov
Online ordering: http://www.osti.gov/scitech

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.gov
Online order: https://classic.ntis.gov/help/order-methods/

ABSTRACT

The Gulf Nuclear Energy Infrastructure Institute (GNEII—pronounced "*genie*") seeks to develop expertise among future leaders of Gulf-region nuclear power programs in global standards, norms and best practices in nuclear energy programs. More specifically, the institute aims to contribute to the enhancement of nuclear security, safety, and safeguards (the so-called nuclear "3S") by providing an avenue for regional nuclear interaction, technical collaboration, lessons-learned discussions, and best-practices sharing. It is a multidisciplinary human capacity development institute offering education, research and technical services to support responsible nuclear energy programs in the Gulf and Middle East regions. In this Joint Report, Chapter 2 discusses GNEII's *origins* (including drivers, milestones, and design principles), Chapter 3 discusses GNEII's *objectives* (including goals, mission, and vision), Chapter 4 discusses GNEII's *operations* (including education, research, and technical service pillars), Chapter 5 discusses major insights and next steps, and Chapter 6 provides a list of publications offering additional depictions and details of GNEII's evolution. Though only one piece of a multi-faceted, multi-national effort to develop human infrastructure needs for nascent nuclear energy programs, GNEII offers a model that addresses the socio-technical attributes of nuclear 3S that can be replicated globally.

ACKNOWLEDGEMENTS

The authors are indebted to our many colleagues who have assisted in the establishment and development of the Gulf Nuclear Energy Infrastructure Institute. There are too many who deserve acknowledgement to name, but a few names that must be listed include H.E. Ambassador Hamad Al Kaabi, Dr. Arif Al-Hammadi, Mr. Adbelaziz Al-Madloum, Mrs. Susannah Cooper, and Mrs. Kasia Mendelsohn. We also want to thank the various sponsoring and implementing organizations not represented by the authors, which include: Critical Infrastructure and Coastal Protection Authority (CICPA), Emirates Nuclear Energy Corporation (ENEC), Federal Authority for Nuclear Regulation (FANR), National Emergency Crisis and Disaster Management Authority (NCEMA), Nawah Energy Company, Texas A&M University (TAMU)/Nuclear Security Science & Policy Institute (NSSPI), U.S. National Nuclear Security Administration Office of Global Material Security (NA-21), U.S. National Nuclear Security Administration Office of Nonproliferation and Arms Control (NA-24), and U.S. Department of State's Partnership for Nuclear Threat Reduction (DOS/PNTR).

CONTENTS

LIST OF FIGURES

LIST OF TABLES

This page left blank

1. INTRODUCTION

The new nuclear energy program in the United Arab Emirates (UAE) demonstrated a need to address the lack of *indigenous* human infrastructure capabilities available to support growing regional interest in nuclear energy [1]. Addressing this gap in nuclear energy human infrastructure development poses two unique challenges. The first is related to limited knowledge and experience in nuclear energy programs existing in Gulf-region states. The second is related to the breadth of safety, security and non-proliferation (or, safeguards) concerns unique to nuclear energy programs. Further, recent research in engineering education indicates that that future engineers "need to be able to deal with complex interrelationships that include not only technical issues…but human and environmental factors as well [2, p. 2]." This statement could not be more relevant to countries developing new nuclear energy programs. In response, a focus arose to synchronize both technical and non-technical aspects of nuclear energy safety, security and safeguards that balances the academic programs with the applied, practical knowledge of hands-on training courses.

The result was the Gulf Nuclear Energy Infrastructure Institute (GNEII—pronounced "*genie*"), housed at Khalifa University of Science and Technology (KU)—in partnership with Sandia National Laboratories (Sandia)—located in Abu Dhabi, United Arab Emirates (UAE). From its inception, GNEII aimed to help generate expertise among future leaders of Gulf-region nuclear power programs in global standards, norms and best practices in safety, security and safeguards. GNEII does not provide a short course training program (e.g., like the various topic-specific courses offered by the International Atomic Energy Agency [IAEA]), nor does it provide a university-based nuclear engineering degree. Rather, it is a multidisciplinary human capacity development institute offering education, research and technical services to promote and support responsible nuclear energy programs in the Gulf and Middle East regions.

The rest of this Joint Report describing the history and development of GNEII proceeds as follows:

- Chapter 2 discusses the *origins* of GNEII, including the developmental drivers, an overview of major historical milestones, and a review of its underlying design principles;
- Chapter 3 discusses the *objectives* of GNEII, describing institute goals, mission, and vision;
- Chapter 4 discusses the *operations* of GNEII, introducing the three central pillars of the institute (education, research, and technical services);
- Chapter 5 summarizes major insights, conclusions, and next steps for institute evolution; and,
- Chapter 6 provides a list of publications offering additional depictions and details of GNEII's evolution.

Over its history, GNEII has contributed to the enhancement of nuclear security, safety, and safeguards (the so-called nuclear "3S") understanding—both within and across individual state nuclear energy programs. Providing an avenue for regional nuclear interaction, technical collaboration, lessons-learned discussions, and best-practices sharing is another benefit that GNEII will continue to offer. Via regional and international discussions that spanned from Vienna to Morocco to Seoul to Amman to Orlando, GNEII is now a well-known institute that continues to draw high levels of interest—as evidenced by inquiries into the institute by Argentina, France, Japan, South Africa, and South Korea. Though only one piece of a multi-faceted, multi-national effort to develop human infrastructure needs for nascent nuclear energy programs, GNEII offers a model that addresses the socio-technical attributes of nuclear 3S that can be replicated globally.

2. ORIGINS

The origins of the Gulf Nuclear Energy Infrastructure Institute (GNEII) lie in the desire to meet a dynamic and evolving need with a systematic and sustainable solution. The institute's structure was initially sketched on the back of napkin (literally) and emphasized that success in meeting Middle East and Gulf-region human infrastructure development needs for nuclear energy must be educational (incorporating more than topical trainings), regional (or, demand-driven), and strategic (aimed at influencing long-term planning in nuclear energy programs). Desiring to be both responsive and responsible, these initial plans were also found on the core assumption that success could best be built via a strategic partnership between regional and international stakeholders. As discussed in the rest of this chapter, GNEII has had unique and interesting developmental history.

2.1. Drivers

The late 2000s and early 2010s saw an increased global interest in nuclear energy, primarily driven by a desire for improved living and social standards, energy security, and climate change mitigation. Many of the regions expressing a strong interest in nuclear energy programs—such as the Gulf region—lacked the necessary human infrastructure to support such programs. Here, human infrastructure incorporates two key aspects. First, it includes having adequate numbers of individuals available to work in nuclear-energy-related government and industry positions. Second, it also includes ensuring such individuals have the appropriate level of education, training, experience, and knowledge across a range of responsibilities within nuclear power programs. In one specific example, the new nuclear energy program in the United Arab Emirates (UAE) demonstrated a need to address the lack of indigenous human infrastructure capabilities available to support growing regional interest in nuclear energy

These drivers suggested that many of the regions expressing a strong interest in nuclear energy programs—such as the Gulf region—lacked human infrastructure development opportunities to support such programs. Here, human infrastructure incorporates two key aspects—one quantitative and the other qualitative. The first relates to having adequate numbers of responsible users of nuclear energy throughout government and industry positions. The second aspect seeks to ensure that such individuals have the appropriate level of education, training, experience, and knowledge across a range of responsibilities within nuclear power programs. Taken together, these trends and drivers indicate that addressing both the quantitative and qualitative aspects of human infrastructure development is necessary to meet responsible nuclear energy objectives and operations.

