ULTRA SAFE NUCLEAR CORPORATION

An Update on the Development of FCM fuels for Micro-Modular Reactors (MMR)

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SNETP FORUM

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Contents

- Introduction to USNC
- USNC MMR
- FCM^{TM} Fabrication
  - Artisanal
  - Engineering Scale
- FCM Qualification strategy
  - Fabrication
  - Irradiation qualification
- Next steps for MMR and FCM^{TM}

Ultra Safe Nuclear Corporation

Background

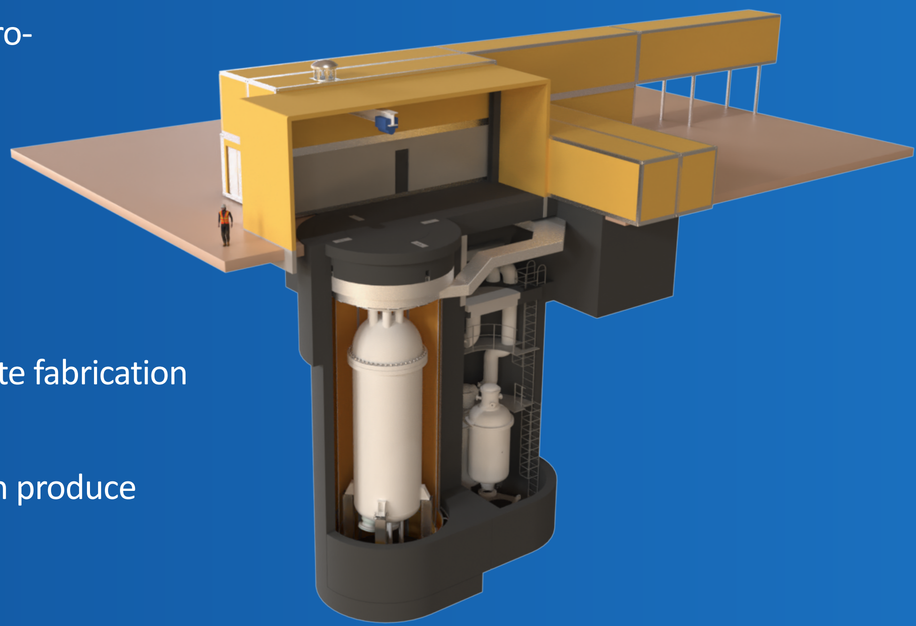
- Founded in 2011, privately funded, $50m investment to date
- Developer of the small-scale Gen IV Micro Modular Reactor (MMR™) system
- Multiple patents for ceramic micro-encapsulated nuclear fuel
- MMR™ Designed for safe, clean, cost-effective energy with no refueling for 20 years
- Specifically developed the MMR-REM for off-grid, northern/remote application in Canada

- Formed Canadian subsidiary USNC-Power
- Formed First Commercial Micro Reactor JV with Ontario Power Generation – Global First Power

