The Nuclear Fuel Cycle

How a Pressurized Water Reactor works…

Source: https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html
93 REACTORS AT 54 PLANT SITES ACROSS THE COUNTRY

Reactors can operate for 80 years (at least)

About 500 direct jobs per reactor

Wages about 1/3 higher than average jobs in local area

KEY
- Nuclear power reactor
Nuclear generated 19% of U.S. electricity in 2021

Source: U.S. Energy Information Administration
Updated: March 2022
Nuclear power continued to provide the majority of U.S. emissions-free electricity in 2021

<table>
<thead>
<tr>
<th>Resource</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>50.1%</td>
</tr>
<tr>
<td>Wind</td>
<td>24.4%</td>
</tr>
<tr>
<td>Hydro</td>
<td>17.1%</td>
</tr>
<tr>
<td>Solar</td>
<td>7.4%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

Source: U.S. Energy Information Administration
Updated: March 2022
Total Generating Costs 2002 – 2020

Source: Electric Utility Cost Group
Updated: September 2021
Declining U.S. Wholesale Electricity Prices

$/MWh

$100.00

$80.00

$60.00

$40.00

$20.00

$-


ISONE Conn.
ISONE NE Mass.
Michigan Hub
MISO Illinois Hub
NYISO West
NYISO Hudson Val
PJM Eastern Hub
PJM Western Hub
PJM Chicago Hub

Forward Prices

$45 - $75/MWh
$30 - $50/MWh
$28 - $36/MWh
$24 - $32/MWh

$20 - $60/MWh

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THE EMISSIONS REDUCTION IMPERATIVE

McDonald's sets greenhouse gas reduction targets

Lisa Baertels

(Reuters) - McDonald's Corp on Tuesday announced an approved, science-based target to cut greenhouse gas emissions and battle climate change, saying it is the first restaurant company to do so.

Blue chips act to cut supply chain greenhouse gas emissions

Rolls-Royce, Nestlé and Panasonic among larger companies taking action

Michael Poole

The number of large companies taking serious action to tackle greenhouse gas emissions in their supply chains has doubled, according to research by an

Let's face it, manufacturing cars is no easy feat. Aside from the fact that you have to build a whole fleet of them, you'll also need plenty of resources and energy to manufacture batches of them. But using energy means you're also producing CO₂ emissions, which is never good.

That's right, aside from automobiles, car factories also use plenty of energy that result in more CO₂ emissions that harm the environment and add more greenhouse gases that pollute the air. So how does Toyota plan to combat that? By setting a goal of achieving 35% reduced CO₂ emissions in global plants worldwide by 2030, and having zero CO₂ emissions in all manufacturing plants by 2050.

Part of the “Toyota Environmental Challenge 2050”, the automaker is looking at not just reducing their carbon footprint from their cars, but also from their manufacturing facilities. To do this, Toyota has been finding ways of recycling and using alternative means of generating energy.
UTILITIES WITH EMISSIONS REDUCTION PLEDGES

FIRM, LOW-CARBON GENERATION FROM NUCLEAR ENABLES AFFORDABLE DECARBONIZATION AND SYSTEM RESILIENCE
DECARBONIZATION WILL DRIVE FURTHER COAL PLANT CLOSURES – INCREASING RISKS TO RELIABILITY

MANY OF THESE PLANTS ARE OF SIMILAR SIZE TO SMRs/ADVANCED REACTORS
NUCLEAR GENERATION CREATES LONG-TERM, WELL-PAYING JOBS