2.2. Developmental Design Principles

GNEII was based on three key design features that have been consistently reiterated throughout the institute's development and implementation. First, GNEII is designed to be a regional institute, being physically located in the Gulf region, hosted by a regional state, and sustained by demand-driven interest from regional professionals interested in nuclear energy. From that first sketch on a napkin, this institute was never intended to only serve the host entity or the host country. GNEII's early development was dedicated to early efforts to identify potential host organizations and host nations that had two vital characteristics. First, any potential host needed to be a technological center for the surrounding area. Second, it needed to be a centrally-located and logically straightforward travel destination. In these early days, the inability to meet these characteristics quickly removed organizations from the list of potential hosts. Considering each of these desired

characteristics, the Khalifa University of Science and Technology (KU) in Abu Dhabi, UAE was selected for—and has been an effective partner in—enhancing the "regionality" design of the institute's early concepts. In addition, every aspect of GNEII's early development was designed to support regional participation and collaboration. Providing numerous, clearly identifiable mechanisms for regional participation in all aspects of GNEII's development—from the novel curriculum to course structure to management and oversight—was paramount.

Second, GNEII is designed to be an educational institute, and moves beyond narrowly focused topical training courses and provides a broader, more comprehensive forum through which regional nuclear professionals are prepared to think, to lead, and to have long-term impacts within their nuclear energy programs.[1] To overcome the human infrastructure development shortcomings introduced in the previous section, GNEII needed to provide a deeper, more rigorous mechanism for knowledge transfer than that offered in more traditional training or professional development programs. This aspect of the institute began with the development of a novel curriculum designed around nuclear energy safety, security and safeguards (3S).[3] [4] This curriculum centers on a systems-theory based *responsible nuclear energy program* (RNEP) framework, wherein safeguards, security and safety (and their interactions—the so-called, "3S") are viewed as system level properties. GNEII's educational model seeks to reduce the potential risks to people, infrastructure or the environment (e.g., system constraints) while supporting the ability of nuclear energy programs to generate low cost, low carbon electricity (e.g., system objective). Because it was an original goal for GNEII's intellectual standard to require a deeper conceptual understanding of this underlying framework, education will continue to be the institute's knowledge transfer paradigm.

Third, GNEII is designed to be a strategic institute, with plans to be indigenized within five years, sustained through regional financial and operational ownership. In so doing, this represents a long-term investment for the development of responsible nuclear energy programs throughout the region. Once developed, GNEII has worked to become a sustainable producer of strong, capable professionals ready to instill the RNEP principles into regional nuclear energy programs. From the outset, the expectation has been for the institute to deploy a long-term, dynamic, and evolutionary approach to human infrastructure development. Another characteristics of the strategic design project relates to the intentional, beneficial, and appropriate incorporation of resources and capabilities from partner stakeholders to support institute objectives.

Taken together, these three key design features make GNEII a novel institute with a unique opportunity to institutionalize nuclear energy safety, safeguards, and security in future Middle East regional nuclear energy program decision-makers. Since its 2011 inception, GNEII has increased its ability to instill its lessons in the daily operations of regional nuclear energy programs and has moved toward its goal of being a fully indigenous regional institute. By design, US financial commitment has decreased from 2011 to 2016, allowing Emirati nuclear stakeholders—primarily KU—to take a more operational and financial responsibilities. The transition of GNEII from a primarily U.S.-supported initiative to a UAE-supported institute is symbolic of the institute's strategic core values and three design principles.

[1] It is important to note that GNEII is not a nuclear engineering degree granting entity. GNEII does support the Nuclear Engineering Masters of Science program offered by Khalifa University.

2.3. Strategic Partnership

In order to manifest these design principles, GNEII's creation emerged from a strategic partnership between a group of multinational sponsors, stakeholders, and implementers. Though hosted at the Khalifa University of Science and Technology (KU) in Abu Dhabi, several organizations and entities have played key roles in GNEII's development. As illustrated in Table 1, no less than 10 government, non-governmental, and academic entities collaborated to support the institute's growth and development.

Table 1. Members of the Strategic Partnership necessary for GNEII's development

Organization	Stakeholder Responsibility	Institutional Role
Khalifa University of Science and Technology	UAE university with responsibility for nuclear-energy related education	Chair of the Steering Committee, Institute Host & Management
Emirates Nuclear Energy Corporation (ENEC)	UAE nuclear utility	Founding Steering Committee Member
Federal Authority for Nuclear Regulation (FANR)	UAE nuclear regulator	Founding Steering Committee Member
Critical Infrastructure and Coastal Protection Authority (CICPA)[2]	UAE entity responsible for security	Founding Steering Committee Member
National Emergency Crisis and Disaster Management Authority (NCEMA)	UAE entity responsible for managing emergency, crisis and disaster	Steering Committee Member
Nawah Energy Company[3]	UAE nuclear operator	Steering Committee Member
Sandia National Laboratories	Primary U.S. implementer	Founding Steering Committee Member, Operational consultant, Research partner
Texas A&M University (TAMU)/Nuclear Security Science & Policy Institute (NSSPI)	U.S. academic implementer	Steering Committee Member (during early development phase)
U.S. National Nuclear Security Administration Office of Nonproliferation and Arms Control (NA-24)	Sponsor for U.S. implementers	Observer to the Steering Committee
U.S. National Nuclear Security Administration Office of Global Material Security (NA-21)	Sponsor for U.S. implementers	Observer to the Steering Committee
U.S. Department of State's Partnership for Nuclear Threat Reduction (DOS/PNTR)	Sponsor for U.S. implementers	Observer to the Steering Committee

[2] This entity was previously known as *Critical National Infrastructure Authority* (CNIA), so this acronym is used in older GNEII-related publications.

[3] This entity was created in 2016 as the operating organization for the UAE's nuclear power units at the Barakah Nuclear Power Plant. Since it split organizationally from ENEC, its previous collaborations were conducted via ENEC.

2.4. History

The institute's developmental and operational history has had an aggressive—and somewhat surprising—trajectory. Its early history centered on developing the Fundamentals Course (see the next Chapter for more details), which matured from a paper concept to the Pilot Course in 14 months. The ultimate goal was a limited term with the US as primary lead and to build institutional capacity to allow a "soft landing" where all stakeholders have reached research partner status. GNEII's developmental path—with major events and milestone summarized in Table 2—molded and shaped it into an institute that produced nearly 100 graduates from its Fundamentals Course and numerous research publications in the last seven years.

GNEII's operational history is divided into two phases. Phase I officially began with the signing of the Memorandum of Understanding (MOU) titled *Developing and Operating the Gulf Nuclear Energy Infrastructure Institute* on February 21, 2011. This first phase focused on initiating operations and continual improvement of the Fundamentals Course. Specific areas of development included: expansion of the strategic operational partnership; regional outreach and Fellow participation; curriculum refinement supporting a novel, integrated 3S framework; establishing the institute's research framework; and, initiating technical services.[4] [5]

Table 2. Summary of GNEII operational events & milestones

Date	Event/Milestone
November 2009	*First planning meeting between KU, SNL & TAMU*
March 17, 2010	*Letter of Intent signed between KU, FANR, ENEC, SNL & TAMU to formally mark the beginning of GNEII's 'Phase I'*
June 2010	*White House Office of Science and Technology Policy listed GNEII as a "Top 5" Science and Technology related in the region*
February 20, 2011	*MOU 1.0 signed by KU, SNL & TAMU to 'develop & operate' GNEII*
February-May 2011	*GNEII 'Pilot' Fundamentals Course*
October 2011	*1st Annual GNEII Steering Committee Meeting*
Mar., Apr.-May, June-July & Oct. 2012	*GNEII Fundamentals Course (in 'modular' style + First regional participation) & GNEII Symposium*
February-May 2013	*Fundamentals Course (+ regional participation) & GNEII Symposium*
February-May 2013	*First KU-sponsored Faculty Coordinator*
February-May 2014	*Fundamentals Course & GNEII Symposium*
February-May 2015	*Fundamentals Course (+ regional participation) & GNEII Symposium*
May 2015-May 2016	*First official GNEII Visiting Research Scholar*
April 12, 2016*	*MOU 2.0 signed by KU, SNL & TAMU 'for continuing collaboration' with GNEII*
May 2017*	*Co-hosted the IAEA's Nuclear Energy Management School with KU*
November 2017*	*Part of KU's being named an IAEA Collaboration Center for "Nuclear Infrastructure and Human Capacity Development"*
September 2019*	*Submission of the "Integrated Nuclear Safety" applied master degree to the UAE Ministry of Higher Education and Scientific Research for accreditation*
	**These items are considered "Phase II" activities.*

Phase II officially began on April 12, 2016 with the signing of a second MOU entitled *Establishing a Framework for Continuing Collaboration with the Gulf Nuclear Energy Infrastructure Institute.* This new phase focuses GNEII's developmental partners toward collaborating together to achieve the institute's vision and mission. [6] [7] Current efforts supported by this MOU include joint KU/GNEII and SNL research projects (for example, [8]), aligning operations with IAEA best practices and implementing a multi-faceted sustainability plan. Other Phase II activities include supporting KU as it was named the IAEA collaborating center for human resource and nuclear infrastructure development in late 2016 (see Chapter 5 for more details). Over this operational history, GNEII has navigated through a challenging, fast-paced development phase into an institute already making its mark to improve nuclear energy safety, security and safeguards locally, regionally and globally.