The Ultra Safe Nuclear Solution

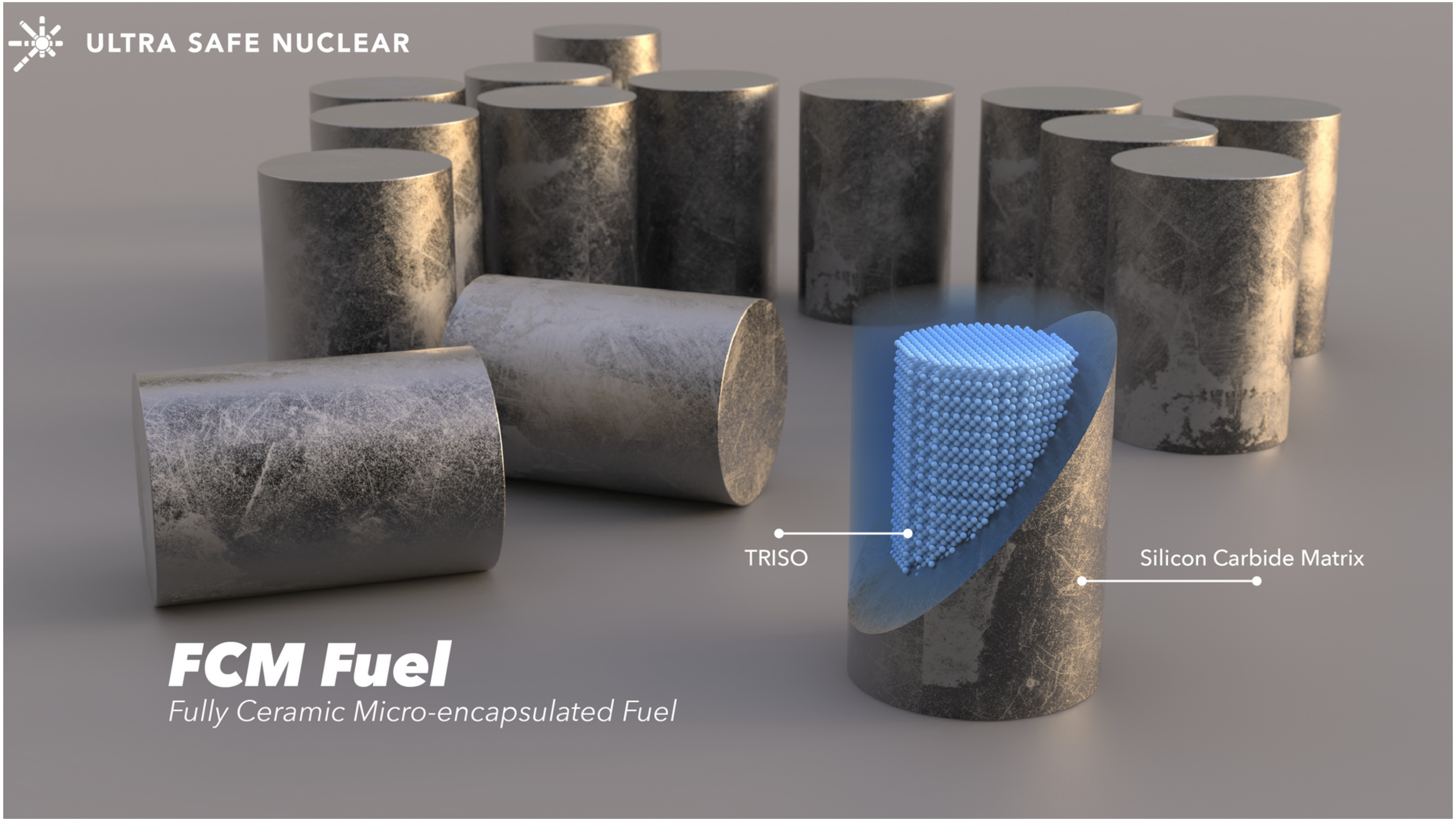
Gas-cooled MMR™

- Transformative fuel technology using fully ceramic micro-encapsulated (FCM™) fuel
- 5 MW to 50 MW plant size (electrical)
- Fueled once for 20-year life, mitigating supply risk
- Meltdown-proof with no safety risks
- Designed for Arctic conditions
- Modular design allows for rapid construction and off-site fabrication
- Fraction of the capital cost of traditional nuclear plants
- Flexible design outputs electricity, process heat and can produce hydrogen
- Minimal waste aligns with national plans for disposal
- Stable, long-term energy costs lower than highly-unpredictable fossil fuels



