NA-YGN
Global Civilian Nuclear Infrastructure Development Dynamic Learning Activity

Developed for the 2010 NA-YGN
Professional Development Conference

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Goal

Develop an interactive workshop where teams, representing various countries shall develop solutions for addressing the fuel cycle needs of the country they represent, as well as those from other developing countries.

Background & Purpose

North American – Young Generation in Nuclear provides professional development (PD) opportunities for our members. The main avenue for providing this service has been the annual PD conference. Attendance at the conference continues to grow and in 2009 exceeded 370 participants. Feedback from conference participants consistently includes a desire to have more interactive activities. Participants also have expressed a desire to learn something at the conference that can be applied to their job after they return to work.

The theme of the NA-YGN PD conference in 2010 is *Leading the Change: Go* Green and will focus on nuclear being a green source of energy. Additionally, subthemes include having a focus on change management and the nuclear fuel cycle.

The PD Conference Committee was tasked to develop an entire program with session topics, speakers, and formats based around these three general themes. The DC Chapter of NA-YGN proposed to the PD Committee the idea of developing a dynamic learning activity on the nuclear fuel cycle as a breakout session at the upcoming national meeting. The DC Chapter of NA-YGN acts as the facilitator for this session and has developed all of the necessary materials for executing this activity.

The nuclear renaissance is taking hold globally. The International Atomic Energy Agency (IAEA) has over 70 countries considering the possibility of constructing civilian nuclear power facilities to meet their growing need for electricity. Most of these countries have no existing nuclear infrastructure and must find ways to develop, construct and operate nuclear power plants. They must do this while maneuvering the highly complicated regulatory and political environment of the nuclear power industry.

One of the current issues surrounding nuclear power in the developing world is access to fuel sources. Developing countries are focusing their efforts on turn-key development and construction contracts. This model, however, would cause fuel loading contracts to be initially placed with the Nuclear Steam Supply Service (NSSS) vendor who designed and potentially constructed the facility. As such, some developing countries suspect that they will lose the ability to negotiate and adequately control fuel and maintenance contracts during operation because of the potential for a vendor monopoly. They are also worried that, due to these potential vendor monopolies, their countries would not have the energy independence they desire.

To counter this concern, some of these countries are researching the possibility of developing fuel enrichment plants along with their new nuclear power plants in order to establish national control over their energy production. There has been concern that these developing countries have ulterior motives and are truly interested in developing enrichment plants that may allow the diversion of highly enriched uranium to a military program or other non-peaceful uses.

The DC chapter decided to sponsor the development of this dynamic learning activity to help all NA-YGN member better understand the fuel cycle and potential proliferation concerns. With global focus on this issue being what it is, NA-YGN felt this would be a worthwhile activity for the 2010 Professional Development Conference and asked the DC Chapter to develop the product.

Early on, it was determined that there may be requests to repeat this activity. NA-YGN would like all of the professional development materials produced to be used by other organizations. This document contains all of the materials needed to replicate this dynamic learning activity.

Dynamic Learning Activity Overview

This activity will be run as a break out session in which up to 140 individuals may participate in the dynamic learning activity (DLA). Individuals will be broken up into teams of 10 sitting at tables. Each table will represent a country or worldwide organization. The session will be designed to operate in a three hour period.

As the participants enter the room, they will be asked to sit randomly at one of the 14 tables and complete a questionnaire. This questionnaire will be a pre-test that will be used to show the knowledge level of the group prior to the DLA. On the table will be name tags identifying which team the individual is a part of. The team names are not actual country names, instead, colors have been chosen to separate the groups.

Once all of the 140 participants are in their seats a pre-job brief will be given where all participants will be given the basic scenario, the overall objective, boundaries for the scenario, and an introduction to the teams at the other tables.

At the conclusion of the pre-job brief, each table will be instructed to open an envelope with their team's information. This information will include a one page paper describing the fuel cycle needs of that country, fake money, fuel cycle certificates representing the needs of their country and capability stickers representing the internal capabilities of that country. Each team was designed to have different needs, capabilities and financial resources. Therefore, even though each team's goal is the same, each team will have unique challenges to overcome in order to be successful.

Before the game begins, each table will discuss their individual strategy for ensuring that their country obtains the necessary infrastructure (fuel, personnel, construction, etc.) for the development and operation of potential nuclear power facilities. This time will test of the group's ability to act as a team, make decisions and develop a strategy.

Once the activity begins, the individuals on the team may interact with other countries to barter for the goods and services they need to complete their country's fuel cycle needs. During the activity, five timeouts have been developed to add elements of reality into the complexity of the global nuclear fuel cycle. The group collectively will have to deal with physical security, proliferation, and market issues following the timeouts.

At the end of the game period, a facilitated discussion will be used to review lessons learned by each group. During this time, a take away brochure will be handed out that provides information on all of the issues the game introduced to participants. This takeaway will be a reminder for the participants of what they learned during the activity.

At the end of the game, participants will be asked to complete the questionnaire again. This will help the facilitators measure the learning that occurred during the 3 hour activity and refine the activity for future use.

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Learning Objectives

1. Participants are introduced to fuel cycle concepts including knowledge of where uranium is mined, separated, enriched, recycled and disposed.

   Active mines are in Canada, Kazakhstan, Australia, Namibia, Russia, Niger, Uzbekistan, USA, Ukraine, China, South Africa, Brazil, India, Czech Repubic, Romania, Germany, Pakistan and France.

   Uranium mining is the process of extraction of uranium ore from the ground. Three basic processes for extracting uranium are used globally. The traditional method of accessing deep underground deposits via underground excavation is still the most common but some sites have uranium core very close to the surface of the earth and open pit mining utilized. A more modern approach to uranium mining can be taken when the uranium ore is located in sandy habitats. A slurry approach allows for miners to inject water and a non-toxic chemical into the sand, thereby dissolving the uranium into the water which is then pumped into a tank. A series of ion exchangers then allows the uranium to be separated from the water.

   Uranium is then processed by grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching. This material then undergoes a milling process which commonly yields dry powder-form material consisting of natural uranium, “yellowcake,” which is sold in the uranium market as U_3O_8 (natural uranium).

   Natural uranium can be used in heavy water reactors, but light water reactors require enriched uranium. There are currently two generic commercial methods employed internationally for enrichment: gaseous diffusion and gas centrifuge which consumes only 6% as much energy as gaseous diffusion. Enriched uranium is a kind of uranium in which the percent composition of uranium-235 has been increased through the process of isotope separation.