3. OBJECTIVES

Stemming from its origins, GNEII's ultimate aim is to be a demand-driven initiative that focuses on using education and research-based approaches to build responsible nuclear energy programs in Gulf and Middle Eastern nuclear professionals. The institute's primary objective, then, is to immerse future nuclear program decision makers in safety, safeguards, security, and nonproliferation concepts and to familiarize them with how these concepts apply in a regional and international context. Here, it is important to note that familiarity with safety, security, safeguards, and nonproliferation (3S) concepts—and their interactions—compose what GNEII alludes to in its *responsible nuclear energy program* (RNEP) paradigm. Such institute-level objectives stand as the desired operational end-state and have helped shape both development and operational goals for GNEII's evolution.

3.1. Goals

During Phase I operations, *developmental goals* were set to guide the decisions made and actions taken to establish the institute. Built on—and closely related to—the design principles introduced in the previous chapter, GNEII's developmental goals were:

- Establish GNEII as a regional educational, training, and research hub for promoting a nuclear safety, safeguards, and security culture
- Maintain regional relevancy, demonstrated by regular participation by students and membership on the GNEII Advisory Council by regional state representatives
- Transition full operational responsibility of an indigenously sustainable GNEII to KU and a majority of educational duties to regional instructors by the end of Phase I activities

Achieving the developmental goals marked the institute's establishment and necessitated the creation of additional goals to drive regular operations. GNEII's Phase II activities are guided by *operational goals* that mark evolutionary and revolutionary institutional changes, which include:

- Maintain reputation as a regional educational, training, and research hub for promoting a nuclear safety, safeguards, and security culture
- Increase regional relevancy, demonstrated by regular participation by students and membership on the GNEII Advisory Council by regional state representatives
- Support independent and collaborative research projects aligned with responsible nuclear energy program topics
- Evolve GNEII as an indigenously sustainable educational institute with full operational responsibility (including budget authority) within KU
- International recognition as "best-in-class" as a human infrastructure development resource, particularly for 3S or responsible nuclear energy programs

3.2. Mission

Generally, a mission statement describes what an organization "wants to do now." As discussed in the previous chapter, GNEII was initiated to meet an identified gap in education-based opportunities to support responsible nuclear energy program development. Thus, what GNEII "wants to do now" is provide a coherent and coordinated program to build up a cadre of regional experts in responsible nuclear energy programs. Clear and succinct, GNEII's mission statement outlines the key design features and couples them with the overall aim of the institute as:

> To develop a responsible nuclear energy culture and institutionalize key safety, security and nonproliferation norms in the future decision-makers of Gulf-region nuclear energy programs through professional development and training

3.3. Vision

In contract, a vision statement is generally considered to describe what an organization "wants to do in the future." Emerging from the design principles discussed in the previous chapter, desire future states of GNEII seek to change the regional and operational drivers of the institute. Aligned with the operational goals introduced above, what GNEII "wants to do in the future" is meet regional needs to support the growth of responsible nuclear energy programs. GNEII's vision reflects the forward-looking nature of the institute:

> To provide the Gulf, and surrounding region, with a continual source of indigenous nuclear energy professionals with whom the global community can effectively partner and collaborate to achieve broader nuclear energy security and safety priorities

4. OPERATIONS

In support of the GNEII's vision and mission, the institute consists of three operational pillars: education, research and technical services. These pillars are not intended to be independent, but rather were designed with the intent for frequent interaction. Development and evolution of each pillar has progressed at different rates, but the interdependencies between the three are regularly leveraged to enhance both the experience of Fellows at, and the professional reputation of, the institute. For example, the technical services offered to the Port of Abu Dhabi provided opportunities for Fundamentals Course participants to conduct site visits to observe radiation portal monitor activities. Taken together, GNEII's primary operational elements – education, research, and technical services (Figure 1) – support the institute's key design features; reflect the institute's mission and vision; and serve the institute's regional relevance and sustainability.

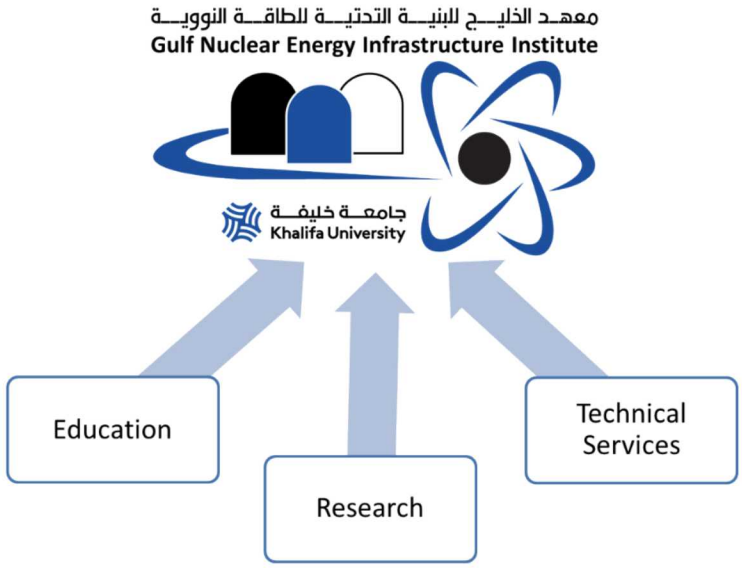

Figure 1. Graphical illustration of GNEII's operational pillars

4.1. Education Pillar

Under the **education pillar** (during Phase I operations), the primary focus was developing and implementing the GNEII Fundamentals Course. This course was based on a multidisciplinary, systems theory-based pedagogical approach consisting of two key elements. First was the multidisciplinary approach, similar to [9] and [10], to help new nuclear professionals identify where nuclear energy safety, security and safeguards (3S) interdependencies to exist (Figure 2). This also helped emphasize the need for future nuclear energy program leaders to manage across these aspects, as responsible nuclear energy decisions often require interactions between safety, security and safeguards. Second was a systems-thinking based program structure similar to that described by Bozkurt and Helm [11] underlying their *Systems Engineering Framework* for online education development. Here, the systems engineering concepts of a *holistic view*, *life-cycle orientation*, *identification of system requirements*, and *interdisciplinary effort* helped develop our responsible nuclear energy program (RNEP) framework, which reframed the multidisciplinary aspects of nuclear energy enterprises in systems theory terms.[5] [12]