<table>
<thead>
<tr>
<th>Coal Plant Position</th>
<th># Dedicated Coal Positions</th>
<th>SMR Position</th>
<th># Dedicated SMR Positions</th>
<th>Position Type</th>
<th>Degree of Retraining Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations Supervisor</td>
<td>5</td>
<td>Senior Reactor Operator</td>
<td>5</td>
<td>Supervisor</td>
<td>High</td>
</tr>
<tr>
<td>Control Room Operator</td>
<td>10</td>
<td>Reactor Operator</td>
<td>15</td>
<td>Operator</td>
<td>High</td>
</tr>
<tr>
<td>Field Operator</td>
<td>15</td>
<td>Non-Licensed Operator</td>
<td>25</td>
<td>Operator</td>
<td>Low</td>
</tr>
<tr>
<td>Lab Operator/Chemistry/Scrubber</td>
<td>4</td>
<td>Chem Tech</td>
<td>14</td>
<td>Craft</td>
<td>Medium</td>
</tr>
<tr>
<td>Maintenance Supervisor</td>
<td>2</td>
<td>Maintenance Supervisor</td>
<td>3</td>
<td>Supervisor</td>
<td>Medium</td>
</tr>
<tr>
<td>Mechanical Craft</td>
<td>12</td>
<td>Mechanical Craft</td>
<td>21</td>
<td>Craft</td>
<td>Low</td>
</tr>
<tr>
<td>I&amp;C Craft</td>
<td>9</td>
<td>I&amp;C Craft</td>
<td>10</td>
<td>Craft</td>
<td>Medium</td>
</tr>
<tr>
<td>Electrician Craft</td>
<td>5</td>
<td>Electrician Craft</td>
<td>11</td>
<td>Craft</td>
<td>Low</td>
</tr>
<tr>
<td>Technician</td>
<td>11</td>
<td>Technician</td>
<td>13</td>
<td>Laborer</td>
<td>Low</td>
</tr>
<tr>
<td>Security Officer</td>
<td>20</td>
<td>Security Officer</td>
<td>48</td>
<td>Laborer</td>
<td>Low</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>93</td>
<td></td>
<td>165</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Other Positions</td>
<td>14</td>
<td></td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total On-Site Positions</td>
<td>107</td>
<td></td>
<td>237</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible Centralized Positions</td>
<td></td>
<td></td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Positions</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: NuScale; ScottMadden analysis


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BIPARTISAN LEADERS EMBRACE NUCLEAR ENERGY

Biden American Jobs Plan:
• Recognizes important role of existing nuclear
• Pledges support for demonstration projects, manufacturing infrastructure investments

Bipartisan Infrastructure Bill:
• Operating nuclear plant credit program
• Advanced reactor demonstration funding
• Large-scale H2 demos

Build Back Better Bill:
• Tax credits for existing reactors
• Tax credits for all new clean generation
• Expanded federal loan guarantees
## Utility and State Interest

<table>
<thead>
<tr>
<th>State</th>
<th>Legislative Action</th>
<th>Utility Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>Bills introduced to repeal Legislature approval to site</td>
<td>Eielson AFB site for first micro-reactor for DoD</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Partially repealed nuclear moratorium (allows new nuclear at Millstone)</td>
<td>Dominion actively supported repeal</td>
</tr>
<tr>
<td>Idaho</td>
<td>Tax incentives passed</td>
<td>Host of UAMPS/NuScale SMR</td>
</tr>
<tr>
<td>Indiana</td>
<td>Nuclear Certificate of Necessity program enabled</td>
<td>Duke and AEP have SMRs in their IRPs</td>
</tr>
<tr>
<td>Montana</td>
<td>Passed bill to study coal to SMR</td>
<td>NorthWestern Energy exploring coal to nuclear</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Passed bill on SMR tax incentives and SMR study funding approved</td>
<td>TBD – strong support for SMRs in state</td>
</tr>
<tr>
<td>North Carolina</td>
<td>Passed decarbonization plan bill</td>
<td>Duke Energy includes SMRs in IRP</td>
</tr>
<tr>
<td>Virginia</td>
<td>Nuclear Energy Strategic Plan and SMR Task Force created</td>
<td>Dominion includes SMRs in IRP</td>
</tr>
<tr>
<td>Washington</td>
<td>Clean energy standard including nuclear</td>
<td>Energy Northwest with X-energy demo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grant County PUD MOU with X-energy and NuScale</td>
</tr>
<tr>
<td>West Virginia</td>
<td>Repealed nuclear moratorium</td>
<td>Dominion Energy and AEP have SMRs in IRPs</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Passed bill calling for coal retirements to be replaced with SMRs</td>
<td>Rocky Mt. Power siting for TerraPower demo</td>
</tr>
</tbody>
</table>
Types of Advanced Reactors