   Reprocessed uranium (RepU) is the uranium recovered from nuclear reprocessing, as done commercially in France, the UK and Japan and by nuclear weapons states' military plutonium production programs. Even with reprocessing, there is a still a small amount of waste that must eventually be disposed. Deep geological repositories have been suggested for this disposal. Repository sites are being sited and licensed around the world. Long term repositories for highly enriched materials are being planned for Sweden, Finland and the U.S.A.

2. Participants should understand reasons why developing countries want nuclear power and enrichment including:

   a. Energy independence

      After September 11, 2001, global crude oil prices sky rocketed. Large price swings in natural gas and coal due to market forces have also been seen in recent years. All nations saw their economies suffer due to high energy costs. Energy independence for any nation is the ability to produce abundant and affordable energy. Nuclear Power creates large amounts of baseload energy that is not dependent upon foreign

oil. This alternative is attractive to many countries because of the ability to procure fuel from more stable countries.

b. Developing infrastructure

Infrastructural development is not merely about erecting giant structures, but rather providing vital services, such as power, to increase commerce and business productivity and enhance people's lives. Without stable and affordable energy sources, countries cannot provide electricity to schools, hospitals and businesses.

Human capital development is also a crucial component of nuclear infrastructure development because building internal knowledge and expertise allows a country to function autonomously and ensures an adequate supply of qualified experts to meet the local demand for energy. In order to operate a civilian nuclear power program safely and effectively, countries must train and employ experts in a number of relevant fields including but not limited to nuclear engineering, health physics, physics, and nuclear policy.

c. Power generation sources with greater capacity factors

Stable, clean and reliable energy is needed in every country. With the ability of nuclear power plants to run with over a 90% capacity factor makes nuclear energy appealing to countries with limited land resources and access to renewable energy technologies.

3. Participants should be able to leverage ties and knowledge between established and developing countries when implementing a nuclear power program.

Established nuclear countries must understand that an accident anywhere will affect their operations. Nuclear power is a global industry and countries cannot run their programs in a vacuum. Countries developing nuclear capabilities will compete for the same fuel resources and technology, which could potentially drive up the cost.

Countries developing nuclear capabilities base their technical and regulatory frame work off of existing programs. Educating and training a workforce that is knowledgeable enough to operate a new facility safely and securely requires expertise and experience. Developing countries will most likely look for opportunities within developed nations for education and training.

4. Participants will understand the challenges developing countries face with supplier oligopolies in fuel cycle.

There are very few options available for fuel fabrication. Even though there are numerous global companies, not all can produce each fuel design. This leaves utilities or consumers with only a few options. An oligopoly is a situation in which supply is limited because market resources are controlled by a very few suppliers.

5. Participants are introduced to proliferation topics such as:
   a. Transportation of nuclear materials

Potential theft of nuclear fuel or spent nuclear fuel by terrorists is a major global concern. Spent nuclear material apprehended by terrorists could be used to develop

a dirty bomb or nuclear weapon, both of which pose a major threat to global security.

b. Plutonium separation

Reprocessing of civilian fuel has long been employed in Europe. Reprocessing used fuel can allow for the separation of plutonium which can be used in nuclear weapons. In the late 1970s, fear of nuclear weapons proliferation from used fuel reprocessing swept the United States. This fear led the U.S.A. to suspend commercial fuel reprocessing in order to reduce the production of separated plutonium.

c. Safeguards and Security

The terms *safeguards* is generally used to describe programs that account for the safe and proper use of nuclear material. Safeguards are designed to prevent the diversion of nuclear materials from peaceful uses such as nuclear energy to military purposes. The International Atomic Energy Agency (IAEA) plays a prominent role in accounting for nuclear material and verifying its safe and proper use.

Nuclear security, on the other hand, most often refers to the actual measures taken to protect and secure nuclear materials from theft, sabotage, or any other form of diversion. Several components of nuclear security include but are not limited to physical security of nuclear facilities and personnel screening.

d. Connection between recycling and separation

See above for plutonium separation.

e. Physical security

See above for transportation. In addition to potential mid-transportation theft, theft of nuclear materials from nuclear facilities is of concern. The level of physical security at global nuclear facilities varies and without rigorous participation by the organization who manages those facilities, there is concern that terrorists could target a facility, gain access and steal nuclear materials that could be used in a dirty bomb or to produce a nuclear weapon.

6. Participants should understand the conditions of international safeguards in addition to the benefits of supporting international safeguards agreements.

The Nuclear Non-Proliferation Treaty (NPT), an international safeguards agreement that came into force in March of 1970, allows countries party to the agreement the right of developing safe and secure civilian nuclear energy as long as they commit to the transparency and verification of peaceful nuclear programs and promise not to divert any nuclear material to military use. As such, countries are required to report all activities involved with nuclear material or the nuclear fuel cycle to the International Atomic Energy Agency (IAEA). A benefit of abiding by such verification measures, however, is that most nuclear suppliers are more likely to support the development of civilian nuclear power programs in countries that are committed to safety, security, and verification.

The Nuclear Suppliers Group (NSG), in particular, is a multinational body that limits the export of nuclear material only to those countries that have proven commitments to nuclear safeguards. In following, the NSG makes safety and security a condition for international support towards the development of a civilian nuclear program.

7. Participants should understand that the nuclear industry, market and fuel cycle are not immune to natural disasters or other "greater forces", political change, war, or other unforeseen events (force majeure).

Uranium is an ore that undergoes many processes before being ready for nuclear power production. Any step of the process can be challenged due to force majeure provisions in contracts. Mining activities can be affected by weather and challenging underground conditions (geology) which can cause disruptions in the front end of the fuel cycle. Additionally, some uranium mines are in countries with unstable governments. Political forces like treaty negotiations and war can disrupt production on the front end of the fuel cycle as well. The back end of the fuel cycle can also be affected by political forces. Reprocessing and geological repository storage facilities are continuously being scrutinized and changed due to political changes around the world. Even when there is a strategy to handle used fuel, political activists often find ways to disrupt a company's plan. All of these risks must be analyzed and balanced to ensure the utility can continue to operate successfully.