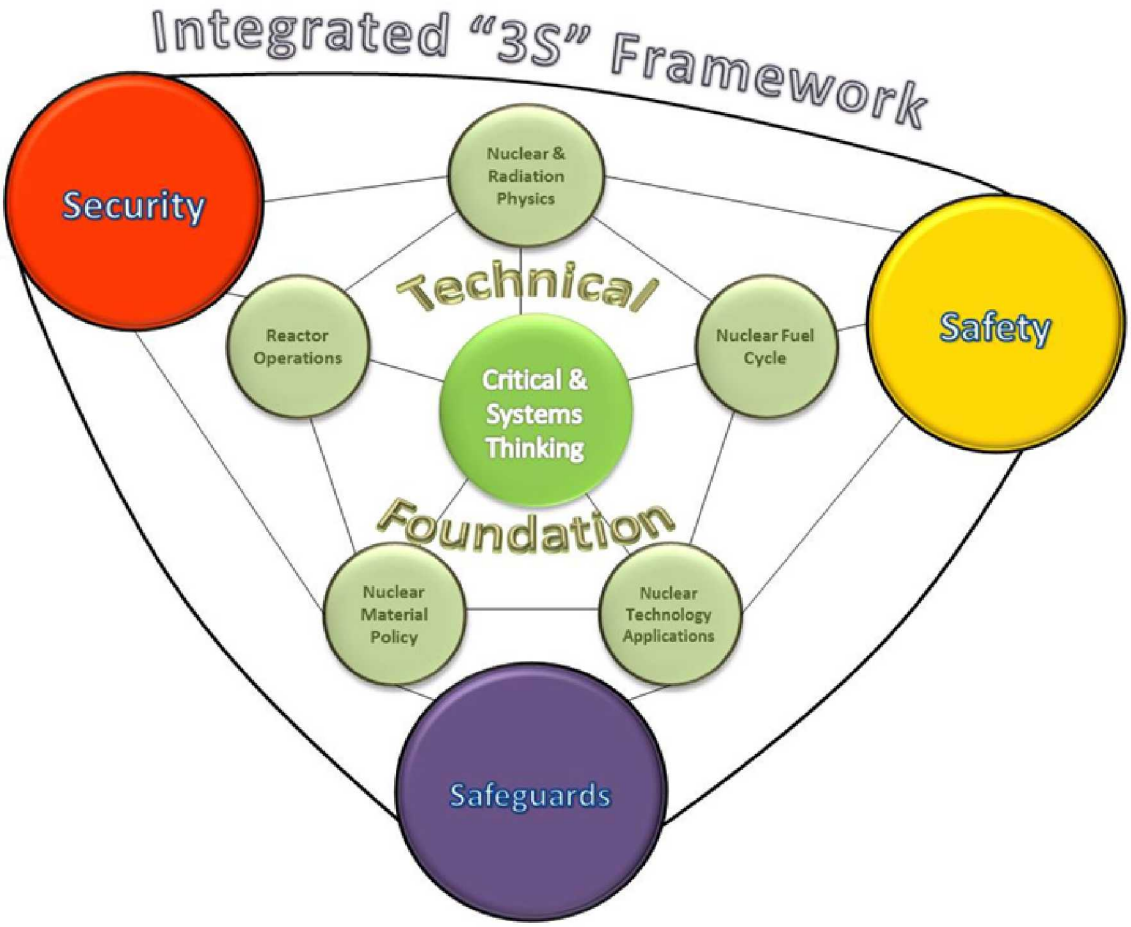

Figure 2. Graphical representation of GNEII's novel, integrated 3S curriculum

In practice, GNEII's educational structure (during Phase I operations) consisted of a semester-long *Fundamentals Course* to address each of the key elements—and their interactions—in Figure 2. On average, each Fundamentals Course lasted for 13 weeks, with each week following a specific and coordinated topic (for example, Figure 3). The first four weeks were dedicated to building a strong technical and logical foundation for the Fellows to better understand safety, security, safeguards, and nonproliferation concepts. This "Nuclear Fundamentals" module consisted of four topics. Week 1 provided the basic logical structure for the Fundamentals Course and included an overview of the need for nuclear energy; history and economics of nuclear energy; critical and systems thinking; and the scientific method. Week 2 built on this structure and introduced basic nuclear science concepts, including nuclear and radiation physics; neutron interactions and radiation effects; and, basic reactor theory. Week 3 expanded this knowledge to discuss nuclear power facilities in more details, with such topics as reactor operations and power plant systems. Finally, week 4 further expanded this nuclear knowledge by discussing broader topics related to the nuclear fuel cycle, as well as nonproliferation history and policy.

The last six week of the Fundamentals Course consisted of two-week modules on nuclear safeguards, nuclear safety, and nuclear security. Each of these modules were designed to discuss both technical and non-technical (e.g., social and political) systems and measures—as well as the interactions between them. To this end, the safeguards module discussed such topics as the state

system for accounting and control; non-destructive and destructive analysis; and, implementation challenges at bulk and item facilities. Likewise, the safety module introduced such topics as safety culture; engineering safety features; and emergency response planning. Lastly, the security module consisted of security culture; physical protection system design and evaluation; and transportation security topics. It is also important to note that the interdependencies *between* safeguards, safety, and security were explicitly and regularly discussed during these modules—including, for example, highlighting the *potentially* conflicting safety and security goals during emergency procedures at a nuclear energy facility.

The last three weeks of the Fundamentals Course were devoted to the Fellows completing their Capstone Projects. On average, Fellows were provided approximately two weeks of dedicated class time for each group to collect, analyze, and report data in support of these short-term research projects. (NOTE: The Capstone Project itself is explained in more detail in the following section.) The last week of the Fundamentals Course was devoted to finalizing Capstone Project reporting and presentation dry-runs. Each Fundamentals Course also ended with a *GNEII Symposium*, where each Capstone group was able to present their projects results in front of an audience of their peers and representatives from regional and international stakeholders.

GNEII 2016 Fundamentals Course Curriculum		
17-Jan *Week 1*	Overview, Need for Nuclear, History, Components, Economics, Critical & System Thinking, Scientific Method, 3S System	
24-Jan *Week 2*	Nuclear & Radiation Physics, Neutron Interactions, Basic Reactor Theory, Radiation Effects, Nuclear Technology	
31-Jan *Week 3*	Reactor Operations, Power Plant Systems, Probabilistic Risk Assessment	
7-Feb *Week 4*	Nuclear Fuel Cycle, Nuclear Nonproliferation History & Policy	
14-Feb *Week 5* – 21-Feb *Week 6*	SAFEGUARDS (2 weeks) State System of Accountancy Controls, Non-Destructive and Destructive Analysis, Bulk and Item Facilities	
28-Feb *Week 7* – 6-Mar *Week 8*	SAFETY (2 weeks) Safety Culture, Engineered Safety Features, Emergency Response Planning, Radiation Safety	
13-Mar *Week 9* – 20-Mar *Week 10*	SECURITY (2 weeks) Security Culture, Physical Protection Systems, Detect, Delay, Respond, Evaluate	
27-Mar *Week 11* – 3-Apr *Week 12*	Capstone Research & Preparation (2 weeks)	
10-Apr *Week 13*	Capstone Preparation & Dry Runs	SYMPOSIUM: Capstone Presentations & Certificates

Figure 3. GNEII 2016 Fundamentals Course curriculum schedule

During the Fundamentals Course, the faculty coordinator oversaw a rotation of U.S., UAE and global subject matter experts as lecturers in support of this multidisciplinary curriculum. Lastly, the course combined lectures, hands-on activities, classroom exercises and case studies to help meet course learning objectives. More details of this multidisciplinary curriculum can be found in [6] [5].

Table 3, below, describes the Fellows who completed the GNEII Fundamentals Course between 2011 and 2016.

Table 3. Summary of GNEII Fundamentals Course Fellows 2011-2016

Year	# UAE Fellows			# Non-UAE Fellows	Yearly Total	Countries Represented
	ENEC*	FANR	CICPA			
2011	4	5	1	0	10	UAE
2012	3	9	2	8	18 (22)**	UAE, Kuwait, Saudi Arabia, Qatar, Jordan
2013	4	6	3	7	20	UAE, Saudi Arabia, Qatar
2014	6	3	3	0	12	UAE
2015	7	4	5	2	18	UAE, Jordan
2016	2	16	3	0	21	UAE
TOTAL	**26**	**43**	**17**	**17**	**99**	**5**

*Includes Fellows from Nawah, the NPP operating company that split from ENEC in 2016.
**Due to modular structure of the course in 2012 not all international participants were able to finish all required modules due to logistical reasons.