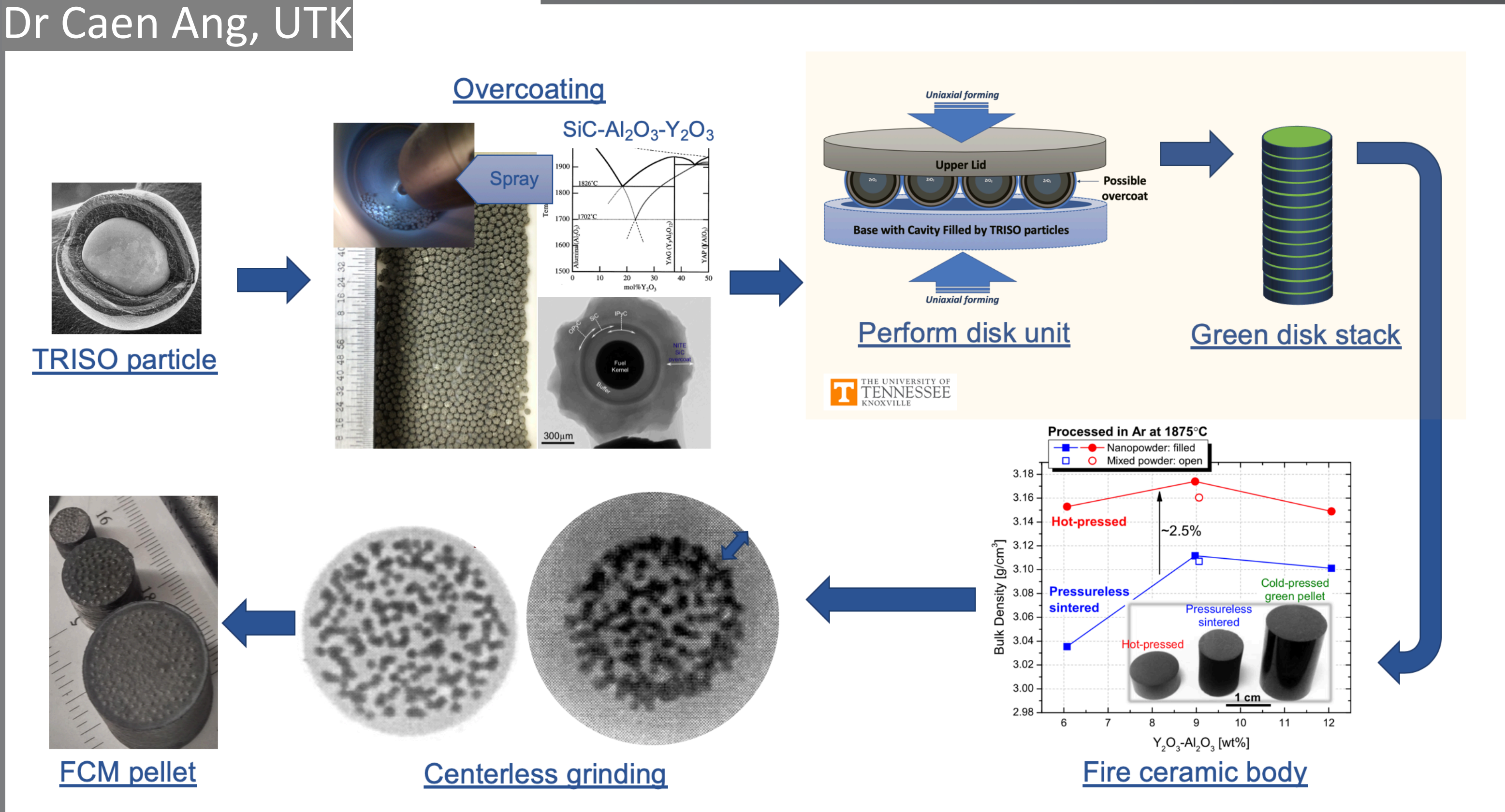
Molten Salt Intermediate Heat Transport Loop

- Eliminates water ingress, chemical attack and fission product wash off
- Allows for heat storage which decouples the primary circuit from the load


ULTRA SAFE NUCLEAR
TRISO
Silicon Carbide Matrix
FCM Fuel
Fully Ceramic Micro-encapsulated Fuel

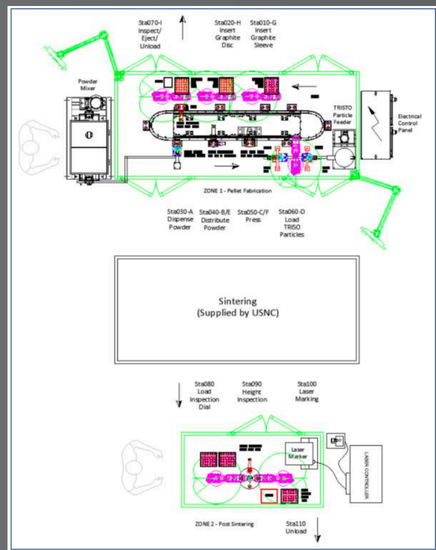
FCM^{TM} FUEL Production Process - Artisanal