Timeline

Time (minutes)	Time (clock)	Activity	Owner
0-10		Seat Participants, Participants Complete Pre-Test	Control Team
10-20		Game Pre-Job Brief	M. Fahmy
20-30		Open Team Packages / Teams Strategize	Participants/Delegates
30-45		Initiate & Play the Game	M. Fahmy / Delegates
45-50		Timeout 1 - Physical Security	C. Csizmadia
50-60		Play Game	Delegates
60-65		Timeout 2 – Non-Proliferation	R. Leitch E. McAndrew-Benavides
65-75		Play Game	Delegates
75-80		Timeout 3 – Market Capacity Decreases	C. Csizmadia
80-90		Play Game	Delegates
90-95		Timeout 4 – Back-end Proliferation	P. Benavides
95-105		Play Game	Delegates
105-110		Timeout 5 – Market Capacity Increase	C. Csizmadia
110-120		Play Game	Delegates
120-125		End Game / Delegates return to their seats	M. Fahmy
125-155		Facilitated Discussion / Take Away Sheets Distributed	E. McAndrew-Benavides
155-160		Review Learning Objectives / Take Away Sheet	C. Csizmadia
165-170		Activity Feedback	M. Fahmy & Delegates
170-180		Post Test	Delegates

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Time-out Scenarios

1. Physical Security
    a. Local militias from Country Teal have breached the outer security of the nuclear power plant currently operating. One security officer was shot and four terrorist entered the power block prior to being apprehended. No nuclear materials were removed from the facility nor was there any damage to the facility other than the breached fence.

       At this point, no one knows if someone currently working at the facility was supporting the terrorist. Therefore, world nuclear organizations are calling for increased measurers to review backgrounds of personnel looking for employment in nuclear facilities.

    b. Announcement
       Hello, I'm Betty Nuclear and this is the World News Report. Reports from Country Teal are surfacing that a terrorist attack on their operating nuclear power plant was just apprehended. No casualties have been reported, but one security office was shot. Four terrorist suspects have been detained by local police forces. The Yellow Nuclear Authority has reported that other than the fence that was cut to gain access, no other damaged or breaches occurring during this failed attempt.

       The Global Nuclear Authority is requesting all nuclear organizations to hold off processing any new security checks until these terrorist suspects can be interrogated. All countries must stop bartering "operations" stickers for the next 10 minutes. You may now resume playing the game.

       10 minutes later

       No additional security threats have been identified from the terrorist attempt in Country Yellow. Bartering of "operations" tickets can now resume.

       Global Nuclear Authority imposes penalties on Country Teal and takes one operational sticker or a fine equaling the value of one operational sticker. This scenario shows the cascading effects which results across the nuclear industry (example of learning objectives three [3] and five [5]).

2. Non-Proliferation
    a. Note: For this scenario to work you need to confirm that Country Navy Blue has bartered away one or more of their ore and conversion stickers. If County Navy Blue has not bartered away any of their stickers read 2.c.

       There are nuclear power plant technologies that do not require enriching fuel. This is attractive because it removes many of the concerns dealing with proliferation and the front end of the fuel cycle.

       "All in one" contracts are being offered to some developing countries to help them develop nuclear power programs. These contracts include: construction, all front end of the fuel cycle end needs, and initial operations. These offers are attractive to countries without nuclear infrastructure, but can

cause issues where one country is beholden to another country for all of their nuclear needs. Thus "possible" increasing fuel, operations and maintenance costs after construction has been started.

b. Announcement

Will Country Navy Blue and all the countries that bought ore and conversion stickers from Navy Blue please send a representative to the stage.
Navy Blue is a country that operates heavy water reactors. These reactors do not require enriched uranium to operate. Instead they operate with natural uranium.

You have a unique opportunity. If you so choose, you can decide to operate heavy water reactors in your countries. If you make this decision, you can eliminate the enrichment demand certificate from your strategy and buy construction stickers from the control group.

This deal comes at a cost. For this "value added" benefit instead of costing $20 per construction ticket, we are charging more per sticker.

Representatives here on the stage, you will need to decide for your country. Do you want to stay with the current market forces to fill your demand needs, or do you want to sole source your purchases from us? And if so, how many construction stickers do you want to purchase? Remember you decision is binding.

Note to controller: 1st country to take the deal is charged $22 per sticker. 2nd country to take the deal is charted $25 per sticker. 3rd country is charged $30 per sticker. If any country does not have the financial resources to meet these higher sole source prices announce:

Your country has attempted to navigate the new nuclear world and has failed. You have bankrupted your country. From this time one, you can no longer attempt to purchase materials; you can only sell what you've accumulated.

Resume the game.

Note that this is a one-time scenario and team navy blue cannot establish this deal later on in the activity. This scenario is a one time only, "let's make a deal" situation. This scenario can be tied to learning objective number 4 and displays the lucrative offers which can later lead to dependencies on vendors for fuel-cycle needs or services.

Announcement 2 – If Navy Blue Stickers have not been bartered.

c. Scenario

Uranium Exports, like other commodities can be affected by political changes. These disruptions can cause the cost of commodities to increase or decrease. If a balance of short term and long term contracts are not in place, some companies cannot afford to buy the commodities they need to operate.

d. Announcement

Hello, I'm Betty Nuclear and this is the World News Report. Reports indicate that ruling party has just lost the election in Country Navy Blue. Leadership of the new party state that halting uranium exports is a top priority. Market analysts predict that this supply disruption will cause the price of ore to increase $4-$8.

Country Navy Blue, turn in your ore stickers as they cannot be exported during the new administration.

3. Market Capacity Decrease - Natural Disaster
   a. Scenario
      Uranium production, like other commodities can have disruptions in production. These disruptions can cause the cost of commodities to increase. If a balance of short term and long term contracts are not in place, some companies cannot afford to buy the commodities they need to operate.

   b. Announcement
      Hello, I'm Betty Nuclear and this is the World News Report. Reports indicate that Country Tan has just felt the effects of global warming. Unusually fast snow melting has caused the uranium mines in this country to flood and disrupt production. Market analysts predict that this supply disruption will cause the price of ore to increase $10-$15.

      Country Tan, you cannot buy or sell any stickers for the next 10 minutes. You need to focus your efforts on cleaning-up from this natural disaster.

      Resume the game.

4. Back-end Proliferation
   a. Scenario
      Shipping used fuel is a highly political issue. A concern about materials being stolen during transportation causes many countries not to close their fuel cycle. These concerns are based upon a concept that stolen used fuel could be processed into nuclear weapons. For countries that do ship fuel to be reprocessed or disposed of, paying for the security and processing is an additional cost to the operation of the current fleet.

   b. Announcement
      Hello, I am Bobby Neutron from the Global Nuclear Authority. Interrogations of the terrorist who recently attempted to infiltrate Country Teal have uncovered a potential plot to steal used fuel when it is being shipped to Country Black. A rogue group of students from "rainbow prosperity" are attempting to disrupt these shipments to prove their position of how unsecure it is to operate commercial nuclear power facilities. Even though the Global Nuclear Authority does not perceive any real proliferation threats, we are asking for increased security coverage.

      Expert manpower is needed to accompany these shipments. All countries with Back-end stickers must turn one "operations" sticker in to the Global Nuclear Authority to cover this manpower shortage.