4.2. Research Pillar

Developing this pillar will allow for the thoughts, ideas and talents of regional professionals to be shared with the greater nuclear energy community in a consistent and rigorous manner. The intent for this pillar is to allow GNEII Fellows and other collaborators to examine technical, operational, and political aspects of three envisioned areas of the core research competency. The first area of GNEII's core competency is integrated 3S methodologies, which seeks to build on both initial efforts and international emphasis on how to best leverage the interactions between safety, safeguards and security. GNEII is well positioned to take advantage of the fresh perspectives of 3S methodologies associated with the emerging nuclear energy professional force in the region. GNEII's second area of core competency is nuclear infrastructure development, given its proximity to new nuclear builds and novel models of nuclear energy program development. The third and last area of core competency envisioned for GNEII is Gulf/Middle East regional nuclear interactions. This area of research provides a vehicle to encourage multinational collaboration on and discussions regarding intraregional nuclear energy issues. [13]

Figure 4. GNEII research framework

To date, the majority of development on this pillar is associated with the Fundamentals Course Capstone Project. As introduced above, the Capstone Project is the culminating requirement for the GNEII Fundamentals Course in which Fellows conduct a practical research project firmly based on one of the institute's three core competencies. [4] In addition to serving as a metric for evaluating the ability of Fellows to learn and synthesize the Fundamentals Course curriculum, the Capstone Project serves two objectives. First, it provides Fellows the opportunity to present their research in front of an audience filled with colleagues, managers and experts from regional nuclear energy organizations. Second (and perhaps, more importantly) this project provides each Fellow with an academic accomplishment – something to 'hang their hat on.' Since these projects are often generated by issues or problems faced by their host organizations, Fellows are able to return to their workplaces with potential solutions in hand. Preparation for the Capstone Project includes lectures on research problem framing, analysis methods and organizing thoughts in slides, poster and written form. As indicated above, Fellows were provided several weeks of 'class-time' to complete the synthesis and analysis for their Capstone Projects without direct instruction – and most Fellows put in work outside of normal business hours to ensure successful projects. Up until this year, Fellows produced a research paper and a 30-minute presentation. The GNEII Steering Committee suggested adding a poster requirement for this year's Capstone Project – an addition that was very well received and implemented at the 2015 Symposium.

Table 4. List of GNEII capstone projects from 2011 to 2016

Year	Capstone Project Title	Author Host Organization(s)
2011	Integration of Nuclear Safety, Security & Safeguards	CNIA/FANR/ENEC
	Effects of the Environmental on Nuclear Power Plant Operations	FANR/ENEC
2012	Station Black Out Roles and Mitigation Plan	ENEC
	The UAE Export Control Laws	ENEC
	Project Control of NPP Construction	ENEC
	Impact of NPP/Desalination on Gulf	SEC/KISR
	MIMIS on APR1400 Reactor	FANR
	APR1400 Liquid Source Terms	FANR
	UAE Strategy for High-Level Waste Management	FANR/CICPA
	Transportation of Fresh Nuclear Fuel	FANR/CICPA
	Radioactive Dose Pathway Modeling	MOD/FANR
	Transparency in Nuclear Security	FANR
	Emergency Preparedness for NPP	FANR
2013	Pyrochemical Reprocessing	ENEC
	A Qualitative Assessment of Fuel Fabrication Options in the UAE	FANR
	The Suitable Mobile Lab for the UAE Condition	FANR
	Emergency Preparedness Plan for Radioactive Material	MOD
	Safety, Security, and Safeguards Challenges for Building a Final Repository for Spent Fuel in the UAE**	FANR
	Use of Microfinned Steam Generator Tubes in NPP	MOEW
	The Role of Management Systems in Protecting the Environment from RNEP	ENEC
	Filling the Gaps Between Safety and Security	ENEC/CICPA
	Emergency Preparedness Plan	CICPA/MOE
2014	Survey of the Current Spent Nuclear Fuel Storage Technologies & Assessing Safety Approaches of Existing Systems for Barakah Nuclear Power Plant (BNPP)	ENEC
	Development of Recommendations for the Nuclear Security Culture in the UAE	FANR

Year	Capstone Project Title	Author Host Organization(s)
	Evaluation of Security and Safeguards Measures for the Transportation Security in the UAE	CICPA
	Evaluation of Safeguards and Security Options for the Dry Cask Storage in the UAE	CICPA/FANR
	Synergy between Safeguards and Security at an NPP	ENEC
	An Initial Radiation Baseline Study of Urban Environment in Abu Dhabi	ENEC
	Effective Enhancements for Integrated Safety and Security Control Systems in BNPP	ENEC
2015	Thermal-hydraulic Studies on Design Extension Condition of Prolong Station Black Out with Additional Failures	EMRC
	Overview of Molten Core – Concrete Interaction (MCCI) and Mitigation Actions	ENEC
	Needs of Atmospheric Dispersion Models in Emergency Situations	CICPA
	Investigation on the Sensitivity of UAE Domestic Agricultural Production to Radiological Contamination Following a Hypothetical Severe Nuclear Accident at Barakah NPP*,**	CICPA/ENEC
	Evaluation of Threats by Drones to a Nuclear Power Plant**	CICPA
	Evaluation UAE Security Culture – Insider Threat	FANR
	Operational Security and Information Protection in the Areas of 3S	ENEC
	Analysis of the Safeguards Measures for the Nuclear Fuel Cycle Back-End Options in the UAE	FANR/ENEC
2016	Review of Accident Tolerant Fuel Concepts for Light Water Reactors – A Qualitative Assessment of Current Technology	ENEC/FANR
	Evaluation techniques for degradation of reactor containment building	FANR
	Evaluation of Cosmic-Ray Dose in the UAE	FANR
	Measurements of radionuclides concentration in UAE cucumber	FANR
	Safeguards and Security approach to final spent fuel repository**	FANR
	Mitigation of national cultural differences effects during safety, security emergency at an NPP site	FANR
	Neutron activation of living insects for safety and security applications	FANR
	Development of nuclear security exercises at a Nuclear Power Plant	CICPA

ENEC = Emirates Nuclear Energy Corporation (UAE); FANR = Federal Authority for Nuclear Regulation (UAE); CICPA = Critical Infrastructure & Coastal Protection Authority (UAE); EMRC = Energy & Minerals Regulatory Commission (Jordan); JAEC = Jordan Atomic Energy Agency (Jordan); KISR = Kuwait Institute for Scientific Research (Kuwait); MOE = Ministry of Environment (Qatar); NCPW = National Committee for the Prohibition of Weapons (Qatar); MOD = Ministry of Defense (Saudi Arabia); MOEW = Ministry of Electricity & Water (Saudi Arabia); MOP = Ministry of Petroleum (Saudi Arabia); SEC = Saudi Electric Company (Saudi Arabia)

*Indicates a successfully presented at a professional conference

**Indicates a project that served as a seed for follow-on, more in-depth research

In addition, GNEII supported a range of more traditional academic research efforts. For example, the institute hosted a Visiting Research Scholar in 2015, which resulted in the article "Analysis of Natural and Anthropogenic Radionuclide Content in Palm Date Fruit of the United Arab Emirates: A Baseline Study." published in the *Health Physics Journal.* Similarly, beginning in 2013, the GNEII Manager position also supported research projects across a variety of topics, including calibration and operation of gamma spectrometers for environmental measurements; advanced analysis of Monte Carlo spectra for safeguards analysis; and nuclear security impacts from unmanned aerial vehicles.

