

# Uranium Mining and Processing 101



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# What is Uranium?

## **Naturally occurring radioactive metal**

- Occurs naturally in the Earth's crust and groundwater
- Northern Saskatchewan's Athabasca Basin hosts some of the highest-grade uranium deposits in the world
- Radioactivity is inherent to the element and managed through strict regulatory controls

## **Very high energy density**

- Uranium mined in Saskatchewan contains exceptionally high concentrations of energy
- Small quantities of fuel can generate large amounts of electricity
- High energy density supports long fuel cycles and reduces overall material handling

## **Measured and traded as uranium oxide**

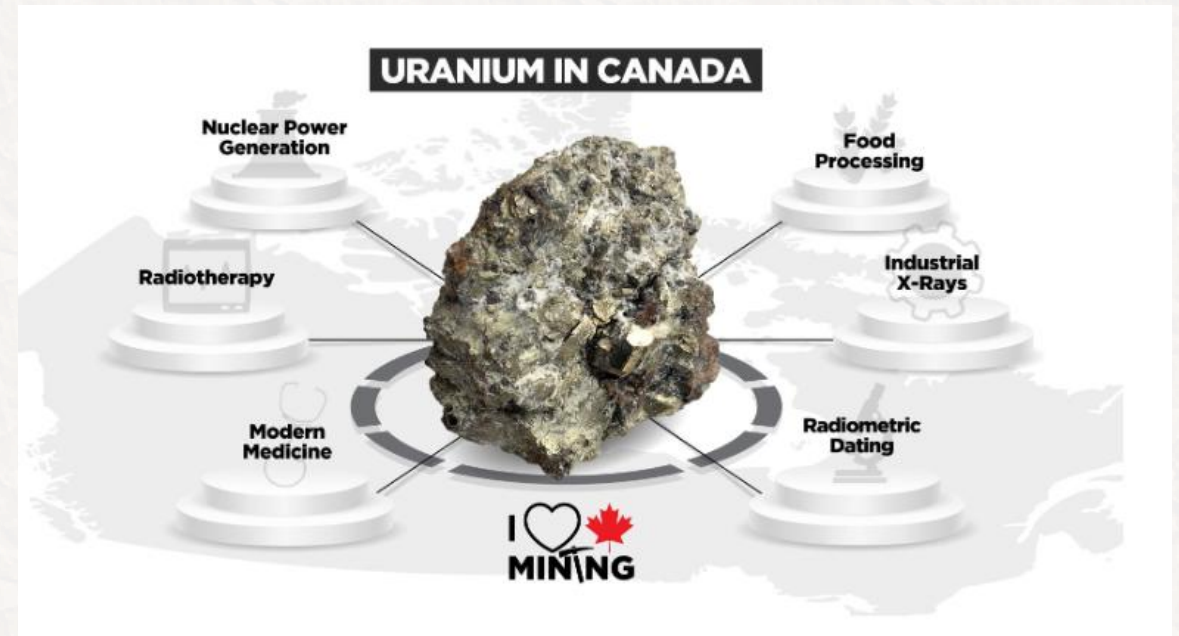
- $(\text{UO}_2)$  Uranium is processed into uranium oxide ( $\text{U}_3\text{O}_8$ ) at Saskatchewan mills (e.g., Key Lake)
- $\text{U}_3\text{O}_8$ , commonly called yellowcake, is the standard commercial product



# Uranium Uses

Used primarily for nuclear electricity generation

- Saskatchewan uranium is exported globally for use in nuclear power reactors
- Supports reliable, baseload electricity generation with low direct greenhouse gas emissions
- Plays a role in global energy security and low-carbon power systems