After collecting the stickers.

Resume the Game.

5. Market Capacity Increase – New Conversion Facility
    a. Scenario
    Fuel cycle procurement is not for the faint of heart. Market fluxes are common and need to be planned for in any company's fuel cycle needs. Increases in price can make it financially possible for new production services to come on line. This usually causes the prices of commodities to decrease.

    b. Announcement
    Hello, I'm Betty Nuclear and this is the World News Report. News organizations in Country Green have reported that a new uranium mine has started production. Investment in this new uranium mine was determined to be a good business venture due to increased demand on Green's resources caused by Country's Tan disruption in production.

    The loss of Country's Tan production recently caused prices to skyrocket allowing capitol to become available for development of a new mine in country Green. While no change in the current ore cost has been observed, market analysts predict that this additional supply will cause the price of ore to decrease $10-$15. Nuclear utilities hope this additional production will help them meet their annual budgets.

    Country Green, please come to the stage and pick-up your additional uranium stickers.

    Resume the game.

    Note that this is a normal occurrence and is not a specific learning objective.

Pre-Job Brief

The Global Fuel Cycle Strategy Activity is a simulation of the international partnerships and challenges which defines the global nuclear energy industry. This activity is designed to replicate the political, financial and regulatory issues associated with meeting worldwide demand. Participants will learn first-hand the complexities and partnerships required to develop and sustain a complete nuclear fuel cycle and develop a civilian nuclear infrastructure. The activity has been designed so that team assignments maximize participant interactions with NA-YGN members outside of your chapter.

During the activity, a control team will be available to answer questions and facilitate activity logistics. This team can modify the activity as necessary to further enhance participation and retention of learning objectives. The control team is called "The Global Nuclear Authority" for the purposes of this activity. Global Nuclear Authority members please identify yourself to the audience.

As participants, you will step into the shoes of country diplomats and nuclear energy industrial leaders and are responsible for maintaining or enhancing the interests of your country while balancing the interests of world nuclear market.

Countries are represented by color, for example "Country Yellow", instead of by name and are loosely based on a conglomeration of countries within a particular world region. There are fourteen "countries" that make up the nuclear-vested world. These fourteen countries can have all, some, or none of the required resources to develop and sustain a nuclear fleet and/or complete fuel cycle.

We are now going to review the materials each team is being provided. Each country will be a given a packet of information to be used during the duration of this activity. Please do not open your packets until after I complete giving the directions.

The team packets contain a country profile sheet, nuclear resources or capabilities stickers, certificates, and financial resources (nuclear bucks) and these instructions I am reviewing.

Country profile sheets:
The country profile sheets outline a country's internal available resources, energy needs, and diplomatic relations. Participants will have access to only their country's specific profile sheet. These sheets should not be shared with other countries and are considered confidential and sensitive information.

Fuel Cycle Certificate:
Each country's fuel cycle certificate represent the demand your country has and shows all the goods and services required to meet the country's complete nuclear fuel cycle needs. Countries should populate these certificates as necessary to meet country/team goals. Each country that wants nuclear power must have a complete fuel cycle available internally. Countries need to place stickers on their certificates to show they have covered their demand profile to have a functioning nuclear power program.

Nuclear resource/capability stickers:
These stickers represent the nuclear related resources and capabilities. Each country will have different internal capabilities and therefore a different number of stickers in your envelope. These stickers are to be used during the activity; teams are allowed

to sell, trade or buy these stickers as necessary to meet their country's nuclear energy demands. On the current market, each of these stickers is selling for:

Ore	*$4 nuclear bucks*
Conversion	*$1 nuclear buck*
Enrichment	*$5 nuclear bucks*
Fabrication	*$2 nuclear bucks*
Construction	*$20 nuclear bucks*
Operations	*$10 nuclear bucks*
Back-end	*$30 nuclear bucks*

Nuclear Bucks:
This is the fictional currency of the world nuclear market. Each team is provided with currency based on their financial stability. This currency can be used to buy services (capability stickers). Similarly, services can be sold to obtain additional nuclear bucks. The world financial market may fluctuate resulting in changes to the value of this currency.

Once I release all of you to start the activity, you should open the team packets. Each participant will have a name badge indicating which country they are members of. Please wear these stickers at all times.

Next, Country delegates will work on developing your team's strategy. You will do this by evaluating your individual country's needs, allocating your internal resources, and deciding how you're going to meet your needs, as a team. During the development of your strategy, you should establish the "completeness" of your fuel cycle certificate. Once again, your strategy and goal should be to enhance the interests of your country while balancing the interests of the world nuclear market. Remember, at least one team member should be at the country's table at all times.

Once country delegates have outlined their strategy, and upon announcement by the activity facilitators, teams will be able to open dialogue with other world countries. During this period, countries can buy, sell, or engage in a trade services to/from other countries in support of meeting the country's nuclear energy goals, per their established strategies. Keep in mind that countries have established prior relationships with countries; those relationships can be good, neutral or bad. Countries are encouraged to buy, sell and trade with countries they have good relationships with first and neutral relationships with second. Countries are discouraged from buying, selling, or trading with countries they have bad relationships with.

Dispersed throughout the activity, we will have "time-out scenarios". When any member of the Global Nuclear Authority announces on the microphone "time-out", everyone should stop what they are doing and listen to the announcement. During these scenarios, teams will be informed of information or events that may affect the game. You'll want to hear these announcements, so please stop all discussions and do not move through the room during these announcements.

The activity will subside at the time indicated on the activity schedule. Upon activity completion, country representatives will be asked to join their country's delegation. At that time the control group will facilitate a discussion to reiterate, and elaborate on, the learning objectives of the activity. The discussion will also allow for an open dialogue amongst all participants about the complexities of the global nuclear fuel cycle. This will be the time to ask questions and for each of us to share our experiences with the activity.

At this point, we will begin the 10 minute strategy session. Countries, please open your packets.

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Questionnaire

1. How many separate contracts does a typical plant need to ensure all aspects of the front end of the fuel cycle are covered?
   a. One – the Nuclear Steam Supply Vendor provides all of the front end services with the Fabrication contract.
   b. Zero – who needs fuel?
   c. Four – separate contracts for Ore, Conversion, Enrichment and Fabrication.
   d. Many – contracts can be developed for any combination of the four steps.