Range of sizes and features to meet diverse market needs

Micro Reactors (<20MW)
- Oklo (shown)
  - Approximately a dozen in development

LWR SMRs <300MW
- NuScale (shown)
- GEH X-300
- Holtec SMR-160

High Temp Gas Reactors
- X-energy (shown)
  - Several in development

Liquid Metal Reactors
- TerraPower Natrium (shown)
  - Several in development

Molten Salt Reactors
- Terrestrial (shown)
  - Several in development

Non-Water Cooled
- Most <300MW, some as large as 1,000 MW
ARDP Demonstration Awards

- **TerraPower**
  - Natrium Reactor
    - Liquid sodium fast reactor - 345 MWe
    - Metallic fuel
    - Molten salt thermal storage for peaking to 500 MWe
ARDP Demonstration Awards

- **X energy® Xe-100**
  - Pebble bed Helium cooled gas reactor – 80 MWe
  - Four reactors
  - TRISO fuel

TRISO Fuel Pebble Cutaway
UAMPS

- Utah Associated Municipal Power Systems (UAMPS) plans to construct and operate a NuScale reactor at Idaho National Lab around 2029
- DOE approved $1.4 billion multi-year cost share in October 2020 for UAMPS
Advanced Nuclear Deployment Plans

Projects in planning or under consideration in U.S. and Canada; >30 globally
MOVING BEYOND ELECTRICITY

TODAY

Electricity focused

FUTURE

Integrated grid system that leverages contributions from nuclear fission beyond electricity sector

Tomorrow’s nuclear will produce more than electricity
GROWING GLOBAL MARKET FOR NEW NUCLEAR ENERGY SYSTEMS

ESTIMATED $8T+ GLOBAL NUCLEAR ENERGY MARKET THRU 2050

KEY TAKEAWAYS

- Consumers and policymakers (U.S. and abroad) increasingly demanding low-carbon electricity; states and utilities responding with ambitious goals

- Growing understanding that new nuclear is extremely valuable to a cleaner energy system
  - Least-cost, most reliable low-carbon systems include firm clean generation
  - State and federal policy actions needed to incentivize investment, drive down costs
  - Nuclear can help decarbonize non-electric energy uses

- Tremendous opportunities in domestic and global markets

WIND + SOLAR + NUCLEAR + STORAGE IS THE BALANCED MIX THAT WILL GET US TO A CLEAN ENERGY FUTURE
QUESTIONS?
The 40 used fuel casks hold all the fuel from 29 years of Connecticut Yankee operations.

If the electricity produced by this fuel instead came from natural gas, the emitted CO2 would fill the Superdome. More than 3,000 times.

TOWARD A DURABLE, INTEGRATED SPENT FUEL MANAGEMENT PROGRAM

• Congress – consider the future of the NWPA

• Biden Administration:
  – Take steps to stand up an organization to resume management of the nuclear waste program
  – Seek Congressional authorization and funding to begin implementation of an integrated nuclear waste management system that allows for private consolidated interim spent fuel storage approaches

$>$40B AVAILABLE IN THE NUCLEAR WASTE FUND
USG ADVOCACY CAN HELP U.S. VENDORS CAPTURE GROWING GLOBAL MARKET FOR NEW NUCLEAR ENERGY SYSTEMS

ESTIMATED $1.3-1.9T OPPORTUNITY FOR U.S. VENDORS THRU 2050

CIVIL NUCLEAR EXPORTS CREATE A CENTURY-LONG RELATIONSHIP

**Licensing & Construction**
- Cooperation on:
  - Reactor system procurement
  - Operator training
  - Regulatory capacity
  - Construction quality & safety
  - Environmental protection

**Operations**
- Cooperation on:
  - Physical security
  - Cyber security
  - Nuclear material protection & accountability
  - Nuclear nonproliferation
  - Supply of fuel & services
  - Research & development
  - Workforce development
  - Nuclear materials transportation
  - Operational safety & performance
  - Safety regulation

**Decommissioning**
- Cooperation on:
  - Decommissioning services
  - Decontamination technologies
  - Nuclear waste management
  - Environmental protection