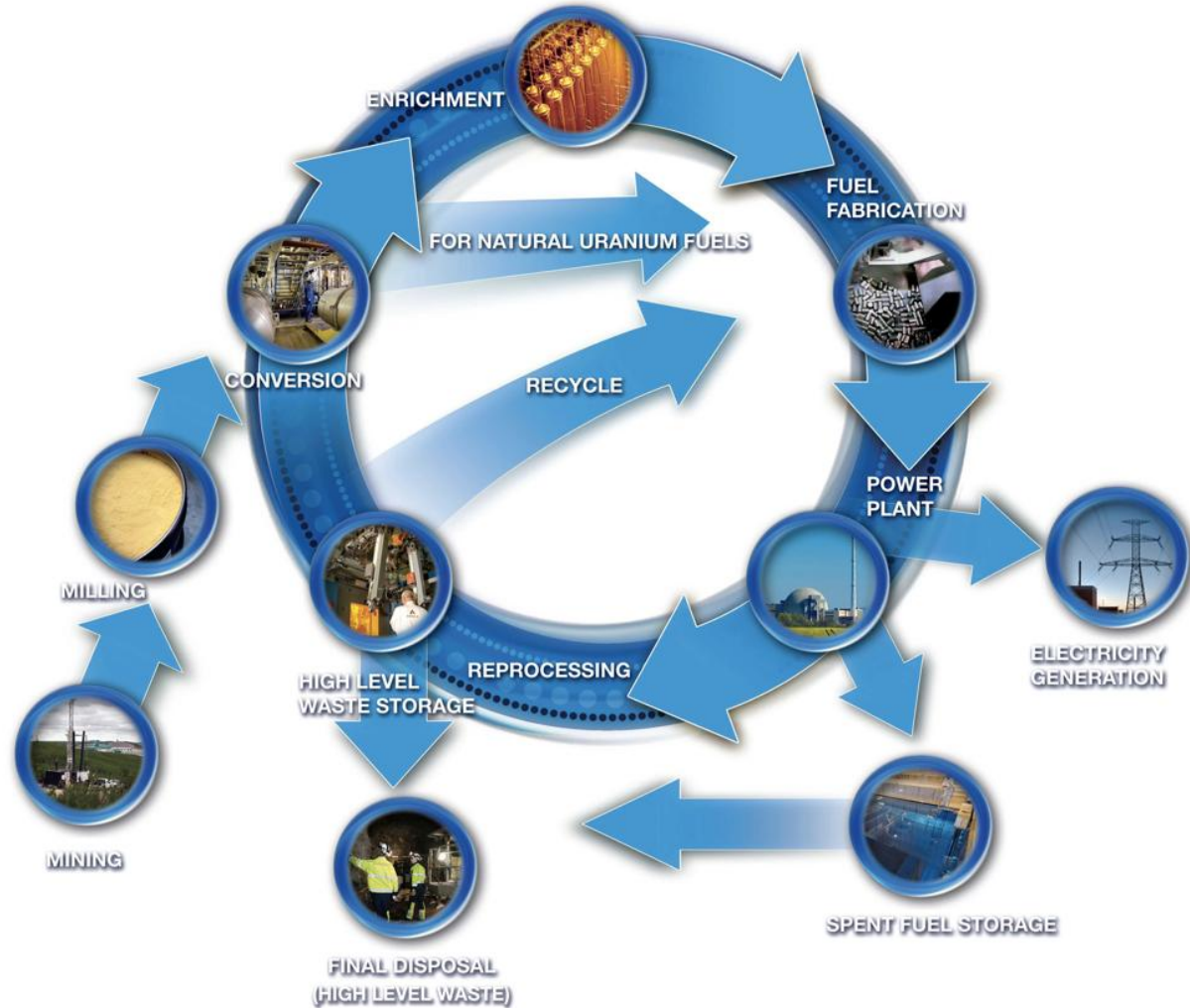


[Source: Uranium in Canada: Everything You Need to Know - Canada Action](#)



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# The Nuclear Fuel Cycle



© IAEA, AREVA, Cameco, Fortum, Posiva, TVO, WNA

# Uranium Mining Methods

Uranium mining methods are selected based on deposit depth, grade, and geology, with Saskatchewan operations dominated by high-grade underground and remote mining techniques.

## Underground Mining (High-Grade, Deep Deposits)

- The primary mining method used for Saskatchewan's Athabasca Basin uranium deposits.
- Targets very high-grade ore bodies located hundreds of metres below surface.
- Uses shafts, ramps, and specialized ground control techniques to manage water inflow and geological complexity.
- High ore grades justify the increased technical complexity and cost of underground operations.