2. Where do countries developing nuclear power plants for the first time find their operating staff?
   a. Internal to their country; no external support is needed.
   b. The Nuclear Steam Supply Vendor building the plant is responsible for staffing the unit.
   c. International organizations like IAEA, WNA and WANO will coordinate the initial staffing of the unit.
   d. Combination of hiring experts from other countries, training internal individuals and working with the Nuclear Steam Supply vendor to staff the plant.
   e. B + C

3. How are the prices for nuclear fuel commodities established?
   a. They are set by the IAEA.
   b. Like all commodities, the cost fluctuates based on the supply and demand for the product.
   c. They are established by the federal government where the commodities originated from.
   d. Are established at a fixed rate of the actual cost to produce the product plus 6%.

4. Developing countries are interested in developing nuclear power production capabilities because?
   a. They want affordable, reliable electricity that can help build their infrastructure.
   b. They want the prestige of being a country capable of operating a nuclear power plant.
   c. It's all a ruse. They really want to develop nuclear weapons.
   d. They want the security that comes from having diverse sources of electricity.
   e. A + B + D

5. What relationship does an established nuclear country have with a developing country interested in nuclear power?
   a. None.
   b. They are a competitor. Sucking up resources and driving-up commodity prices.
   c. They are a customer. Purchasing commodities, services and expertise from established nuclear countries.
   d. They are another sovereign nation with energy strategies that can be benchmarked.
   e. B + C + D

Questionnaire Answers

1. D
2. D
3. B
4. E
5. E

Facilitated Discussion Questions

1. What did you learn about the fuel cycle?
    a. How many people believed before this activity that fuel was ordered from the fuel supplier or fabricator (Westinghouse, GE, AREVA) and they took care of everything for the utility?
    b. Is the fuel cycle more complex or simpler than you thought it was? More stages than you originally thought?

2. Why would developing countries want nuclear power?
    a. Did teams express an interest in nuclear power in hopes of obtaining an increased technical prestige among their peer countries or within their regions? and increase and regional competitions?
    b. What could failure mean to developing countries that do not develop nuclear power?
    c. During the role playing, did anyone witness a teammate take these desires to heart?

3. For those of you who were from small countries trying to develop nuclear power plants, what was it like dealing with countries with a large program with lots of resources?
    a. Were they easy to work with?
    b. Were you taken seriously when trying to barter?
    c. Big Countries, when developing your strategy did you want to work with other big countries with lots of resources or small countries with few resources? And why?

4. If one of the countries took the offer from Time-out 2:
    a. Was it problematic to have one or two people representing the decision authority for an entire country? Did you fellow peers agree or disagree with your decision?
    b. Was it easier to contract for the front end of the fuel cycle, construction and operations from one company? What did you gain by doing this?
    c. What problems did this result in during the remainder of your activity? If none, what potential problems could you have faced? Were there any problems with giving one company control over your countries nuclear power production?

5. What did you learn about fuel cycle and proliferation concerns?
    a. Should we, as western utilities, care about political proliferation discussions?
    b. Did you fully think about the countries you were creating enrichment agreements and how that “enrichment capability may affect national or global security. (proliferation)

6. What did you learn about fuel cycle and market trends?
    a. Is it easy or hard to manage front end of the fuel cycle with these market forces? Not necessarily the time-out scenarios, but including market supply, bartering, price gouging by others, etc. Addition disruptions or supplies/demand.

7. One of the constraints of the program was defining which countries you were friendly with.
    a. Does poor diplomatic relations have an entirely detrimental impact to the market? What was the severity of the impact.
    b. In some cases a country you are friendly with didn't want to reciprocate? What did this teach you?
    c. Which countries did you have friendly diplomatic with?

8. The time-outs were designed to portray the challenges associated with the fuel cycle. They were all loosely based on potential situations?
    a. What did you learn about security, safeguards, and non-proliferation?
    b. What did we learn from each of the five scenarios?
    c. Where there scenarios that affected one country or set of countries without affecting another set of countries. What were the direct and indirect effects of each time out scenario?

9. Did anyone's initial strategy include prioritizing the back-end of the fuel cycle?
    a. Did anyone manage to close their fuel cycle for all of their needs?
    b. In reality, how could you promote people to acknowledge the back-end needs prior to entering into agreements?

10. Did anyone complete all of their demand sheets? – Who beat the game?
    a. What were the hardest stickers to procure?

11. Did anyone procure enrichment services from Country Purple? If they were on your bad diplomatic sheet, did you know why and if so, did you question their intentions?

Country Profiles

Each of the 14 country profiles were developed by reviewing actual global capabilities and then apply artistic license. In some cases, the countries are based off one actual country and in others multiple countries that are closely located were combined.

The team made the assumption that no country would sacrifice or reduce support for operating units to develop new nuclear power. This allowed the team to simplify the game by only considering each countries new nuclear prospect when determining the demand and supply capabilities. The team then applied the concept of zero, small, medium or large interest in developing new nuclear power; allowing for the demand aspects to be set for each of the 14 countries.

Using artistic license, the team then provided each country different levels of internal supply capabilities. In some cases, the countries have excess supply; in others they do not have enough resources.

The team then assigned nuclear buck values for each of the seven steps of the nuclear cycle and provided cash to the teams to begin bartering with other countries for their needs. Just like with the supply, some countries were given excess cash and others were not given enough to meet their needs.

To keep the game interesting, the supply of the seven commodities were purposefully designed to be less than the demand. Many countries have extra nuclear bucks and we believe market forces will take effect raising the prices of all commodities across the globe.

In the Country Packet section of the document, each country prolife is provided. These profiles have four sections.

1. Country's Nuclear Energy Needs – showing how many new faculties that country is trying to develop along with the amount of each commodity they need to support those facilities.

2. Internal Capacity – showing what the country can internally produce. Along with the number of stickers they should have in their packet representing these internal capabilities.

3. Diplomatic Relations – showing which other countries they can do business. Active procurement of nuclear materials/services can take place with Good countries but not with Bad. They can only go to Neutral countries after contacting all of the Good countries.
    - Good - current/active relationship
    - Neutral – not current/active relationship but willing to establish a relationship
    - Bad – not current/active relationship and not willing to establish a relationship

4. Background Information – providing insights to help the team develop their strategy.

Setting-up the Game

When setting-up this game, each team will need a package of materials. Copies of each of these materials are provided.

1. One copy of their country profile.
2. One copy of the pre-job brief.
3. Ten badges for team members to wear with their County Name (e.g. Red, Orange, Teal)
4. Supply and Demand Products (Team Reference Sheet shows required numbers for each package.)
    a. Stickers representing their supply. (7 different stickers designs)
    b. Nuclear Bucks (Total of $2880 broken up into denominations of $1s, $2s and $5)
    c. Certificates representing their demand. (21 different certificates representing 7 products at the Small, Medium, Large demands of the different countries)

(Note: make sure all materials are counted carefully otherwise the game will not work as designed.)