5-10 YEARS 60-80+ YEARS 5-10 YEARS
RUSSIA AND CHINA ARE SEEKING TO DOMINATE THE CIVIL NUCLEAR EXPORT MARKET

BOTH RUSSIA AND CHINA HAVE NUCLEAR ENERGY AGREEMENTS WITH MUCH OF AFRICA, ASIA AND SOUTH AMERICA
A USG STRATEGY TO COMPETE AND WIN IN THE CIVIL NUCLEAR MARKETPLACE

• Ensure high-level coordination across USG and re-establish a senior nuclear energy policy position in the EOP
• Elevate nuclear engagement and advocacy in bilateral dialogues and through intergovernmental agreements
• Continue to employ ExIm Bank, USDFC and USTDA and enhance their competitiveness
• Ensure that nuclear energy is included in international and multinational standards for clean energy development and financing
• Continue to improve the speed and predictability of DOE’s export control licensing process

ACCORDING TO U.S. DOC, EVERY $1B IN CIVIL NUCLEAR EXPORTS CREATES 5,000 TO 10,000 U.S. JOBS
## NUCLEAR GENERATION CREATES LONG-TERM, WELL-PAYING JOBS

### Overall Industry Crosscut Wages, 2019

<table>
<thead>
<tr>
<th>Industry Crosscut</th>
<th>Median Hourly Wage</th>
<th>Premium or Discount Compared to National Median</th>
<th>Total Employment, 2019</th>
<th>Percent of Total Energy Employment, 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>$39.19</td>
<td>104.8%</td>
<td>70,323</td>
<td>0.8%</td>
</tr>
<tr>
<td>Electric Power Transmission &amp; Distribution</td>
<td>$31.80</td>
<td>66.1%</td>
<td>830,291</td>
<td>9.9%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$30.33</td>
<td>58.5%</td>
<td>636,043</td>
<td>7.6%</td>
</tr>
<tr>
<td>Coal</td>
<td>$28.69</td>
<td>49.9%</td>
<td>185,689</td>
<td>2.2%</td>
</tr>
<tr>
<td>Hydropower</td>
<td>$26.97</td>
<td>40.9%</td>
<td>67,772</td>
<td>0.8%</td>
</tr>
<tr>
<td>Oil</td>
<td>$26.59</td>
<td>38.9%</td>
<td>839,831</td>
<td>10.0%</td>
</tr>
<tr>
<td>Wind</td>
<td>$25.95</td>
<td>35.6%</td>
<td>114,774</td>
<td>1.4%</td>
</tr>
<tr>
<td>Solar</td>
<td>$24.48</td>
<td>27.9%</td>
<td>345,393</td>
<td>4.1%</td>
</tr>
<tr>
<td>Energy Efficiency Storage (excl. fossil fuels)</td>
<td>$24.44</td>
<td>27.7%</td>
<td>2,378,893</td>
<td>28.4%</td>
</tr>
<tr>
<td>National Median Wage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$19.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: [https://www.usenergyjobs.org/wages](https://www.usenergyjobs.org/wages)
Life cycle emissions from electricity generation, gCO₂/KWh

- Coal: 820 gCO₂/KWh
- Gas: 490 gCO₂/KWh
- Biomass: 230 gCO₂/KWh
- Large-scale solar: 48 gCO₂/KWh
- Domestic solar PV: 41 gCO₂/KWh
- Hydro: 24 gCO₂/KWh
- Off-shore wind: 12 gCO₂/KWh
- Nuclear: 12 gCO₂/KWh
- On-shore wind: 11 gCO₂/KWh
Raw Material Inputs per TWh

Source: How to Avoid a Climate Disaster, Bill Gates, 2021
Advanced Nuclear Deployment Plans