*Uranium underground Mining Process*



These videos provide an overview of the Underground Mining Process (Credits: Cameco Corporation)

[\(848\) How It's Made - Uranium Part 1 - YouTube](#)

[\(848\) Cameco Fuel Cycle - Jet Bore Mining - YouTube](#)

[Cameco Fuel Cycle - Raisebore Mining](#)



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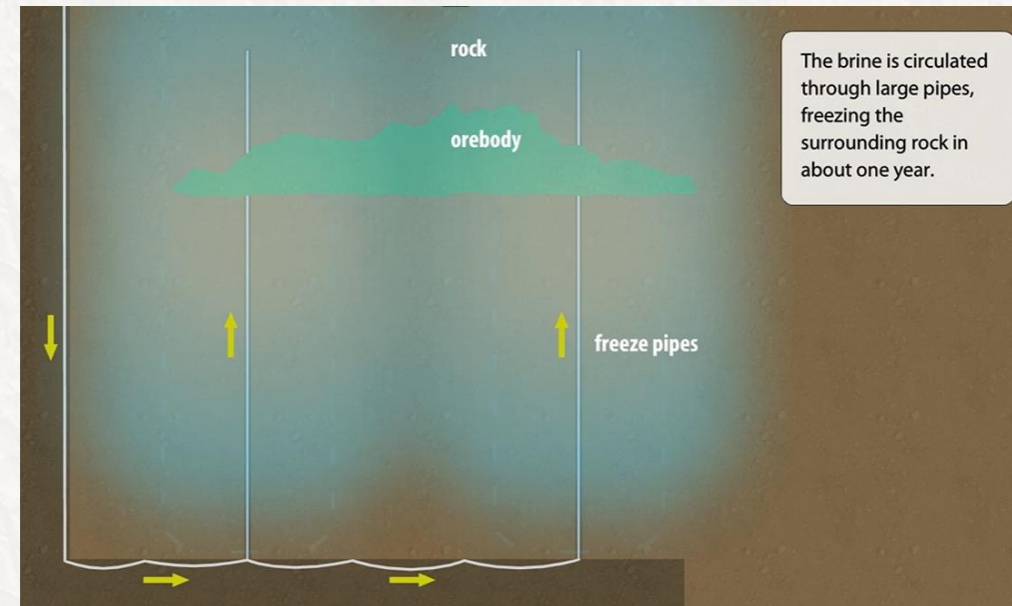
# Uranium Mining Methods

Uranium mining methods are selected based on deposit depth, grade, and geology, with Saskatchewan operations dominated by high-grade underground and remote mining techniques.

## Remote Mining Techniques Due to Radiation Levels

- Saskatchewan's exceptionally high-grade uranium ores require advanced radiation protection measures.
- Mining activities increasingly rely on:
  - Remote-controlled equipment
  - Automation and robotics
  - Shielded facilities and monitoring systems
- These techniques reduce worker exposure while enabling safe extraction of high-grade ore.
- Remote mining is a defining feature of modern uranium operations in northern Saskatchewan.

*Ground freezing process*



# Key Lake Mill



High-grade ore from McArthur River (SK) is trucked 80 km to Key Lake Mill.

Key Lake Mill, SK



Left: Cameco, "McArthur River/Key Lake", <https://www.cameco.com/businesses/uranium-operations/canada/mcarthur-river-key-lake>, Last visited Feb. 2, 2024.

Right: CNSC, "Nuclear facility – Key Lake Operations", <https://www.cnsccsn.gc.ca/eng/uranium/mines-and-mills/nuclear-facilities/key-lake/>, Last visited. Feb 22, 2024.

# Rabbit Lake Underground Mine Operation



Cameco, "Rabbit Lake", <https://www.cameco.com/businesses/uranium-operations/suspended/rabbit-lake>, Last accessed Jan. 17, 2021.



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# Uranium Milling and Processing