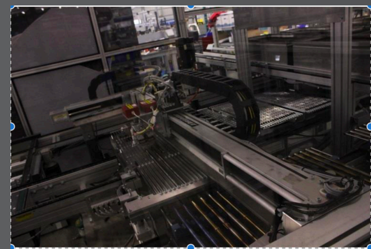
Dr Caen Ang, UTK



FCM^{TM} FUEL Production – Green Pellet Automation

Step 1: Concept Development
Step 2: Proof of principle and selection of vendors
Step 2: Engineering and Detailed tooling design
Step 3: Beta System / Pilot Line
Step 4: Procurement, Manufacturing, Build, Integration and Testing/Validation (FAT)
Step 5: Teardown, Crating and Shipping
Step 6: Installation, Site Acceptance Testing (SAT) /Commissioning and Training





FCM^{TM} FUEL Production – Multi Pellet Sintering

Objectives

- Development of suitable method/conditions of multiple production of sintered pellets by SPS Determination of Tunnel type SPS system specifications which meets system requirements

Phased Development

- Single pellet sintering tests
- Small scale multi-pellet sintering tests
- Large scale single Layer Die/Punch Assembly test.
- Determination of Optimal Tunnel type SPS system

FCM Qualification Strategy

MMR Safety Case will be based on a **claim** of de minimis fission product release to the primary circuit under both normal operation and fault conditions

- USNC FCM fuel will incorporate a previously proven/qualified TRISO fuel particle design – EPRI Topical report
- For both normal operation and fault conditions there is a large margin between the fuel operating envelope for USNC reactor design and the existing TRISO fuel particle qualification envelope

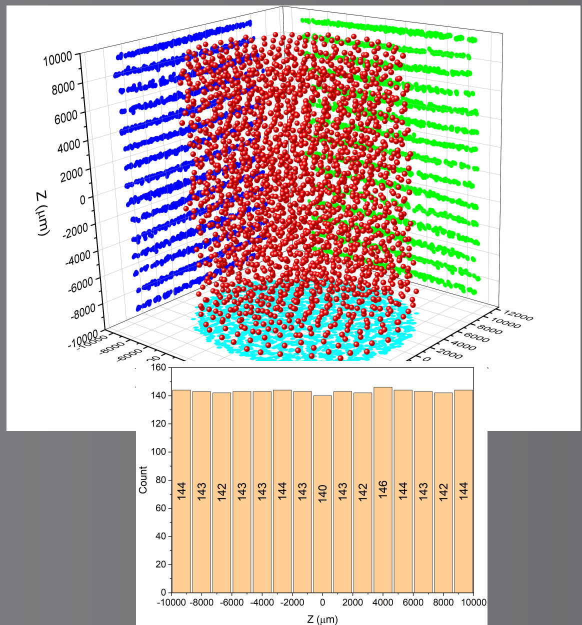
Fabrication

- Incorporation of the TRISO particles in the FCM fuel pellets will not result in significant damage

Irradiation

- Interaction (mechanical, chemical or any other form) between the TRISO particles and FCM matrix during irradiation will not result in any significant damage to the TRISO particle coatings which could significantly impair their ability to act as a barrier to fission product release
- USNC will conduct extensive FCM irradiation trials
- Using the TRISO fuel particle and FCM matrix qualification evidence, simple pessimistic fission product release fractions can be calculated by isotope and used to support the safety case

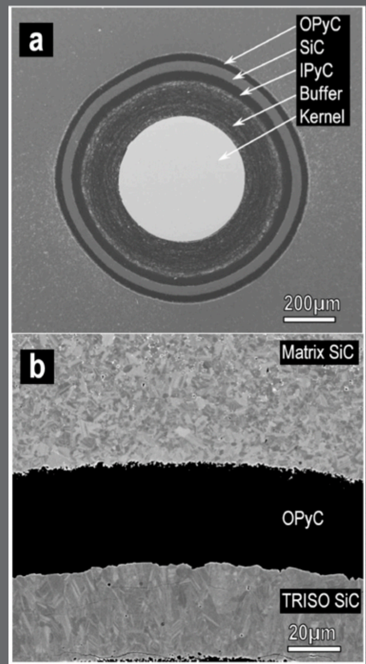
FCM Qualification Strategy – Fabrication Analysis