Organizers also need to remember that additional supplies are needed by the Control Group to facilitate the game and the Time-outs.

Those additional supplies are:

- 280 Questionnaires (½ as pretest and ½ as post test)
- 30 Construction Stickers (may not need all of them)
- 10 Ore Stickers
- Smaller Bills to make change. ($100 – 1's)
- 140 Take Away Sheets (handed out at the end of the game)

Optional:

- Mark the 4 enrichment stickers given to country Purple with small "p"s. This will allow you to track who procures the stickers during the facilitated discussion.

Team Reference Sheet

Team #	Country	Demand	Ore	Conversion	Enrichment	Fabrication	Construction	Operations	Back End	Money
1	Red	Large-10	5	19	15	15	10	14	0	20
2	Orange	Large-10	10	19	37	15	10	12	0	100
3	Yellow	Medium-4	4	0	0	0	0	1	0	100
4	Green	0	20	0	0	0	0	0	0	40
5	Blue	Medium-4	0	0	0	0	0	0	0	700
6	Purple	Small-1	0	0	4	0	0	0	0	300
7	Brown	Small-1	0	1	1	0	1	0	0	100
8	Gray	Large-10	2	3	2	10	0	0	0	600
9	Black	Large-10	0	19	15	15	5	12	11	40
10	White	Medium-4	0	0	0	4	2	5	0	240
11	Tan	0	40	0	0	0	0	0	0	40
12	Navy Blue	Large-10	20	19	0	10	2	5	0	300
13	Teal	Small-1	0	0	0	5	0	0	2	100
14	Pink	Small-1	0	0	7	0	0	0	0	100
Control Team		0	10	0	0	0	30	0	0	100
Total		L-5, M-3, S-4	110	80	81	74	60	49	13	2880

Country Decoder Ring (These profiles are loosely based off of 2010 actual capacities.)

- Red – United States
- Orange – Russia
- Yellow – South Africa
- Green - Australia
- Blue – United Arab Emeritus
- Purple – Iran/Iraq
- Brown – Brazil
- Gray – China
- Black – France
- White – Japan/South Korea
- Tan – Kazakhstan
- Navy Blue – Canada
- Teal – Finland/Sweden
- Pink – Germany/Austria

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Red Country Details
Team1

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
10	10	10	10	10	10	10

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
5	19	15	15	10	14	0	20

Diplomatic Relations	
Relations	Countries
Good	Black, White, Pink, Green, Navy Blue, Teal, Blue
Neutral	Gray, Orange, Brown, Yellow, Tan
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- You have a competitive advantage in human resources and internal capacity for every stage of the fuel cycle – but your challenge is to decide how much you want to use for yourself and how much you want to sell to others.
- Your financial resources are very limited, so you will need to export resources if you want to buy any resources from other countries
- Global pressure to meet political and diplomatic expectations is very high – it would be wise to work with countries in order of diplomatic priority

Orange Country Details
Team 2

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
10	10	10	10	10	10	10

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
10	19	37	15	10	12	0	100

Diplomatic Relations	
Relations	Countries
Good	Gray, Brown, Tan, Black, White, Yellow, Blue, Teal Purple, Pink
Neutral	Navy Blue, Red, Green,
Bad	

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- You have a competitive advantage in human resources and internal capacity for every stage of the fuel cycle – but your challenge is to decide how much you want to use for yourself and how much you want to sell to others.
- Your financial resources are limited, so you will need to export resources if you want to buy any resources from other countries
- Global pressure to meet political and diplomatic expectations is very high – it would be wise to work with countries in order of diplomatic priority

Yellow Country Details
Team 3

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
4	4	4	4	4	4	4

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
4	0	0	0	0	1	0	100

Diplomatic Relations	
Relations	Countries
Good	Red, Pink
Neutral	Green, Teal, Orange, Navy Blue, Brown, Blue, White, Gray, Black, Tan
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your country's energy needs would be fulfilled by 4 reactor units
- Because financial, ore, and operational resources are limited, your nation must be strategic in trading resources with other nations.

Green Country Details
Team 4

Country Nuclear Energy Needs: None
For political reasons, your country has decided not to pursue a nuclear energy program.

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
20	0	0	0	0	0	0	40

Diplomatic Relations	
Relations	Countries
Good	Red, Navy Blue, Black
Neutral	Orange, Teal, Brown, Gray, Blue, Pink, Tan, Yellow, White
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your nation's abundant ore reserves offer a competitive advantage which you can leverage in your relationships with other nations.

Blue Country Details
Team 5

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
4	4	4	4	4	4	4

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	0	0	0	0	0	0	700

Diplomatic Relations	
Relations	Countries
Good	White, Red, Orange, Black, Pink
Neutral	Green, Navy Blue, Gray, Brown, Tan, Teal, Yellow
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your country's energy needs would be fulfilled by 4 reactor units
- Your nation has substantial financial resources to make up for the lack of nuclear resources. Your money gives you a strong competitive advantage against competitors for resources.

Purple Country Details
Team 6

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
1	1	1	1	1	1	1

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	0	4	0	0	0	0	300

Diplomatic Relations	
Relations	Countries
Good	Gray, Orange
Neutral	Blue, White, Tan, Yellow, Brown
Bad	Red, Black, Navy Blue, Green, Teal, Pink

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Political sensitivities about your fuel cycle capabilities limit the countries you should trade with. It would be wise to limit sharing information about your internal fuel cycle capacities with countries.
- Diplomatic sensitivities limit the number of countries you can work with, so it is important to maintain strong relations with your existing diplomatic partners.

Brown Country Details
Team 7

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
1	1	1	1	1	1	1

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	1	1	0	1	0	0	100

Diplomatic Relations	
Relations	Countries
Good	Navy Blue, Black, Orange, Pink, Red
Neutral	Green, Teal, Yellow, Gray, Blue, White, Tan,
Bad	Purple

Note(s): 1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your country's energy needs would be fulfilled by 1 reactor unit
- Because your resources are limited, your nation must be strategic in trading resources with other nations.

Gray Country Details
Team 8

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
10	10	10	10	10	10	10

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
2	3	2	10	0	0	0	600

Diplomatic Relations	
Relations	Countries
Good	Purple, , Black, Orange, Blue, White
Neutral	Red, Navy Blue, Teal, Green, Yellow, Brown, Tan, Pink
Bad	

Note(s): 1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your energy needs are very high, so although you have some internal fuel cycle resources, you must find commercial partners to purchase other necessary resources.
- Your nation has substantial financial resources to purchase necessary nuclear resources. Your money gives you a strong competitive advantage against competitors for resources.