## Crushing and Grinding of Ore

### Liberation of uranium minerals

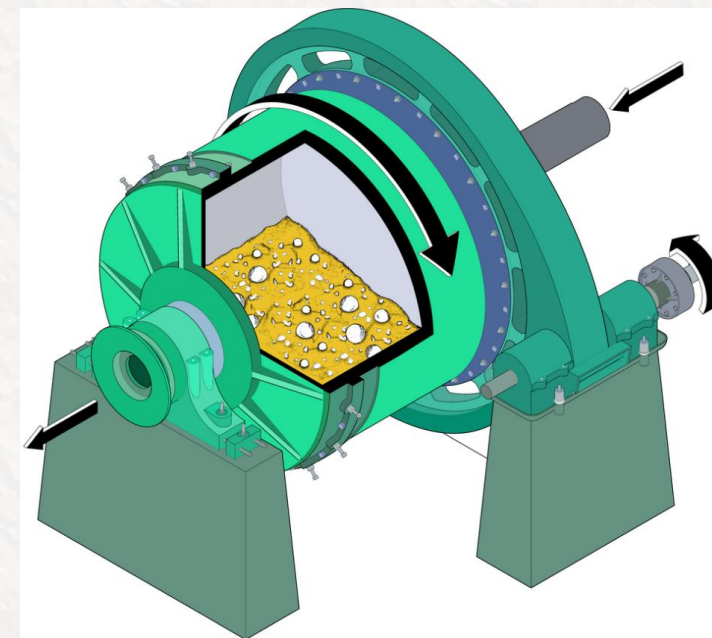
- Mined uranium ore is mechanically crushed and ground to break the host rock and expose uranium-bearing minerals.
- Effective liberation is essential to ensure uranium can be efficiently dissolved during downstream chemical leaching.
- Crushing typically reduces ore size from run-of-mine material to manageable fragments, followed by grinding to fine particles.

### Controlled particle size for process efficiency

Grind size is carefully selected to balance:

- Maximizing uranium recovery
  - Minimizing energy consumption and equipment wear
  - Avoiding excessive production of ultra-fine particles that can hinder leaching and **solid-liquid separation**
- Consistent particle size improves leaching kinetics and overall process stability.

*Grinding Process*



# Uranium Milling and Processing

## Crushing and Grinding of Ore

Crushing and grinding liberate uranium minerals while carefully controlling particle size and exposure risks, providing the foundation for effective and safe uranium recovery

## Design considerations for Saskatchewan's high-grade ores

- Saskatchewan uranium ores can contain exceptionally high uranium grades, requiring specialized design and controls.
- Crushing and grinding circuits are engineered to:
  - Minimize dust generation and airborne particulates
  - Limit unnecessary material handling steps
  - Reduce opportunities for radiation exposure to workers
- Enclosed systems, remote operation, and shielding are commonly used to maintain safe working conditions.



# Uranium Milling and Processing

## Chemical leaching to dissolve Uranium

Chemical leaching uses controlled chemistry to selectively dissolve uranium from crushed ore, enabling its separation from waste rock and preparation for downstream purification

## Dissolving uranium into a liquid phase

- Finely ground uranium ore is mixed with chemical leaching solutions in tanks or leach vessels.
- The objective is to dissolve uranium minerals into solution while leaving most of the host rock undissolved.
- Effective mixing, temperature control, and residence time are critical to maximize uranium recovery.

*Uranium acid solution*



These video provides a processing overview (Credits: Cameco Corporation)

[\(848\) How It's Made - Uranium Part 2 - YouTube](#)



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# Uranium Milling and Processing

## Chemical leaching to dissolve Uranium

Chemical leaching uses controlled chemistry to selectively dissolve uranium from crushed ore, enabling its separation from waste rock and preparation for downstream purification

### Acidic and alkaline leaching systems

- **Acid leaching** (commonly sulfuric acid) is widely used due to its effectiveness and relatively fast reaction rates.
- Oxidizing agents may be added to convert uranium into a soluble form.
- Alkaline leaching may be used where acid consumption is high or where mineralogy or environmental considerations favour it.
- The choice of leach chemistry depends on ore composition, uranium mineralogy, and impurity content.

*Uranium acid solution*



# Uranium Milling and Processing

## Chemical leaching to dissolve Uranium

Chemical leaching uses controlled chemistry to selectively dissolve uranium from crushed ore, enabling its separation from waste rock and preparation for downstream purification

## Chemical separation from solid material

- During leaching, uranium transitions from the solid ore into the liquid solution.
- The remaining solid material—consisting of rock, gangue minerals, and insoluble residues—does not dissolve.
- This creates a uranium-rich solution that can be separated from the solids for further purification.
- Solid residues proceed to tailings management systems under tightly controlled conditions.