Given this strong start to the institute's research pillar, there are several mechanisms to fuel growth. First, the increasing rigor and novel topics of the Fundamentals Course Capstone Projects will continue to plant seeds for future, more in-depth research supported by the institute. Second, another iteration of the institute Research Fellow position has recently been filled. This individual has the sole responsibility to nurture GNEII's nascent research endeavors. This work includes preparing ideas identified in Capstone Projects for further research development, generating new ideas for institute research and completing at least one refereed journal and one professional conference paper submission. Third, plans are in place to grow the annual GNEII Symposium in terms of prominence and attendance. Given that the symposium is currently the primarily vehicle for publicizing the ideas, research and conclusions emerging from the institute, expanding its reach and influence is crucial to establishing the research pillar. Growing GNEII into a regional leader in research related to responsible nuclear energy programs will only further establish the value of the institute and is integral to its sustainability plan.

4.3. Technical Services Pillar

The **technical services pillar** began as a desire to provide demonstration activities to augment the other two pillars. Because such a "hands-on" capability is invaluable, the eventual goal is to help design and build a "3S Laboratory" where detailed demonstrations and basic research on various 3S-related technologies can be conducted. Early in Phase I operations, KU's nuclear engineering department completed construction on several laboratories, all which directly connect to GNEII's areas of educational and research interests, including:

- a scale model of the APR1400 reactor pressure vessel;
- a scale model of the Barakah Nuclear Power Plant (units 1 and 2);
- an environmental radiation laboratory (including alpha, beta, and gamma detectors for environmental sample measurements);
- a reactor analysis, design, and instrumentation controls laboratory (including computers with various nuclear power-related modeling software and a generic, three loop "Compact Nuclear Simulator" that allows for human factors research);
- a radiation sciences laboratory (including sodium-iodide and surface barrier detectors, as well as Geiger-Mueller counters for basics detection experiments); and,
- a nuclear material and chemistry laboratory (including equipment the custom built pressurized water stress corrosion rig).

In practice, various efforts were undertaken to enhance the institute's capabilities (and opportunities) to provide 'hands-on,' practical experiences—to include exercises in KU's nuclear engineering department laboratories, tours of the Barakah Nuclear Power Plant (2012) and (the state-of-the-art)

radiation portal monitoring system at Khalifa Port in Abu Dhabi (2014-2016). The end of Phase I operations involved plans to expand this pillar from simple 'demonstration' to a 'service-providing' focus. For example, GNEII has served as "technical reachback" for the radiation portal monitors at port facilities in the UAE. This pillar has developed into both a way to provide regional stakeholders with short-term, technical and targeted nuclear energy-program services and create a new set of capabilities for the institute.

5. MAJOR INSIGHTS & CONCLUSIONS

GNEII has provided a high-performing, well-prepared cadre of early and mid-career professionals to support regional nuclear energy programs; increased the quality and sophistication of its research efforts; and, grown into a Gulf and Middle East regional hub for addressing nuclear infrastructure and human capacity development needs.

5.1. Sustainability and Transition

The growth and development of GNEII was a part of the strategic plan originated in the 2011 MOU signed by Khalifa University, the Nuclear Security Science and Policy Institute/Texas A&M University and Sandia National Laboratories. This plan established 2017 as the year in which operational ownership is transferred from the US to UAE stakeholders. After the 2016 Fundamentals Course, formal GNEII handover took place at the 2016 Symposium. This resulted in a transfer of GNEII management and operational functions from US to UAE stakeholders. and pushed toward a transition. The main objective was successful knowledge transfer in order to develop a more structured degree-based curriculum with a focus on nuclear safety, security, safeguards, and management and leadership.

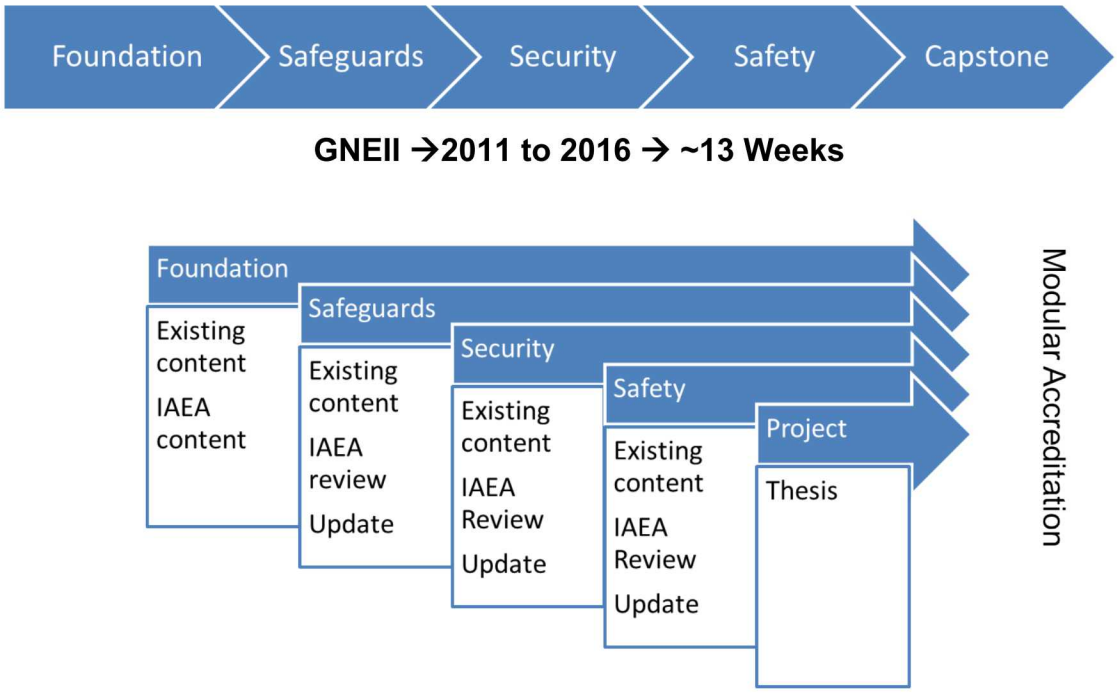

Figure 5. GNEII academic program transition plan

The GNEII Steering Committee (GSC), during its 2015, 2016, 2017, and 2018 meetings, accepted recommendations to have a financial plan fully supported by all local and regional stakeholders, and a human capacity plan resourced from all local stakeholders. Also, the GSC created the "Finance and Sustainability Subcommittee" that consists of representatives from all GNEII stakeholders, meet more frequently than the GSC, and is responsible for discussing and developing viable specific financial and human capacity plans for GNEII.

5.2. Next Steps: GNEII's Phase II Program

The main objective in Phase II of GNEII education curriculum is to re-structure the current GNEII fundamentals course in a format suitable for awarding the fellows graduate credits accredited by the Abu Dhabi Ministry of Higher Education and Academic Research. Typically, GNEII Fellows did not have a Bachelor of Science in nuclear engineering—however, historically the academic background was spread across both the non-technical (e.g., Bachelor of Arts in political science or economics) and technical (e.g., Bachelor of Science in engineering or physics) degrees. As such, the future GNEII academic program seems suitable for non-engineering and engineering graduate credits alike. Considering the content currently in the GNEII curriculum and the design goal for a modularized structure, the result is the proposed *Applied Masters Program in Integrated Nuclear Safety* (AM-INS) illustrated in (Figure 6). This design and structure aligns with the objective if the GSC and inputs from a peer review conducted by IAEA subject matter experts in 2017. The proposed program was submitted for formal accreditation to the UAE's Ministry of Higher Education and Scientific Research in 2019.