Black Country Details
Team 9

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
10	10	10	10	10	10	10

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	19	15	15	5	12	11	40

Diplomatic Relations	
Relations	Countries
Good	Navy Blue, Red, Orange, Teal, Gray, Pink, White, Blue, Tan, Brown
Neutral	Yellow, Green
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your internal fuel cycle capacities are quite extensive, but they do not meet your country's energy demands.
- You will need to engage in trade to make up for limited financial resources.

White Country Details
Team 10

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
4	4	4	4	4	4	4

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	0	0	4	2	5	0	240

Diplomatic Relations	
Relations	Countries
Good	Green, Navy Blue, Black, Red, Orange, Tan, Blue, Gray
Neutral	Teal, Yellow, Pink, Brown
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- You have limited internal fuel cycle capabilities
- Your financial resources make up for a lack in internal capacity, but you must trade wisely to acquire all necessary resources.

Tan Country Details
Team 11

Country Nuclear Energy Needs: None
For political reasons, your country has decided not to pursue a nuclear energy program.

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
40	0	0	0	0	0	0	40

Diplomatic Relations	
Relations	Countries
Good	Gray, Black, White, Teal, Red, Orange, Navy Blue
Neutral	Brown, Yellow, Pink, Green, Blue
Bad	Purple

Note(s): 1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your nation's abundant ore reserves offer a competitive advantage which you can leverage in your relations ship with other nations.

Navy Blue Country Details
Team 12

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
10	10	10	10	10	10	10

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
20	19	0	10	2	5	0	300

Diplomatic Relations	
Relations	Countries
Good	Brown, Green, Tan, Yellow, Gray, Black, White, Red
Neutral	Blue, Pink, Teal, Orange
Bad	Purple

Note(s): 1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your internal fuel cycle capacities are quite extensive, but they do not meet your country's energy demands.
- Your country provides adequate financial resources to make up for areas where capabilities are limited.
- Political changes within your country may limit your ability to sell Ore and Conversion to other countries. Your last President signed an international agreement to sell 100% of your inventory before the end of his term in office. You need to act fast otherwise the newly elected political party will restrict sales of your inventory. (e.g. you need to start selling immediately)

Teal Country Details
Team 13

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
1	1	1	1	1	1	1

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	0	0	5	0	0	2	100

Note(s): 1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Diplomatic Relations	
Relations	Countries
Good	Pink, Navy Blue, Tan, Red, Black
Neutral	Blue, Orange, Green, Brown, Yellow, White, Gray
Bad	Purple

Background Information

- Your country's energy needs would be fulfilled by 1 reactor unit
- Because your resources are limited, your nation must be strategic in trading resources with other nations.
- Be aware that used fuel management capabilities are a commodity to other countries that should be used to your advantage.

Pink Country Details
Team 14

Country Nuclear Energy Needs						
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel
1	1	1	1	1	1	1

Internal Capacity							
Ore	Conversion	Enrich	Fabrication	Construction	Ops	Used Fuel	Money
0	0	7	0	0	0	0	100

Diplomatic Relations	
Relations	Countries
Good	Teal, Navy Blue, Red, Black, Brown
Neutral	Tan, Green, Blue, White, Gray, Orange
Bad	Purple

Note(s):
1. Good - current/active relationship
2. Neutral – not current/active relationship but willing to establish a relationship
3. Bad – not current/active relationship and not willing to establish a relationship

Background Information

- Your country's energy needs would be fulfilled by 1 reactor unit
- Because you're financial resources are limited, your nation must be strategic in selling resources to other nations.

Nuclear Bucks

Contact Elizabeth McAndrew-Benavides at mcandrew@na-ygn.org for the templates.

Demand Certificates

Contact Elizabeth McAndrew-Benavides at mcandrew@na-ygn.org for the templates.

Supply Stickers

Contact Elizabeth McAndrew-Benavides at mcandrew@na-ygn.org for the templates.

Take Away Sheets

What is the Global Fuel Cycle Dynamic Learning Activity?

The Global Fuel Cycle Dynamic Learning Activity is a simulation of the international partnerships and challenges that define the global nuclear energy industry. This dynamic learning activity is designed to replicate the political, financial and regulatory issues associated with meeting worldwide demand for nuclear energy.

As participants, you will step into the shoes of diplomats and decision-makers of the nuclear energy industry. Participants should consider themselves to be delegates of their country. Country delegates are expected to evaluate their individual nation's needs, assess available resources, and develop a national strategy for establishing the country's role in the global nuclear power arena.

In this activity, participants are divided into teams representing countries, each of which is currently active in the nuclear energy industry or looking to become a stakeholder in the industry. Countries range in size, available resources, and economic advantages. By balancing the country's resources and needs, country delegates determine the role each country plays in the global nuclear market.

This interactive learning activity teaches vital skills in negotiation, public speaking, problem solving, conflict resolution, research and communication. It not only encourages participants to study and discuss global nuclear issues, but also enables the development of skills such as consensus building, compromise and cooperation.

What are the Global Fuel Cycle Dynamic Learning Activity Learning Objectives?

Uranium is an energy resource which must be processed through a series of steps to produce an efficient fuel for generating electricity. Each fuel has its own distinctive fuel cycle, however, the uranium or 'nuclear fuel cycle' is more complex than the others.

To prepare uranium for use in light water nuclear reactors, it undergoes the steps of mining and milling, conversion, enrichment and fuel fabrication. These steps make up the 'front end' of the nuclear fuel cycle.