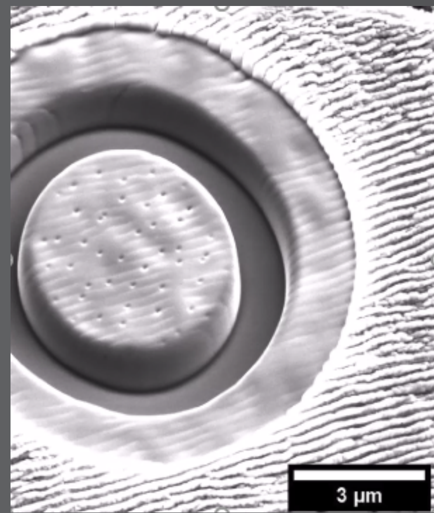
Number of particles per layer

University of BRISTOL

Alex Leide, Don Liu



FCM Microstructure



FIB-SEM of TRISO

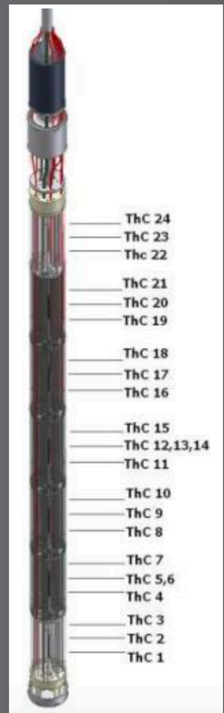
FCM Qualification Strategy – Irradiation Normal Operation

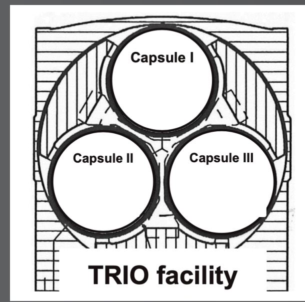
A campaign of integrated fuel irradiation testing at normal MMR operating conditions to provide final performance data envelope for MMR fuel qualification.

Although accelerated the FCM pellets are tested under conditions that are analogous to MMR reactor condition so that we can be sure that all degradation mechanisms are tested during the irradiation

In -situ measurements will be made

- Monitoring of fuel temperature during irradiation
- Sweep Gas analysis to determine fission product release during irradiation





NRG TRIO Facility (Knol, Vreeling)

FCM Qualification Strategy – Irradiation Accident Transient

MMR-FCM Off-Normal

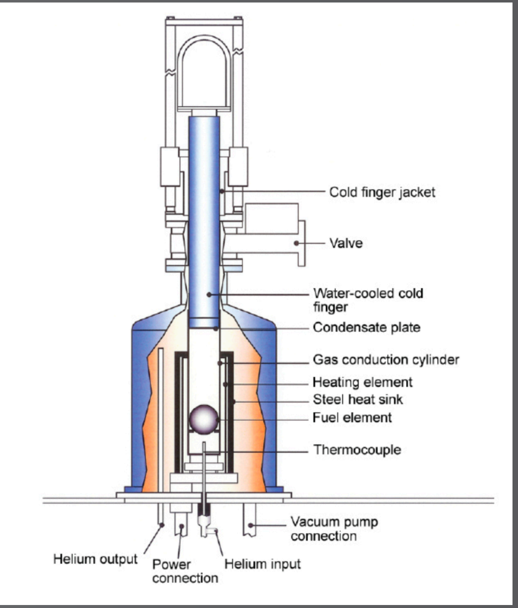
- Qualification for Off-Normal Operating Conditions: following irradiation to desired burnup, furnace heat up tests will be conducted on FCM fuel providing data for MMR off-normal conditions.
  - The design of MMR negates rapid temperature transients in the fuel and removes the need for in-pile transient tests

Materials test reactors will be utilized to deliver an accelerated qualification programme

The normal and Off normal tests will be conducted at 30% and 110% lifetime burnup

- 30%, which covers approximately 7 years of FOAK operation, in approximately two years from commencement of test and delivered ahead of FOAK plant assembly
- 110% in approximately 4 to 5 years

Off normal testing conducted at separate facility



KUFA Test Facility (Seeger)

Next Steps - Executing Canada's First SMR Project

- Vendor design review with the CNSC is entering Phase 2.
- Agreement to site at CNL/AECL has been signed
- Active application for an Environmental Assessment and License to Prepare Site
- Partnership established with OPG through GFP to build, own, and operate the plant
- Schedule brings Canada's first SMR into operation by 2026 or earlier
- Advancing Canada's SMR Action Plan and decarbonization goals before 2030 (one 5 MW MMR™ can replace 220 million of litres of diesel)
- 80 per cent of project expenditures to be spent in Canada
- Job creation estimated at 400 (direct) and 1,000 (indirect) by 2022

GLOBAL FIRST POWER

ONTARIO POWER GENERATION

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