Figure 6. Proposed New Applied Master's Degree Model for GNEII

This AM-INS degree is proposed to consist of 30 credit hours and is intended to be a two-year program as indicated in (Figure 6). Admission into the program requires having earned a *National Qualifications Framework, United Arab Emirates* (QFEmirates, or QFE) Level 7 qualification (bachelor or its equivalent), as well as must also having participated in one of the IAEA overview programs (Nuclear Energy Management or Nuclear Infrastructure Development schools) or completed the GNEII Fundamentals Course. The program consists of 30 credits (which is in line with the Commission for Academic Accreditation QFE Level 9 [14]) and is structured as follows:

- Four mandatory, core courses (12 credits)
    - GNEI-601 Critical Thinking and Nuclear Energy Fundamentals
    - GNEI 602 Principles of Nuclear Safety
    - GNEI 603 Principles of Nuclear Security
    - GNEI 604 Principles of Nuclear Safeguards
- Three courses in a chosen specialization (9 credits)
    - Nuclear Security Specialization
        - GNEI 611 Nuclear Security Management

        - GNEI 612 Non-proliferation and Security
        - GNEI 613 Physical Protection Systems Design and Evaluation
    - Nuclear Safeguards Specialization
        - GNEI 621 Methods and Instrument for Nuclear Materials Measurements
        - GNEI 622 Nuclear Material Accountancy and Inventory Control
        - GNEI 623 Nuclear Nonproliferation and Arms Control
    - Nuclear Safety Specialization
        - GNEI 631 The Safety of Nuclear Fuel Cycle
        - GNEI 632 Nuclear Safety for Reactor Designs
        - GNEI 633 Radiation Protection and the Safety of Radiation Sources
- One elective course from a *different* specialization (3 credits)
- Research seminar and thesis courses (6 credits)
    - GNEI 695 Seminar in Research Methods
    - GNEI 699 Thesis

Within the AM-INS program, there is an early exit option wherein the completion of Capstone Project (GNEI 690) will result in an Applied Graduate Diploma of Integrated Nuclear Safety (AGD-INS). Thus, GNEII's proposed Applied Masters Program in Integrate Nuclear Safety offers opportunities to earn several different credentials:

- IAEA-sponsored professional certificates
- UAE-accredited *Applied Graduate Diploma of Integrated Nuclear Safety*
- UAE-accredited *Applied Masters Degree in Integrated Nuclear Safety*

5.3. KU-IAEA Collaborating Centre

In late 2017, Khalifa University of Science and Technology was named an IAEA collaborating center [15], which are any

> IAEA Member State institution, department or laboratory within an institution, designated by the relevant IAEA Deputy Director General (DDG), that on the basis of the IAEA Collaborating Centre Agreement designating such institution, department or laboratory within an institution as an IAEA Collaborating Centre, supports the IAEA's programmatic activities through the implementation of a Work Plan that is agreed with the relevant IAEA Division(s), and included as an annex to the IAEA Collaborating Centre Agreement.

Consistent with GNEII's mission of going above and beyond traditional training events, the naming of the IAEA *Collaborating Center for Nuclear Energy Infrastructure and Human Resource Development* at KU marks a four-year period of cooperation to implement activities in the field(s) of nuclear energy infrastructure and human resource development. GNEII's key role in demonstrating KU's capacity in enhancing knowledge in support of regional responsible nuclear energy programs is enshrined on the official IAEA plaque commemorating this collaborating center. During the its opening ceremonies, (then) interim President Tod A. Laursen stated that

> We are honoured by the IAEA designation as an IAEA Collaborating Centre. Since I signed our first Practical Arrangement with the IAEA in 2010, we have engaged with the IAEA on human resource development through our Gulf Nuclear Energy Infrastructure Institute (GNEII) programme and by hosting the joint UAE-IAEA Nuclear Energy Management Schools. We look forward to enhancing our offerings in this area, both within the UAE and to support other IAEA Member States

As of one of the world's newest nuclear power states, the UAE has a tremendous wealth of experience and growing expertise in nuclear infrastructure development—including that of GNEII. This collaborating center provides a robust mechanism through which institute collaborative efforts can be reinforced, including developing and implementing specific short courses to hosting best practices/lessons learned workshops to designing advanced versions of IAEA Nuclear Energy Management and Nuclear Infrastructure Development Schools. In its support role to collaborate with the IAEA to enhance Member State capabilities for building, assessing, and maintaining the legislative, organizational, and personnel infrastructure required for responsible nuclear energy programs, GNEII is well on its way of meeting its vision.

5.4. A Last Word…

Lastly, the Fellow Keynote Address at the 2016 GNEII Symposium offered a comprehensive description of the impact the institute has had—and *can have*—on emerging leaders in regional nuclear energy programs, where:

> *GNEII is not just a training course that you add to your CV…It is a very powerful educational tool that changes your perspective from being narrowly…to broadly adopt the sense where all of us are parts of something bigger…It's not you as an operator or me as a regulator or them as a defense force, it is us together, working hand by hand to establish a responsible nuclear energy program that effectively integrate the 3S.*

6. GNEII PUBLICATIONS LIST

The following is a list of publications describing GNEII:

- Alameri, S.A., A.D. Williams, A.K. Alkaabi , A.A. Solodov, P.A. Beeley, A.H. Mohagheghi, and A. Hechanova. (2019) 'Partnering between the IAEA Collaboration Center for Human Resource and Nuclear Energy Infrastructure Development & Gulf Nuclear Energy Infrastructure Institute (GNEII),' Proceedings Paper for the *Institute for Nuclear Materials Management 60th Annual Meeting*, Palm Desert, CA, July 14-18.

- Williams, A.D., S.A. Alameri, A.A. Solodov, P.A. Beeley, A.H. Mohagheghi, and A. Hechanova. (2018) 'The Next Steps for the Gulf Nuclear Energy Infrastructure Institute (GNEII),' Proceedings Paper for the *Institute for Nuclear Materials Management 59th Annual Meeting*, Baltimore, MD, July 22-26.

- Williams, A.D., A.A. Solodov, P.A. Beeley, S.A. Alameri, and A.H. Mohagheghi. (2017) 'Evaluating the Educational Impact of the Gulf Nuclear Energy Infrastructure Institute (GNEII)'s Novel 3S Approach,' Proceedings Paper for the *Institute for Nuclear Materials Management 58th Annual Meeting*, Palm Desert, CA, July 16-20.

- Williams, A.D., A.A. Solodov, A.H. Mohagheghi, P.A. Beeley, and C.A. Gariazzo. (2016) 'Ending Phase I: The Evolution of the Gulf Nuclear Energy Infrastructure Institute (GNEII),' Proceedings Paper for the *Institute for Nuclear Materials Management 57th Annual Meeting*, Atlanta, GA, July 24-28.

- Solodov, A., P.A. Beeley, A.D. Williams, A.H. Mohagheghi, R.J. Finch and D.R. Boyle. (2015) 'Developing the Gulf Nuclear Energy Infrastructure Institute for Regional Expansion,' *American Nuclear Society, Conference on Nuclear Training and Education (CONTE)*, Jacksonville, FL, February 1-4. (presentation)

- Williams, A.D., A.H. Mohagheghi, D.R. Boyle, and P.A. Beeley. (2015) 'Regional, Educational & Strategic: the Gulf Nuclear Energy Infrastructure Institute in Year 5.' *The Third Arab Conference on the Prospects of Nuclear Power for Electricity Generation and Seawater Desalination*, Manama, Bahrain, 1-3 December. (presentation)

- Mohagheghi, A.H., A.D. Williams, P.A. Beeley and A. Solodov. (2015) 'The Gulf Nuclear Energy Infrastructure Institute (GNEII),' *Forum for International Physics*, Fall 2015.

- Williams, A.D., A. Solodov, D.R. Boyle, A.H. Mohagheghi, P.A. Beeley and M.R. Sternat. (2015) 'Expanding into Research Opportunities: Gulf Nuclear Energy Infrastructure Institute (GNEII) in Year 5,' Proceedings Paper for the *Institute for Nuclear Materials Management 56th Annual Meeting*, Indian Wells, CA, July 12-16.

- Beeley, P.A., A.H. Madhloum, B.K. Kim, M.J. Schuller, D.R. Boyle, R.J. Finch, A.H. Mohagheghi, F. Ghanbari and A.D. Williams. (2013) 'The Gulf Nuclear Energy Infrastructure Institute (GNEII): Two Years On,' *American Nuclear Society, Conference on Nuclear Training and Education (CONTE)*, Jacksonville, FL, February 3-6. (presentation)

- Finch, R., A.M. Al-Madhoum, M.J. Schuller, D.R. Boyle, A.H. Mohagheghi, A. Solodov, P.A. Beeley, F. Ghanbari and A.D.Williams. (2013) 'The Gulf Nuclear Energy Infrastructure Institute (GNEII) After Three Years,' Proceedings Paper for the *Institute for Nuclear Materials Management 54th Annual Meeting*, Palm Desert, CA, July 14-18.

