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10 CFR 70.5

August 9, 2018

ATTN: Document Control Desk
Director, Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001.

X-energy LLC
NRC Docket No.: 70-7027

Subject: Submittal of the Fuel Facility Licensing Regulatory Engagement Plan

Reference: Letter from Harlan Bowers, President X-energy, LLC to the NRC, "Updated Design and Licensing Submittal Information, NRC Regulatory Issue Summary (RIS)2017-08, Process for Scheduling and Allocating Resources for Fiscal Years 2020 through 2022 for the Review of New Licensing Applications for Light-Water and Non-Light-Water Reactors," XE00-R-R1-RD-L-000027, dated January 18, 2018

In the Reference letter, X-energy committed to submit a Regulatory Engagement Plan (REP) for its fuel facility implementation. Accordingly, this letter submits the REP covering the pre-application interactions with the NRC in support of the preparation of X-energy's TRISO-X fuel fabrication facility license application. This REP is based on the Nuclear Energy Institute's (NEI's) technical report, "Guidelines for Development of a Regulatory Engagement Plan," NEI 18-06, Revision 0. This guidance document was prepared for use by applicants and potential applicants for advanced reactor licenses, whether a reactor developer or site applicant, and not fuel cycle facilities. However, X-energy has adapted this guidance to its plans to prepare a license application for a fuel fabrication facility that will produce TRistructural ISOtropic (TRISO) nuclear fuel that can be used in various forms, (e.g., pebbles, compacts, etc.) to fuel various advanced reactor designs as well as currently operating light-water reactors. Accordingly, only those elements of the NEI guidance document that could be applied to a fuel cycle facility were followed in preparing this REP. Those elements are reflected by the specific sections that make up the attached REP.

If there are any questions or a need for additional information, please contact Mr. Rod Krich at the address above, by telephone at 301-658-2321, or by email at rkrich@x-energy.com.

Respectfully,

Harlan W. Bowers

Harlan W. Bowers
President, X Energy, LLC

NMSS20

Attachment: Regulatory Engagement Plan for the TRISO-X Fuel Fabrication Facility License Application

Regulatory Engagement Plan (REP)
for X Energy, LLC's TRISO-X Fuel Fabrication Facility

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List of Abbreviations

ADUN	Acid Deficient Uranyl-Nitrate
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ATF	Accident Tolerant Fuel
CAT	Category
CVD	Chemical Vapor Deposition
DOE	Department of Energy
EPlan	Emergency Plan
ER	Environmental Report
FOAK	First-Of-A-Kind
HALEU	High Assay, Low Enriched Uranium
HALEU-O	High Assay, Low Enriched Uranium Oxide
HTGR	High-Temperature Gas-cooled Reactor
ISA	Integrated Safety Analysis
IPyC	Inner Pyrolytic Carbon
LWR	Light Water Reactor
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
OPyC	Outer Pyrolytic Carbon
ORNL	Oak Ridge National Laboratory
QA	Quality Assurance
QAPD	Quality Assurance Program Description
REP	Regulatory Engagement Plan
SPD	Safety Program Description
SiC	Silicon Carbide
Sol-gel	Solution-gelation
TRISO	TRistructural ISOtrophic
UCO	Uranium oxide – carbide mixture
X-energy	X-Energy, LLC

1. INTRODUCTION/PURPOSE OF THIS REGULATORY ENGAGEMENT PLAN

1.1. CONTACT INFORMATION

X Energy, LLC (X-energy) is privately owned and funded with U.S government support. Approximately $85M investor, Strategic Partner, and U.S. Department of Energy commitments define X-energy's current capital sources. X-energy is located at 7701 Greenbelt Road, Suite 320, Greenbelt, MD 20770. The telephone number is 301-358-5600. Mr. Harlan Bowers is the President and Dr. Peter Pappano is the Vice President, Fuel Production. Mr. Rod Krich is the Director, Fuel Regulatory Affairs and is the primary point of contact with the Nuclear Regulatory Commission (NRC). Mr. Krich's contact information is rkrich@x-energy.com, and direct telephone line is 301-658-2321.