# Uranium Milling and Processing

## **Solvent Extraction or Ion Exchange**

Solvent extraction and ion exchange selectively purify and concentrate uranium from solution, producing a clean feed for final uranium concentrate production

## **Purification and concentration of uranium solution**

- After leaching, uranium exists in a liquid solution along with dissolved impurities.
- Solvent extraction or ion exchange is used to selectively remove uranium from this solution and concentrate it.
- These steps significantly increase uranium purity prior to final product formation.



# Uranium Milling and Processing

## Solvent Extraction or Ion Exchange

Solvent extraction and ion exchange selectively purify and concentrate uranium from solution, producing a clean feed for final uranium concentrate production

### Solvent extraction

- Uranium is selectively transferred from the aqueous solution into an organic solvent phase.
- Chemical extractants bind preferentially to uranium, leaving most impurities behind.
- The uranium is then stripped from the organic phase into a clean solution for further processing.
- Commonly used in Saskatchewan mills due to its effectiveness for high-grade uranium circuits.

*Uranium purification process*

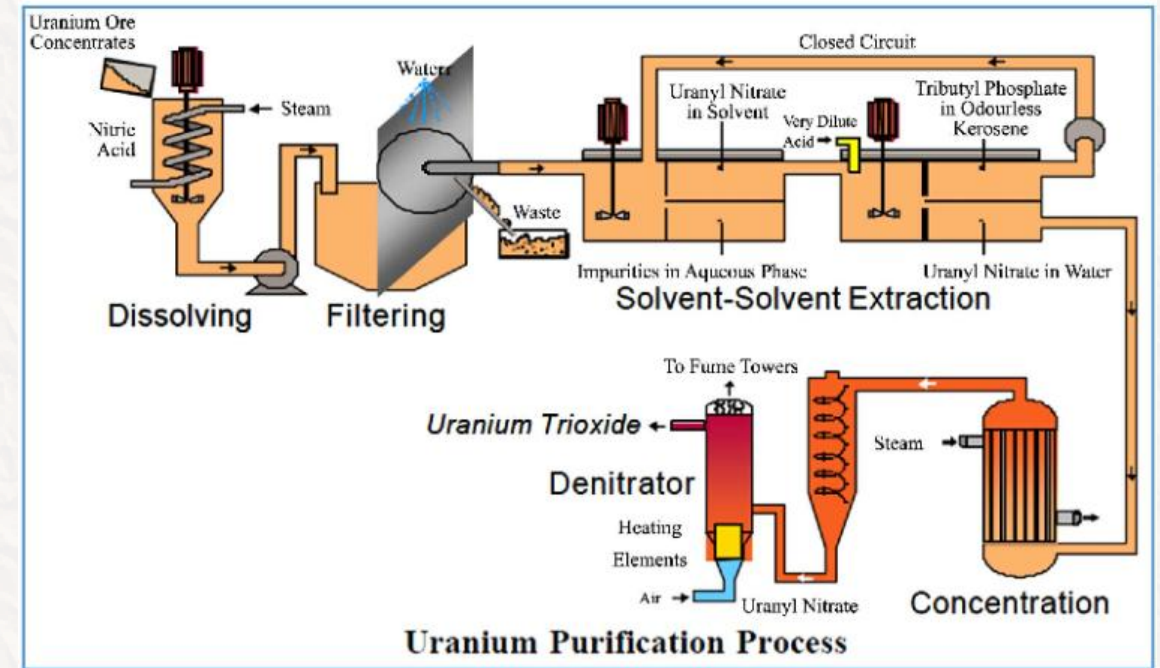


Figure 1 from [Reduction Kinetics of Uranium Trioxide to Uranium Dioxide Using Hydrogen | Semantic Scholar](#)



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# Uranium Milling and Processing

## Solvent Extraction or Ion Exchange

Solvent extraction and ion exchange selectively purify and concentrate uranium from solution, producing a clean feed for final uranium concentrate production

### Ion exchange

- Uranium ions are captured onto specialized ion-exchange resins as solution passes through columns.
- Once the resin is saturated, uranium is stripped off using a controlled solution.
- Ion exchange is well suited to lower concentrations or specific water chemistries.
- Produces a purified uranium solution with reduced impurity levels.



# Uranium Milling and Processing

## **Impurity removal and product quality**

- Both methods remove unwanted elements such as iron, aluminum, and other dissolved metals.
- Improved purity is essential for producing consistent, market-acceptable uranium concentrate.
- Process performance directly affects recovery, yield, and downstream efficiency.