- Finch, R., Williams, A.D., M.S. Schuller, D.R. Boyle, A.H. Mohagheghi, F. Ghanbari, A. Al Madhloum, P.A. Beeley and B.K. Kim. (2012) 'The Gulf Nuclear Energy Infrastructure Institute (GNEII): Update & Expansion,' *The Second Arab Forum on the Prospects of Nuclear Power for Electricity Generation and Seawater Desalination*, Amman, Jordan, June 19-21. (presentation)

- Williams, A.D., A.M. Al-Madhoum, P.A. Beeley, B.K. Kim, D.R. Boyle, A.H. Mohagheghi, M.J. Schuller, and F. Ghanbari. (2012) 'Results from and Expansion of the Gulf Nuclear Energy Infrastructure Institute (GNEII)' Proceedings Paper for the *Institute for Nuclear Materials Management 53rd Annual Meeting*, Orlando, FL, July 16-20.

- Williams, A.D., D.R. Boyle, and P.A. Beeley. (2011) 'The Gulf Nuclear Energy Infrastructure Institute (GNEII): A New Approach to Nuclear "3S" Education,' *American Nuclear Society, Conference on Nuclear Training and Education (CONTE)*, Jacksonville, FL, February 6-9. (presentation)

- Williams, A.D., P.A. Beeley, D.R. Boyle, A.H. Mohagheghi, and A.M. Nilsen. (2011) 'Gulf Nuclear Energy Infrastructure Institute (GNEII): Overview and Status Update,' Proceedings Paper for the *Institute for Nuclear Materials Management 52st Annual Meeting*, Palm Desert, CA, July 18-22.

- Williams, A.D., A.H. Mohagheghi, D.R. Boyle, and P.A. Beeley. 'The Gulf Nuclear Energy Infrastructure Institute: 'An Integrated Approach to Safety, Security and Safeguards,'" (2010) *League of Arab States Workshop* and *Round Table* "*Strengthening Nuclear Safety and Security Culture: Infrastructure Development and Capacity Building in the Arab Countries*," Cairo, Egypt, April 25-26. (presentation)

- Boyle, D.R., A.H. Mohagheghi, and A.D. Williams. (2010) 'GNEII – Instilling Global Standard for Nuclear Safety, Security and Safeguards in Developing Countries.' Proceedings Paper for the *Institute for Nuclear Materials Management 51st Annual Meeting, Baltimore*, MD, July 11-15.

REFERENCES

[1] United Arab Emirates Permanent Mission to the International Atomic Energy Agency, *Delivered remarks of H.E. Ambassador Haman Alkabbi to the International Conference on Human Resource Development for Nuclear Power Programmes,* Vienna, 2014.

[2] N. J. Hayden, D. M. Rizzo, M. M. Dewoolkar, M. D. Neumann, S. Lathem and A. Sadek, "Incorporating a Systems Approach into Civil and Environmental Engineering Curricula: Effect on Course Redesign, and Student and Faculty Attitudes," *Advances in Engineering Education,* vol. 2, no. 4, pp. 1-27, 2011.

[3] D. R. Boyle, A. H. Mohagheghi and A. D. Williams, "GNEII--Instilling Global Standards for Nuclear Safety, Security, and Safeguards in Developing Countries," in *Proceedings of the 51st Annual Meeting of the Institute of Nuclear Materials Management*, Baltimore, 2010.

[4] A. D. Williams, P. A. Beeley, D. R. Boyle, A. H. Mohagheghi and A. Nilsen, "Gulf Nuclear Energy Infrastructure Institute (GNEII) Overview & Status Update," in *Proceedings of the 52nd Annual Meeting of the Institute of Nuclear Materials Management*, Palm Desert, 2011.

[5] A. D. Williams, A. M. Al-Madhoum, P. A. Beeley, B. Kim, D. R. Boyle, A. H. Mohagheghi, M. S. Schuller and F. Ghanbari, "Results from and Expansion of the Gulf Nuclear Energy Infrastructure Institute (GNEII)," in *Proceedings of the 53rd Annual Meeting of the Institute of Nuclear Materials Management*, Orlando, 2012.

[6] A. D. Williams, A. Solodov, D. R. Boyle, A. H. Mohagheghi and P. A. Beeley, "Regional, Educational & Strategic: the Gulf Nuclear Energy Infrastructure Institute (GNEII) in Year 5," *Transactions of the American Nuclear Society,* vol. 113, pp. 91-94, 8-12 November 2015b.

[7] A. D. Williams, C. A. Gariazzo, P. A. Beeley, A. Solodov and Amir H. Mohagheghi, "Ending Phase I: The Evolution of the Gulf Nuclear Energy Infrastructure Institute (GNEII)," in *Proceedings of the 57th Annual Meeting of the Institute for Nuclear Materials Management*, Atlanta, 2016.

[8] A. Solodov, A. D. Williams, S. Alhanaei and B. Goddard, "Analyzing the Threat of Unmanned Aerial Vehicles (UAV) to Nuclear Facilities," *Security Journal,* pp. 1-20, 2017.

[9] M. Gorman, L. G. Richards, W. R. Scheree and J. K. Kagiwada, "Teaching Invention and Design: Multi-Disciplinary Learning Modules," *Journal of Engineering Education,* vol. 84, no. 2, 1995.

[10] J. Rhee, C. Oyamot, D. Parent, L. Speer, A. Basu and L. Gerston, "A Case Study of a Co-instructed Multidisciplinary Senior Capsteon Project for Sustainability," *Advances in Engineering Education,* vol. 4, no. 2, pp. 1-29, 2014.

[11] I. Bozkurt and J. Helm, "Development and Application of a Systems Engineering Framework to Support Online Course Design and Delivery," *Advances in Engineering Education,* vol. 3, no. 3, pp. 1-24, 2013.

[12] R. J. Finch, A. M. Al-Madhloum, M. J. Schuller, D. R. Boyle, A. H. Mohagheghi, A. Solodov, P. A. Beeley, F. Ghanbari and A. D. Williams, "The Gulf Nuclear Energy Infrastructure Institute (GNEII) After Three Years," in *Proceedings of the 54th Annual Meeting of the Institute of Nuclear Material Management*, Paln Desert, 2013.

[13] A. D. Williams, A. Solodov, D. R. Boyle, A. H. Mohagheghi, P. A. Beeley and M. R. Sternat, "Expanding into Research Opportunities: Gulf Nuclear Energy Infrastructure Institute (GNEII) in Year 5.," in *Proceedings of the 56th Annual Meeting of the Insitute of Nuclear Materials Management*, Indian Wells, 2015a.

[14] United Arab Emirates National Qualifications Authority, "Qualifications Framework for the

Emirates Handbook," QFEmirates, Abu Dhabi, 2012.

[15] International Atomic Energy Agency, "The International Atomic Energy Agency Collaboraing Centres Scheme Reference Guide," 2016. [Online]. Available: https://www.iaea.org/sites/default/files/16/07/iaea_collaborating_centres_scheme_external_guide_v1.1_april_2016.pdf. [Accessed 17 June 2019].

DISTRIBUTION

Email—External

Name	Company Email Address	Company Name
Dr. Philip Beeley	Philip.beeley@kustar.ac.ae	Khalifa University of Science and Technology
Dr. Saeed Al-Ameri	Saeed.alemeri@kustar.ac.ae	Khalifa University of Science and Technology

Email—Internal

Name	Org.	Sandia Email Address
Alexander Solodov	6815	aasolod@sandia.gov
Amir Mohagheghi	6833	ahmohag@sandia.gov
Dianna Blair	6830	dsblair@sandi.gov
Rodney Wilson	6800	rkwilso@sandia.gov
Technical Library	9536	libref@sandia.gov

This page left blank

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.