1.2. COMPANY/PROJECT STRUCTURE

X-energy is developing an advanced commercial process for producing TRistructural ISOtropic (TRISO) uranium fuel and will be preparing a license application for a TRISO-X fuel fabrication facility. This project will be carried out under a cooperative agreement from the U.S. Department of Energy's "Advanced Nuclear Technology Development" funding opportunity. This Regulatory Engagement Plan (REP) covers X-energy's pre-application activities leading to the submittal of a license application for the TRISO-X fuel fabrication facility. The key personnel in the development of the license application are shown in Table 1.

Table 1: Roles, responsibilities, and experience for key team members

Contact	Roles, Responsibilities, and Experience
Mr. Harlan Bowers (President, X-energy)	Defines corporate strategy, implementation and oversees the development of a smaller, safer, next-generation nuclear reactor and advanced reactor uranium fuel that expands reliable, zero-emission nuclear energy into entirely new markets. Conducts periodic reviews of X-energy programs to ensure cost, schedule and technical progress meet investor expectations and are performed efficiently and effectively. Harlan has over 30 years of experience managing very large, complex new business initiatives and highly technical engineering development programs with NASA and commercial customers, as well as U.S. government agency engineering services contracts up to $750M in value. Harlan received a B.S. in Aerospace and Ocean Engineering from Virginia Tech and an MBA from the University of Maryland, College Park.
Dr. Peter Pappano (Vice President, Fuel Production, X-energy)	Develops and implements TRISO-based fuel fabrication production module from pilot to commercial operations through role as Principal Investigator of two DOE cooperative agreements. Conducts onsite reviews of TRISO fabrication to ensure product quality and compliance with all regulatory requirements. Pete has over 17 years of experience in the fabrication of graphite-based materials and TRISO particle fuel, including leading the development of the DOE Advanced Gas Reactor compact fabrication process and laboratory build out. He currently manages $91M over two DOE contracts. Pete received a PhD in Fuel Science from Penn State University.

Mr. Rod Krich (Director, Fuel Regulatory Affairs, X-energy)	Responsible for all aspects of the TRISO-X license application development process and interactions with the NRC. During his more than 40 years in the Nuclear Power Industry, Mr. Krich has held various positions in Licensing and Engineering. Prior to joining X-energy he was Vice President of Licensing and Regulatory Affairs for Exelon, led the successful efforts to obtain licenses for the LES and Eagle Rock gas centrifuge uranium enrichment facilities, and was the Senior Vice President, Regulatory Affairs for UniStar Nuclear Energy, LLC (UniStar Nuclear Energy is a consortium between Constellation Energy Group, Inc. and EdF formed to license and build the U.S. Evolutionary Power Reactor (EPR).

1.3. SUMMARY STRATEGIC PROJECT APPROACH/GOALS

As a commercial TRISO fuel fabrication facility has not previously been licensed by the NRC, this effort represents a first-of-a-kind (FOAK) project. Furthermore, it is X-energy's intention to apply for a license for a Category (CAT) II fuel fabrication facility as defined in 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," since the planned enrichment is higher than the CAT III limit. A commercial CAT II fuel fabrication facility has also not been previously licensed by the NRC. Accordingly, these factors present unique aspects with respect to X-energy's license application preparation and the NRC review of the license application. It is X-energy's intention to provide the NRC with as much information as is needed during the pre-application period so that the NRC will be fully informed as its review of the application begins. X-energy intends to prepare the license application in accordance with applicable NRC regulatory requirements and guidance. If during the pre-application process or the application preparation process X-energy determines that deviations or exceptions from requirements or guidance are called for, X-energy will notify the NRC in a timely manner and initiate discussions with the appropriate NRC staff. X-energy's goal is to conduct highly informative pre-application activities and, based on feedback obtained from the NRC during the pre-application phase, submit a complete license application that will be accepted for review by the NRC. At this time, X-energy does not envision the need to request any conditional NRC staff findings during the pre-application period.

1.4. BACKGROUND

The NRC gained a degree of familiarity with TRISO fuel and its fabrication while reviewing other applicant (including General Atomics, South Africa's Pebble Bed Modular Reactor Project, and the DOE's Next Generation Nuclear Plant/Advanced Gas Reactor Program documentation) and licensees' interaction with the NRC staff. As such, there is a substantial body of documents from the NRC regarding TRISO fuel. X-energy has reviewed the applicable historical information and has been developing a production process that addresses the shortcomings of previous efforts. X-energy intends to focus on a number of complex issues during the pre-application period, including topics such as fabrication technology. This effort has already started with the NRC's tour of X-energy's demonstration TRISO-X fabrication facility at the Oak Ridge National Laboratory (ORNL) on April 3, 2018.