## **Control and environmental protection**

- Tight control of chemistry, flow rates, and containment is required.
- Saskatchewan operations emphasize:
  - Enclosed systems
  - Secondary containment
  - Continuous monitoring and regulatory compliance
- These controls protect workers, the environment, and product quality.



# Uranium Milling and Processing

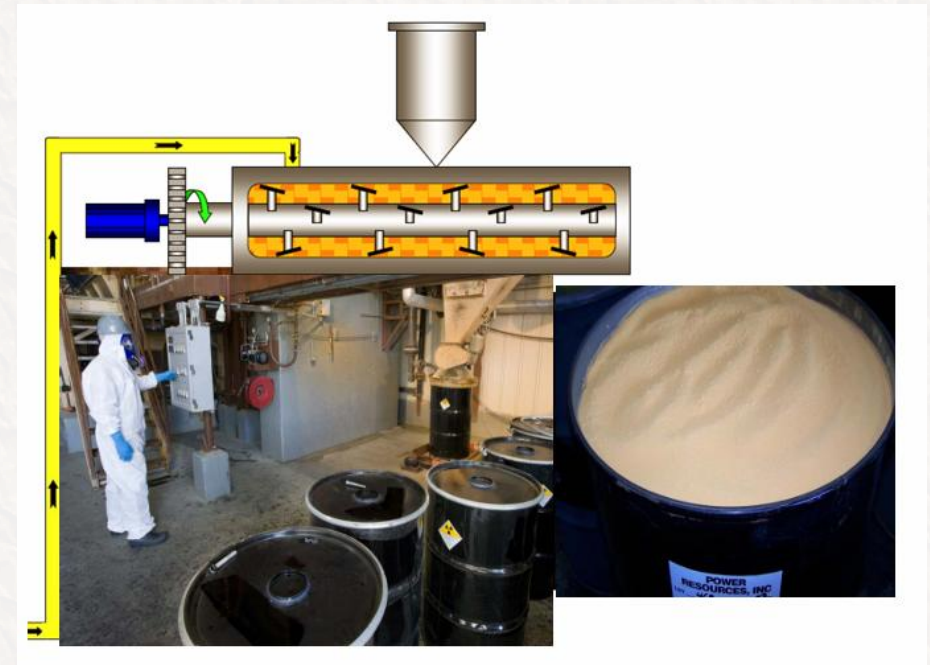
## Production of Uranium Concentrate (Yellowcake)

Uranium milling culminates in the production of yellowcake ( $U_3O_8$ ), a stable, transportable concentrate that feeds the global nuclear fuel cycle

### Precipitation, filtration, and drying

- The purified uranium solution from solvent extraction or ion exchange is chemically treated to precipitate uranium out of solution.
- The precipitated uranium compound is separated from liquid through filtration or thickening.
- The solid material is then roasted at controlled temperatures to remove remaining moisture.
- The final dried product is triuranium Octoxide, most commonly  $U_3O_8$ .

*Yellowcake is dried in a rotary vacuum dryer into a powder and loaded into drums*



[0450 - F104 - Health Physics for Uranium Recovery - 03 - Overview of Uranium Recovery Facilities.](#)



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# Uranium Milling and Processing

## Packaging and storage

- Yellowcake is packaged into **sealed steel drums** designed to prevent leakage and limit contamination.
- Drums are carefully weighed, labeled, and tracked to meet strict regulatory and quality requirements.
- Storage areas are engineered with radiation monitoring, secondary containment, and safety controls.
- Saskatchewan uranium concentrate is transported to Ontario for Refining and Conversion.



Cameco, "Blind River Refinery",  
<https://www.camecofuel.com/business/blind-river-refinery>, Last visited Jan. 14, 2022.



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# Refining & Conversion

- Refining: Blind River, Ontario
- World's largest capacity at 18 Million kgU
- Refines  $U_3O_8$  to  $UO_3$



[Refining: Blind River | Cameco](#)

Conversion, Port Hope, Ontario  
 $UO_3$  converted to  $UO_2$  or  $UF_6$   
 $UF_6$  exported for enrichment  
 $UO_2$  used in Canada for CANDU fuel fabrication.



[Conversion: Port Hope | Cameco](#)



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