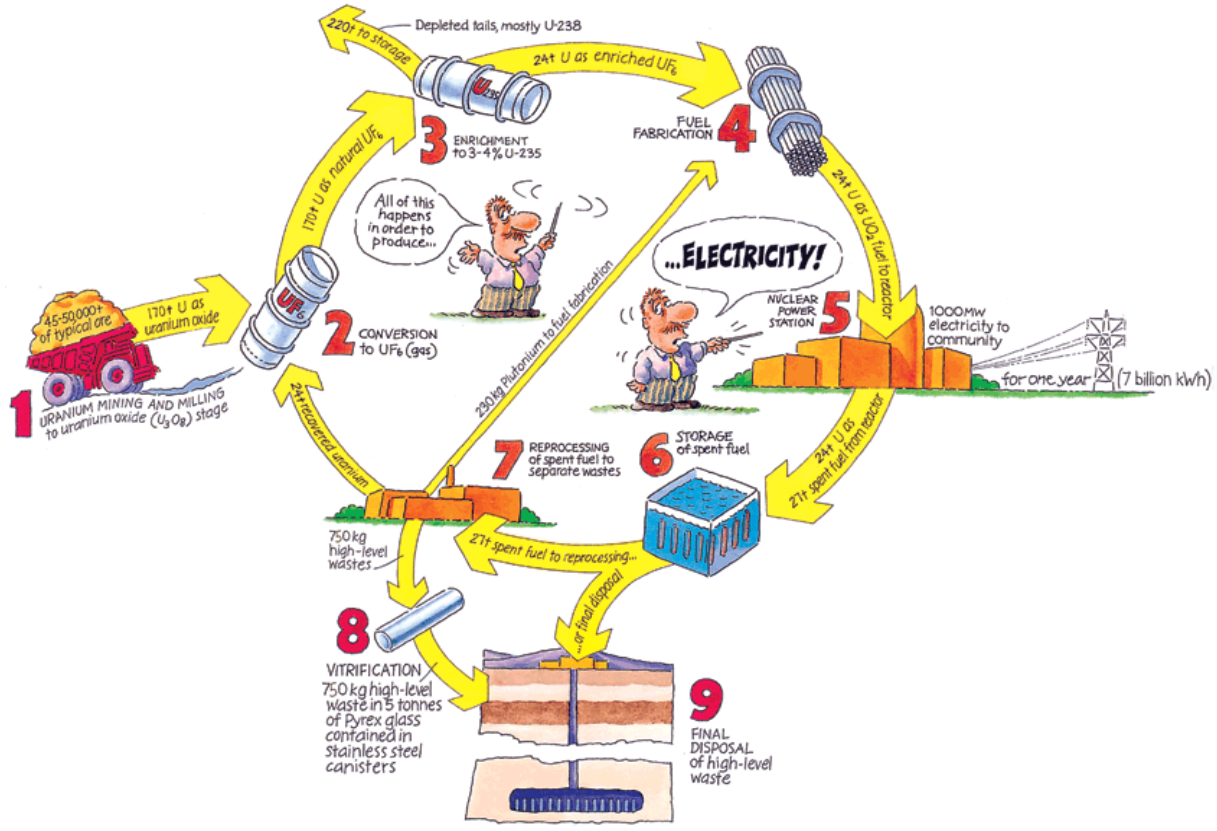
After uranium has been used in a reactor to produce electricity it is known as 'spent fuel' and may undergo a further series of steps including temporary storage, reprocessing, and recycling before eventual disposal as waste. Collectively, these steps are known as the 'back end' of the fuel cycle.

These are the various steps that together make up the entire Nuclear Fuel Cycle.

1) **Ore:** Uranium is usually mined by either surface (open cut) or underground mining techniques. From these, the mined uranium ore is sent to a mill which is usually located close to the mine. At the mill the ore is crushed and ground to a fine slurry which is leached in sulfuric acid to allow the separation of uranium from the waste rock. It is then recovered from solution and precipitated as uranium oxide (U_30_8) concentrate. U_30_8 is the uranium product which is sold. About 200 tonnes is required to keep a large (1000 MWe) nuclear power reactor generating electricity for one year.

2) **Conversion:** Because uranium needs to be in the form of a gas before it can be enriched, the $U_3 0_8$ is converted into the gas uranium hexafluoride (UF_6) at a conversion plant in Europe, Russia or North America.
3) **Enrichment:** The vast majority of all nuclear power reactors in operation and under construction require 'enriched' uranium fuel in which the proportion of the U-235 isotope has been raised from the natural level of 0.7% to about 3.5% or slightly more. The enrichment process removes about 85% of the U-238 by separating gaseous uranium hexafluoride into two streams.
4) **Fabrication:** Enriched UF_6 is transported to a fuel fabrication plant where it is converted to uranium dioxide (UO_2) powder and pressed into small pellets. These pellets are inserted into thin tubes, usually of a zirconium alloy (zircalloy) or stainless steel, to form fuel rods. The rods are then sealed and assembled in clusters to form fuel assemblies for use in the core of the nuclear reactor.
5) **Construction:** Nuclear power plant construction is a multi-year process of designing, licensing, constructing and testing the facility. This process can take in excess of 10 years to complete. Quality assurance for every step of this process is more robust than for other large construction projects. Companies that undertake these projects are usually very large and have experience constructing large facilities all over the world.
6) **Operations:** Engineers, operators, technicians and security guards with special knowledge are all needed to safely operate a nuclear power plant. Training and certifying these workers can take years. For new reactors, best practices show and some regulators require certain percentages of experienced personnel in key positions. Developing countries need to find ways to entice experienced personnel to move to their countries to help during the initial years of operations so their own staff can become experienced. The purpose of the operations phase is too safely, reliably and cost effectively produce electricity.
7) **Back End:** Used fuel assemblies taken from the reactor core are highly radioactive and give off a lot of heat. They are therefore stored in special ponds which are usually located at the reactor site. Spent fuel can be stored safely in these ponds for long periods. It can also be dry stored in engineered facilities, cooled by air. However, both kinds of storage are intended only as an interim step before the spent fuel is either reprocessed or sent to final disposal. Reprocessing separates uranium and plutonium from waste products (and from the fuel assembly cladding) by chopping up the fuel rods and dissolving them in acid to separate the various materials. Recovered uranium can be returned to the conversion plant for conversion to uranium hexafluoride and subsequent re-enrichment.

World Nuclear Association – nuclear graphic
http://www.world-nuclear.org/education/nfc.htm (all steps excluding question 6)



Facilitated Discussion Questions

1. What did you learn about the fuel cycle?

   _____
   _____
   _____

2. Why would developing countries want nuclear power?

   _____
   _____
   _____

3. For those of you who were from small countries trying to develop nuclear power plants, what was it like dealing with countries with a large program with lots of resources?

   _____
   _____
   _____

4. If one of the countries took the offer from Time-out 2:

   _____
   _____
   _____

5. What did you learn about fuel cycle and proliferation concerns?

   _____
   _____
   _____

6. What did you learn about fuel cycle and market trends?

   _____
   _____
   _____

7. One of the constraints of the program was defining which countries you were friendly with.

   _____
   _____
   _____

8. The time-outs were designed to portray the challenges associated with the fuel cycle. They were all loosely based on potential situations?

   _____
   _____
   _____

9. Did anyone's initial strategy include prioritizing the back-end of the fuel cycle?

   _____
   _____
   _____

10. Did anyone complete all of their demand sheets? – Who beat the game?

    _____
    _____
    _____

11. Did anyone procure enrichment services from Country Purple? If they were on your bad diplomatic sheet, did you know why and if so, did you question their intentions?

    _____
    _____
    _____

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