1.5. REP APPROACH

In addition to follow-up tours of the demonstration TRISO-X fuel fabrication facility at ORNL, X-energy plans to conduct a number of pre-application meetings with the NRC beginning in September 2018 that will cover unique or complex technical issues. At this this time, the following meeting topics have been identified:

- Introductory meeting to discuss project scope and schedule,
- Licensing considerations for the use of high assay low enriched uranium (HALEU) as the feed material, including criticality safety analysis methodology and transportation,
- Material control and accounting considerations for HALEU,
- Facility site selection and characterization,
- Security Plan considerations, and
- Integrated Safety Analysis (ISA) plan.

X-energy also plans to prepare a Quality Assurance Program Description (QAPD) topical report early in the application preparation process and submit it by late 2018 for NRC review and approval. This QAPD topical report will cover all aspects of the Management Measures section of the license application, i.e., Chapter 11 of the Safety Program Description.

X-energy recognizes that the need for additional meetings and/or submittals may be identified as a result of the meetings identified above. X-energy intends to update this REP during the pre-application timeframe and will notify the NRC of any changes/revisions.

2. TECHNICAL SUMMARY

2.1. OVERVIEW OF TRISO-BASED FUEL ELEMENT PRODUCTION

UCO (i.e. UO_2 + UC_2) TRISO-based fuel elements include fuel forms where TRISO particles are dispersed in a matrix material, such as graphite or silicon carbide, and formed into a specific geometry. These fuel elements are suitable for multiple types of advanced reactors, as well as potentially for accident tolerant fuel for existing light water reactors. **Figure 1** illustrates the diverse nature of TRISO-based fuel elements and their applicability toward different reactor designs.

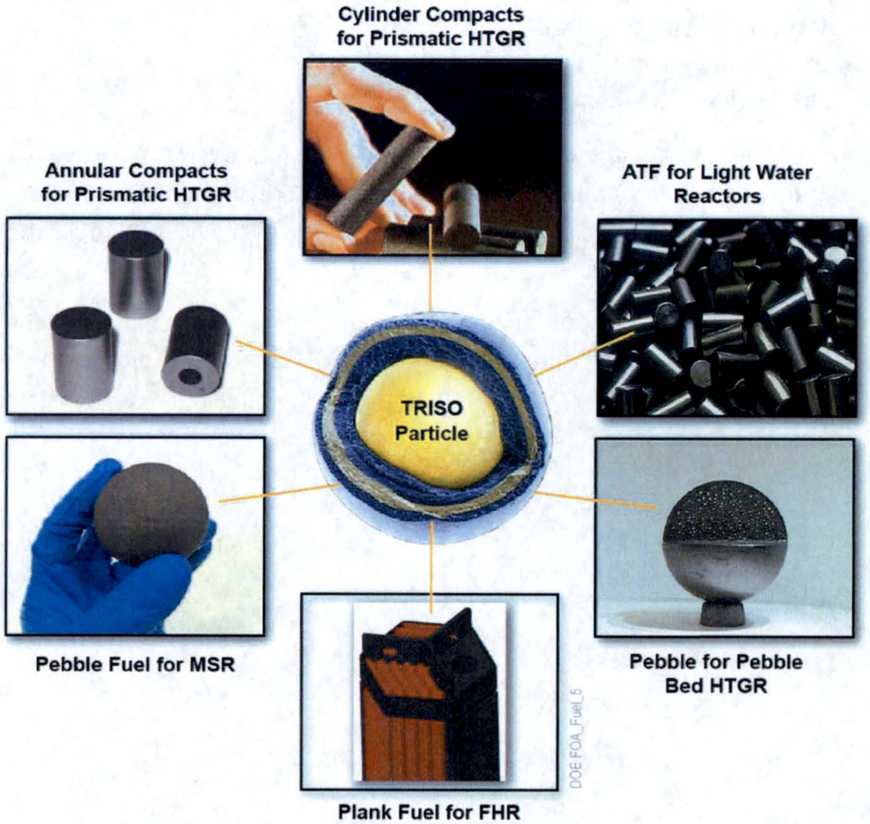


Figure 1: TRISO-based fuel elements support multiple reactor designs

UCO TRISO-based fuel element production includes these major steps: 1) UCO Kernel production, 2) TRISO particle coating, 3) matrix production, 4) particle overcoating, 5) fuel form pressing, 6) heat treatment, and 7) machining. Inspections and characterization tests at various stages are included for quality control. Each step is described in the following sections and illustrated notionally in **Figure 2**.