Projects in planning or under consideration in U.S. and Canada; >30 globally

KEY
- State policies to support advanced nuclear in place
- State policies to support advanced nuclear under consideration
- Planned project
- Under construction
<table>
<thead>
<tr>
<th>Number</th>
<th>Customer/Developer</th>
<th>Location</th>
<th>Design/Type</th>
<th>Size</th>
<th>Online</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grand County Public Utility District/Energy Northwest</td>
<td>Richland, Wash.</td>
<td>X-energy Xe-100 (HTG SMR)</td>
<td>four 80-MW units</td>
<td>Online 2027</td>
</tr>
<tr>
<td>2</td>
<td>UAMPS, Idaho Falls (INL)</td>
<td>(INL)</td>
<td>NuScale VOYGR (PWR SMR)</td>
<td>six 77-MW units</td>
<td>Online 2029</td>
</tr>
<tr>
<td>3</td>
<td>Oklo, Idaho Falls (INL)</td>
<td>(INL)</td>
<td>Oklo Aurora (metal-cooled microreactor)</td>
<td>1.5 MW</td>
<td>Online 2025</td>
</tr>
<tr>
<td>4</td>
<td>Sponsor TBD, Idaho Falls (INL)</td>
<td>(INL)</td>
<td>Radiant Industries Kaleidos (helium/air-cooled microreactor)</td>
<td>1.2 MW</td>
<td>Online 2026</td>
</tr>
<tr>
<td>5</td>
<td>Department of Defense, Idaho Falls (INL)</td>
<td>(INL)</td>
<td>X-energy Xe-mobile (HTGR microreactor)</td>
<td>1.5 MW</td>
<td>Online 2025</td>
</tr>
<tr>
<td>6</td>
<td>Rocky Mountain Power, Kemmerer, Wyo.</td>
<td>TerraPower-GEH Natrium (liquid sodium fast reactor; SMR)</td>
<td>345-500 MW</td>
<td>Online 2028</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SaskPower, Saskatchewan, Canada</td>
<td>developer TBD</td>
<td>four 300-MW units</td>
<td>Online 2032-2042</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sponsor TBD, Western Canada</td>
<td>Westinghouse eVinci (metal-cooled microreactor)</td>
<td>5 MW</td>
<td>Online 2027</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>University of Illinois, Urbana-Champaign, IL</td>
<td>Ultra Safe Nuclear MMR (HTGR microreactor; test and research)</td>
<td>5 MW</td>
<td>Online 2027</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Tennessee Valley Authority, Clinch River, Tenn.</td>
<td>BWR X-300 (BWR SMR)</td>
<td>300-MW</td>
<td>Online 2032</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>TVA/Kairos, Oak Ridge, Tenn.</td>
<td>Kairos Power FHR (salt-cooled, HT SMR)</td>
<td>35 MW</td>
<td>Online 2026</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Southern Company, Waynesboro, Ga.</td>
<td>Westinghouse AP1000 [Vogtle 3/4] (PWR)</td>
<td>two 1,117-MW units</td>
<td>Online 2022-2023</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bruce Power</td>
<td>Westinghouse eVinci (metal-cooled microreactor)</td>
<td>5 MW</td>
<td>Online 2027</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Ontario Power Generation/Global First</td>
<td>Chalk River Laboratory, Ontario, Canada</td>
<td>Ultra Safe Nuclear MMR (HTGR microreactor demonstration)</td>
<td>5 MW</td>
<td>Online 2025</td>
</tr>
<tr>
<td>15</td>
<td>Ontario Power Generation</td>
<td>Darlington</td>
<td>BWR X-300 (BWR SMR)</td>
<td>300 MW</td>
<td>Online 2028</td>
</tr>
<tr>
<td>16</td>
<td>Sponsor TBD</td>
<td>Oyster Creek, New Jersey</td>
<td>Holtec SMR-160 (PWR SMR)</td>
<td>160 MW</td>
<td>Online 2030</td>
</tr>
<tr>
<td>17</td>
<td>New Brunswick Power, New Brunswick, Canada</td>
<td>ARC Clean Energy ARC-100 (sodium-cooled fast SMR)</td>
<td>100 MW</td>
<td>Online 2030</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>New Brunswick Power, New Brunswick, Canada</td>
<td>Moltex Energy Stable Salt Reactor (SSR) (molten salt SMR)</td>
<td>300 MW</td>
<td>Online 2032</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Eielson Air Force Base, Fairbanks, Alaska</td>
<td>X-energy Xe-mobile (HTGR microreactor)</td>
<td>1-10 MW</td>
<td>Online 2025</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Copper Valley Electric Association, Glennallen, Alaska</td>
<td>Ultra Safe Nuclear MMR (HTGR microreactor)</td>
<td>10 MW</td>
<td>Online TBD</td>
<td></td>
</tr>
</tbody>
</table>