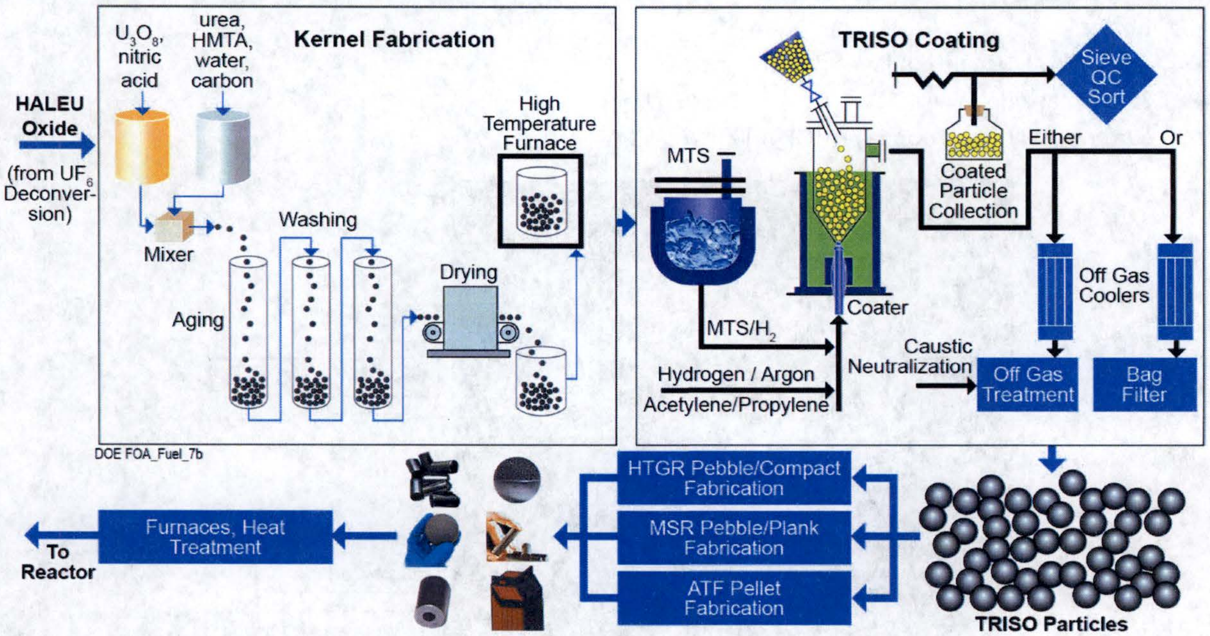


Figure 2: Fabrication processes within the TRISO-X production facility capable of producing multiple TRISO-based fuel element forms

2.2. KERNEL PRODUCTION

The kernel is produced via a solution-gelation (sol-gel) process. high assay low enriched uranium oxide (HALEU-O) is dissolved in acid to form an acid deficient uranyl-nitrate (ADUN) solution. In parallel, a carbon source and dispersant are mixed with a gelation promoter solution that is then combined with the ADUN in a casting fluid. The casting fluid, containing carbon and uranium oxide, is then run through a manifold to form spherical droplets that fall into a bath of oil, causing the gelation of the carbon-uranium oxide mixture. The gel spheres are then aged, washed, and dried. Next, the kernels are sintered to promote carbothermic reduction of carbon + uranium oxide to UCO, which is a mixture of UO_2 and UC_2. At this point, the sintered UCO kernels are sized to ensure kernel consistency in preparation for TRISO coating application.

2.3. TRISO COATING

After sorting and portioning, a batch of sintered kernels are coated in a fluidized bed chemical vapor deposition (CVD) furnace. The furnace is loaded from the top and the batch of kernels is fluidized using an inert carrying gas. Coating gases specific to each TRISO layer are flowed into the furnace for a pre-set period and at a set temperature to promote decomposition of the coating gas and deposition on the fluidized particles. A TRISO particle has four distinct layers. From the kernel moving outward the layers are as follows (and are illustrated in **Figure 3**):

- Buffer layer
- Inner pyrolytic carbon layer (IPyC)
- Silicon carbide layer (SiC)
- Outer pyrolytic carbon layer (OPyC)

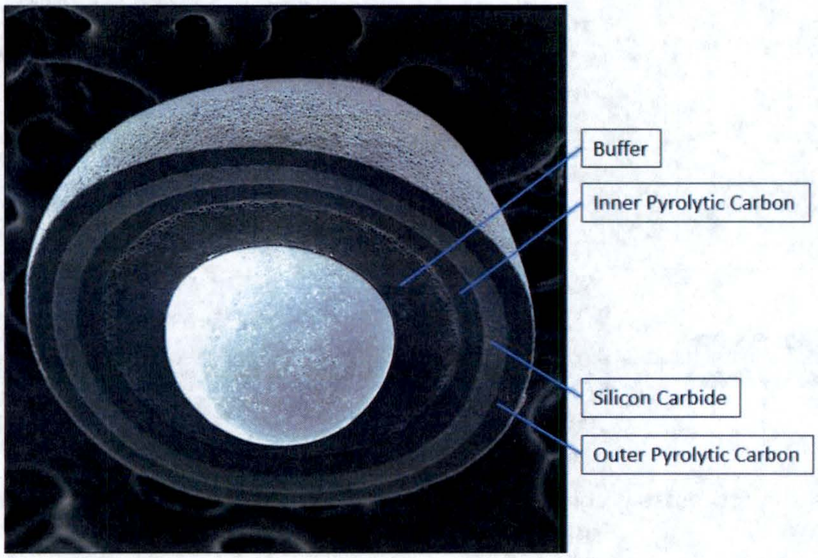


Figure 3: Scanning electron microscopy (SEM) image of X-energy produced TRISO particle

2.4. MATRIX PRODUCTION

Matrix is a mixture of powdered natural graphite, synthetic (or electro) graphite, and phenolic resin. Matrix is formed by combining the two types of powdered graphite, in a predefined ratio of natural to synthetic graphite, followed by the addition of phenolic resin.

The two graphites (natural and synthetic) are mixed together while the phenolic resin is dissolved in a solvent. The mixed graphites and dissolved resin are kneaded together to form a "resinated" powder where all graphite particles in the mixed graphite batch are coated with a layer of resin. The resinated powder is then dried to remove the solvent, forming an agglomerate that is then reduced back to a powder through crushing and milling steps. After milling, the powder is homogenized and made ready for the next step of overcoating.

2.5. OVERCOATING

Overcoating involves combining matrix powder and TRISO particles in a rotating, semi-fluidized vessel. As the matrix and particles are spun together, a solvent mist is sprayed into the rotating chamber to promote adhesion of the matrix powder to the particles. This method of overcoating is sometimes called "centrifugal" overcoating as centrifugal forces are used to push the mixture of matrix and particles to the

walls of the rotating chamber. After the TRISO particles are overcoated in the unit, they are sorted according to size and prepared for pressing/forming.

2.6. **FUEL ELEMENT FORMING**

The steps described up to this point (e.g., making kernels, TRISO particles, preparing matrix, and applying overcoat to the TRISO particles) are identical regardless of the final fuel form. The fuel element form is specific to the given reactor and therefore requires specific forming processes/equipment. Three fuel element geometries are described here for high temperature gas-cooled and molten salt reactors.

2.6.1. Spherical Pebble Fuel Elements

Spherical fuel element pebbles can be used in both high temperature gas-cooled reactors (HTGRs) and some molten salt designs. Pebbles are comprised of a fueled core that contains the TRISO particles, and an outer shell that is free of TRISO particles ("fuel-free zone"). The fuel core and fuel free zone are achieved in two distinct pressing steps.

The fuel core is pressed first and involves pressing of overcoated particles in a spherical rubber mold to pressures sufficient to achieve the specified matrix density. The newly formed or "green" fuel core is then removed from the mold and placed into one hemisphere of a larger spherical mold that has been previously packed with matrix. The matrix packed hemisphere contains a hollowed-out center where the fuel core is placed. The corresponding mold hemisphere is then combined with the fuel core containing hemisphere and packed with matrix through an opening in the top of the mold. After matrix has been added to the mold, the top opening is closed with a rubber plug, and the mold is again pressed to pressures sufficient to achieve the specified matrix density.

Following the second press, the mold is opened and the green pebble (fuel core + fuel free zone) is removed. The green pebble is then machined to size, carbonized in an inert flowing gas furnace, and then heat treated in a vacuum furnace.

2.6.2. Cylindrical Prismatic Fuel Elements

Cylindrical fuel compacts are used in prismatic block HTGR designs. Compacts are made in a single pressing step. Overcoated particles are charged to a warmed mold and uniaxially pressed with a ram to pressures sufficient to achieve the specified matrix density. The green compact is then removed from the mold and carbonized in an inert flowing gas furnace and heat treated in a vacuum furnace to 1800-1950°C. No machining of compacts is required and no "fuel-free zone" is included in the design.

2.6.3. Rectangular plank Fuel Elements

Rectangular, or "plank" fuel elements are used in some molten salt design. The process for making plank fuels involves mixing overcoated particles with matrix and an additional binder, such as phenolic resin. The mixture of overcoated particles, matrix, and binder are kneaded into a paste that is extruded through a warmed die. The plank is extruded onto a strong back to provide support for the green form. The green plank is then carbonized in an inert flowing gas furnace to 800-1000°C and sintered in a vacuum furnace to 1800-1950°C. The plank is bound to the strong back during carbonization to prevent slumping of the form as it is heated. After carbonization, the plank is rigid enough to be sintered without the strong back.

2.6.4. Cylindrical Pellets for Accident Tolerant Fuel for Light Water Reactors:

There is the potential that TRISO particles can be formed into fuel pellets and used for existing light water reactors (LWRs). The process for forming TRISO-based accident tolerant fuels (ATFs) is not yet defined, but would involve TRISO particles being combined with a matrix of graphite or silicon carbide, then being formed, through compression or extrusion, into a cylindrical pellet. The pellet would then be heat treated.

An isometric view of the envisioned commercial facility is shown in **Figure 4**. The facility layout is subject to change as the facility design and license application preparation proceed.

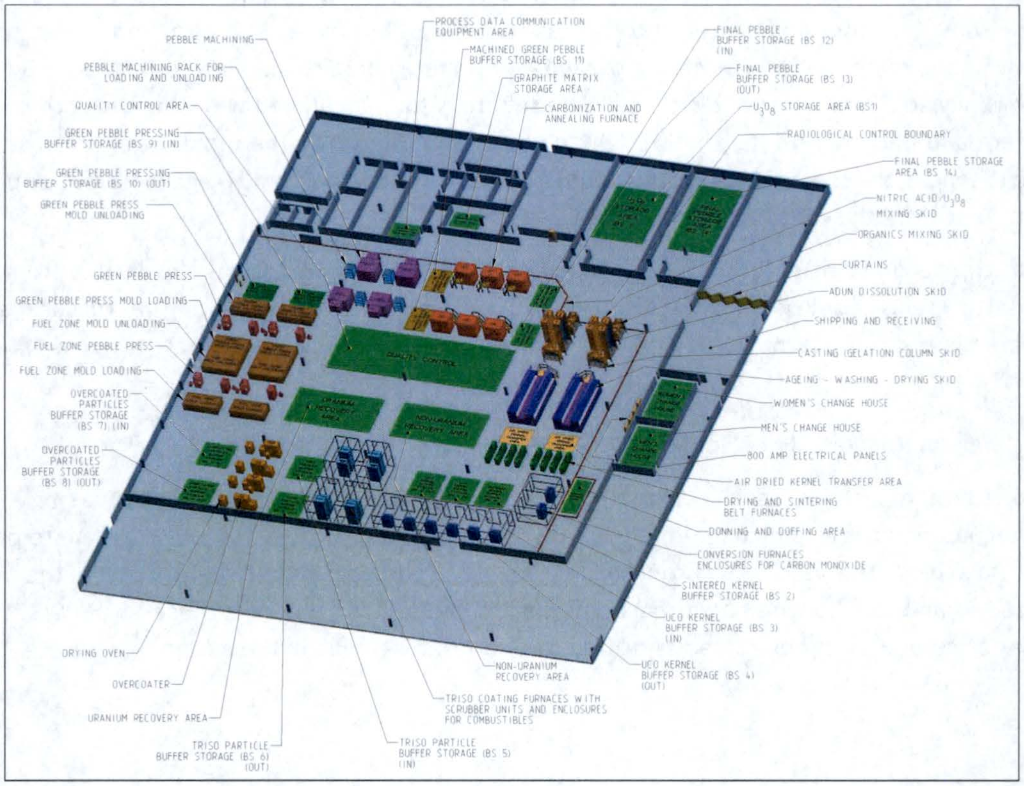


Figure 4: Initial conceptual layout of TRISO-X Fuel Fabrication Facility

3. REGULATORY STRATEGY

3.1. APPLICATION TYPE

X-energy plans to prepare the TRISO-X fuel fabrication facility license application in compliance with the applicable requirements of 10 CFR Part 70, and following applicable guidance, particularly NUREG-1520, "Standard Review Plan for Fuel Cycle Facilities License Applications," Revision 2 for the development of the Safety Program Description (SPD). The first activities will be to identify candidate sites for the facility and the preparation of the QAPD, following the guidance in Chapter 11, "Management Measures," and the appropriate appendices in NUREG-1520. Preparation of the QAPD will be informed by the applicable elements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) Quality Assurance (QA) Standard NQA-1-1994, "Quality Assurance Program for Nuclear Facilities," as revised by NQA-1a-1995 addenda, as well as currently approved QAPDs for similar fuel cycle facilities. X-energy intends to submit the QAPD for NRC review and approval ahead of the license application submittal.

The site selection process will comply with the applicable requirements of 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," and informed by the applicable NRC guidance in NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," Section 6.2, "Alternatives." The result of this process will be the selection of a site for the fuel fabrication facility that will be appropriately justified in the license application.

The license application will be composed of the SPD, including but not limited to the Integrated Safety Analysis Summary Report and the Fundamental Nuclear Material Control and Accounting Plan, the Environmental Report (ER), the Emergency Plan (EPlan), and the Security Plan. The ER will be prepared in compliance with the applicable requirements of 10 CFR Part 51 and follow the format and content guidance of NUREG-1748. The EPlan will be developed in compliance with the applicable requirements of 10 CFR Part 70 and follow the applicable guidance in NRC Regulatory Guide (RG) 3.67, "Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities," Rev. 1. The Security Plan will be prepared in compliance with the applicable requirements of !0 CFR Part 70 and 10 CFR Part 73, "Physical Protection of Plants and Materials," and informed by the guidance in RG 5.59, "Standard Format and Content for the Licensee Physical Security Plan for the Protection of Special Nuclear Material of Moderate or Low Strategic Significance," Rev. 1. X-energy is aware that the NRC is in the process of revising its guidance for material facilities' security plans and therefore will work to address new or additional guidance promulgated by the NRC. A meeting between X-energy and the NRC to discuss Security Plan considerations is one of the pre-application interactions identified above.

3.2. KEY ISSUES

There are a number of key issues that X-energy will strive to reach resolution with the NRC during the pre-application phase. At this time, the key issues that have been identified are prioritized as follows:

- Special licensing considerations for a CAT II fuel fabrication facility,
- Licensing considerations for the use of HALEU and associated concerns, e.g., qualified transportation containers, international suppliers, etc.,
- Criticality Safety analysis methodology,
- Special material control and accounting considerations,
- Possible additional security considerations for a CAT II facility,
- Facility site selection, and
- Performance of the ISA.

X-energy recognizes that other key unique or complex issues may be identified by X-energy or the NRC as the pre-application interaction proceeds. X-energy intends to address any additional key issues as they arise and work with the NRC to reach a timely resolution. As discussed above, X-energy plans to meet with the NRC on an approximately monthly basis to describe how these topics will be addressed in the license application, including addressing any NRC questions or concerns.

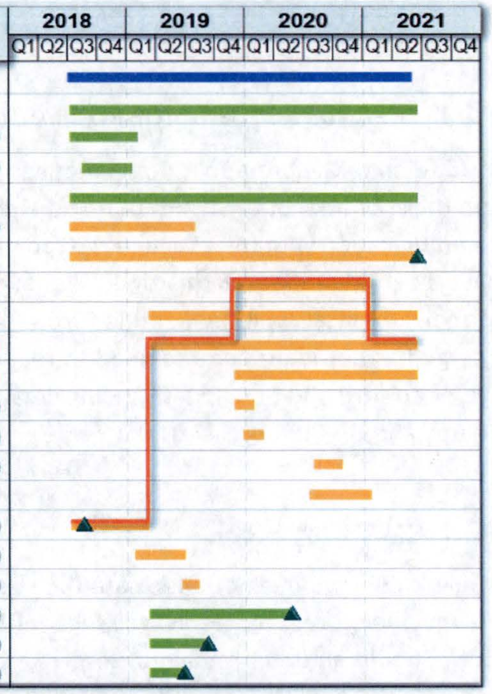
3.3. TESTING

X-energy is currently in the process of constructing and operating a pilot fuel fabrication facility at the Oak Ridge National Laboratory for the purpose of maturing and optimizing the fabrication processes. A number of NRC representatives recently toured the pilot facility. No other testing is planned at this time.

3.4. NRC REVIEW TIMEFRAMES

A preliminary Level 1 schedule is shown in **Figure 5** for information. X-energy plans to present its license application preparation schedule during its first meeting with the NRC. At that time, the NRC will have information upon which to base its pre-baseline review schedule.

Activity Name	Start	End
400 - Facility License Application Development	07-01-18	06-30-21
Regulatory Engineering Management	07-01-18	06-18-21
Regulatory Strategy Development	07-01-18	02-01-19
Pre-application NRC Engagement	07-01-18	01-18-19
Safety Program Description (SPD)	07-02-18	06-18-21
Ch. 1 - General Information	07-02-18	07-22-19
Ch. 2 - Organization and Administration	07-02-18	06-18-21
Ch. 3 - Integrated Safety Analysis and Summary	11-12-19	01-28-21
Ch. 4 - Radiation Protection	03-05-19	06-18-21
Ch. 5 - Nuclear Criticality Safety	03-05-19	06-18-21
Ch. 6 - Chemical Process Safety	11-12-19	06-18-21
Ch. 7 - Fire Safety	11-12-19	01-13-20
Ch. 8 - Emergency Management	12-31-19	02-19-20
Ch. 9 - Environmental Protection	08-04-20	10-19-20
Ch. 10 - Decommissioning	07-21-20	01-28-21
Ch. 11 - Management Measures	07-02-18	03-04-19
Ch. 12 - Material Control and Accounting	01-22-19	07-01-19
Ch. 13 - Physical Protection	06-27-19	08-07-19
Environmental Report	03-05-19	05-25-20
Security Plan	03-05-19	08-05-19
Emergency Plan	03-05-19	07-22-19



Legend: Level 1 Level 2 Level 3 Critical Path ▲Deliverables ◆Milestones FOA_003v3

Figure 5: Preliminary Level 1 schedule showing TRISO-X Fuel Facility license application development and submittal

4. PRE-APPLICATION ENGAGEMENT

4.1. TYPES AND FREQUENCY OF INTERACTIONS

In addition to the pre-application meetings to discuss the technical issues identified in Section 1.5 and 3.2 and the submittal of the QAPD during the pre-application phase, X-energy expects to maintain consistent communication with the assigned NRC point of contact. While no other specific topics for future meetings have been identified at this time, X-energy anticipates that additional topics, meetings, and possibly formal submittals will be identified from NRC feedback as the pre-application interaction proceeds. X-energy has not identified the need to request any NRC conditional staff findings at this time. However, the need for conditional staff findings may be identified as the pre-application interaction between X-energy and the NRC proceeds.

4.2. ESCALATION

While X-energy does not anticipate the need to escalate issues that may arise between the NRC and X-energy, the process for resolving issues will be led by Mr. Krich and involve direct interaction with the NRC staff. Should an issue remain unresolved, it will be escalated first to X-energy's VP For Fuels, Dr. Pete Pappano, who will address the matter with the NRC NMSS Director. If the issue is still unresolved, it is then escalated to the X-energy President, Mr. Harlan Bowers, who will then interact directly with NRC management.

4.3. APPLICATION SUBMITTAL

X-energy intends to keep the NRC informed regarding its progress in preparing the license application. X-energy plans to begin holding discussions with the NRC concerning the submittal of the application at least one year prior to its submittal. At that time X-energy intends to begin discussions with the NRC regarding post-application submittal engagement, i.e., interactions during the NRC review period.