General Atomics Electromagnetic Systems

General Atomics Fast Modular Reactor for Distributed Carbon-Free Energy Generation

November 7, 2022

Presented At: **COLORADO RURAL ELECTRIC ASSOCIATION ENERGY INNOVATIONS SUMMIT**
Small Modular Reactors: An Update

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Strategic Development
Nuclear Technologies and Materials
GA-EMS

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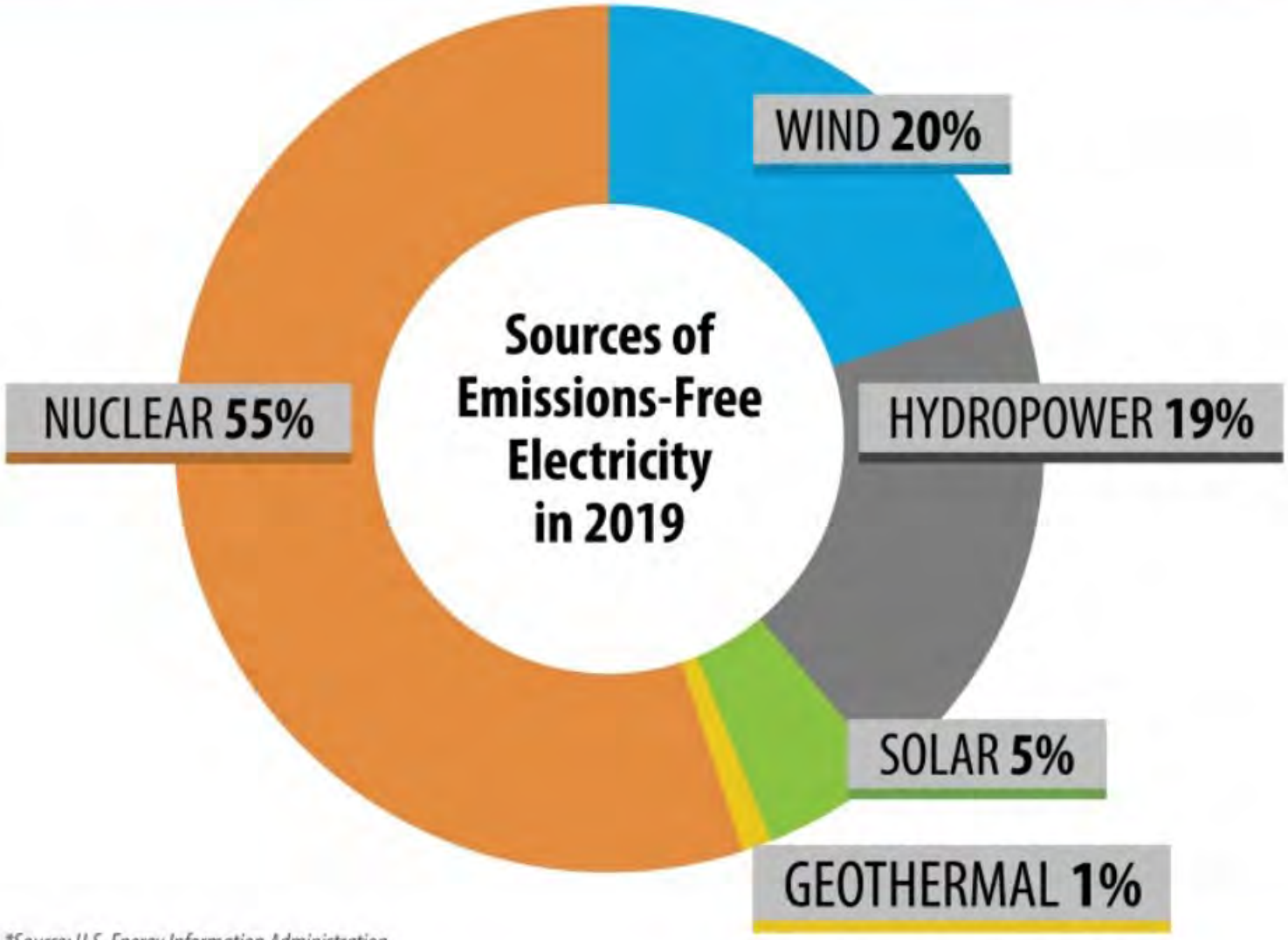
U.S. Emissions-Free Electricity Generation Share by Source - 2019



*Source: U.S. Energy Information Administration

Fast Facts on NUCLEAR ENERGY

Nuclear fuel is **extremely energy dense.**

1 uranium pellet
(~1 inch tall)

17,000 cubic ft
of natural gas

120 gallons
of oil

1 ton
of coal

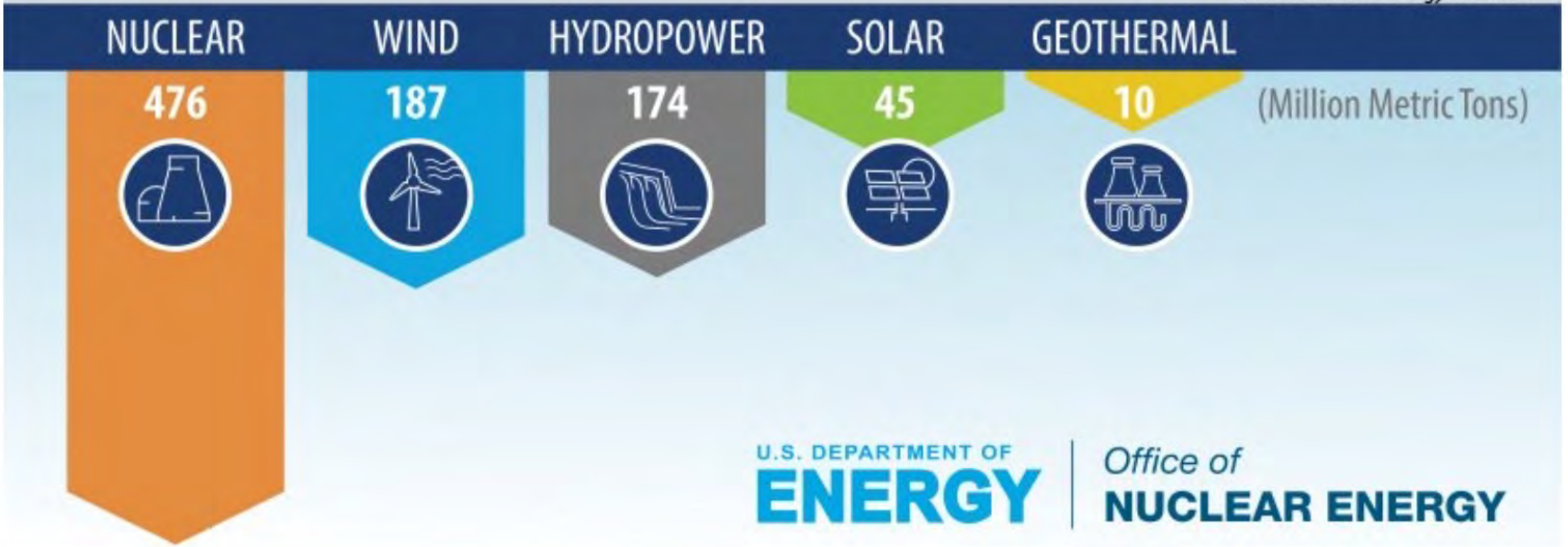
U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

LEARN MORE energy.gov/ne

Data source: U.S. Energy Information Administration

CO_2 Emissions Avoided by U.S. Power Industry

*Source: Nuclear Energy Institute



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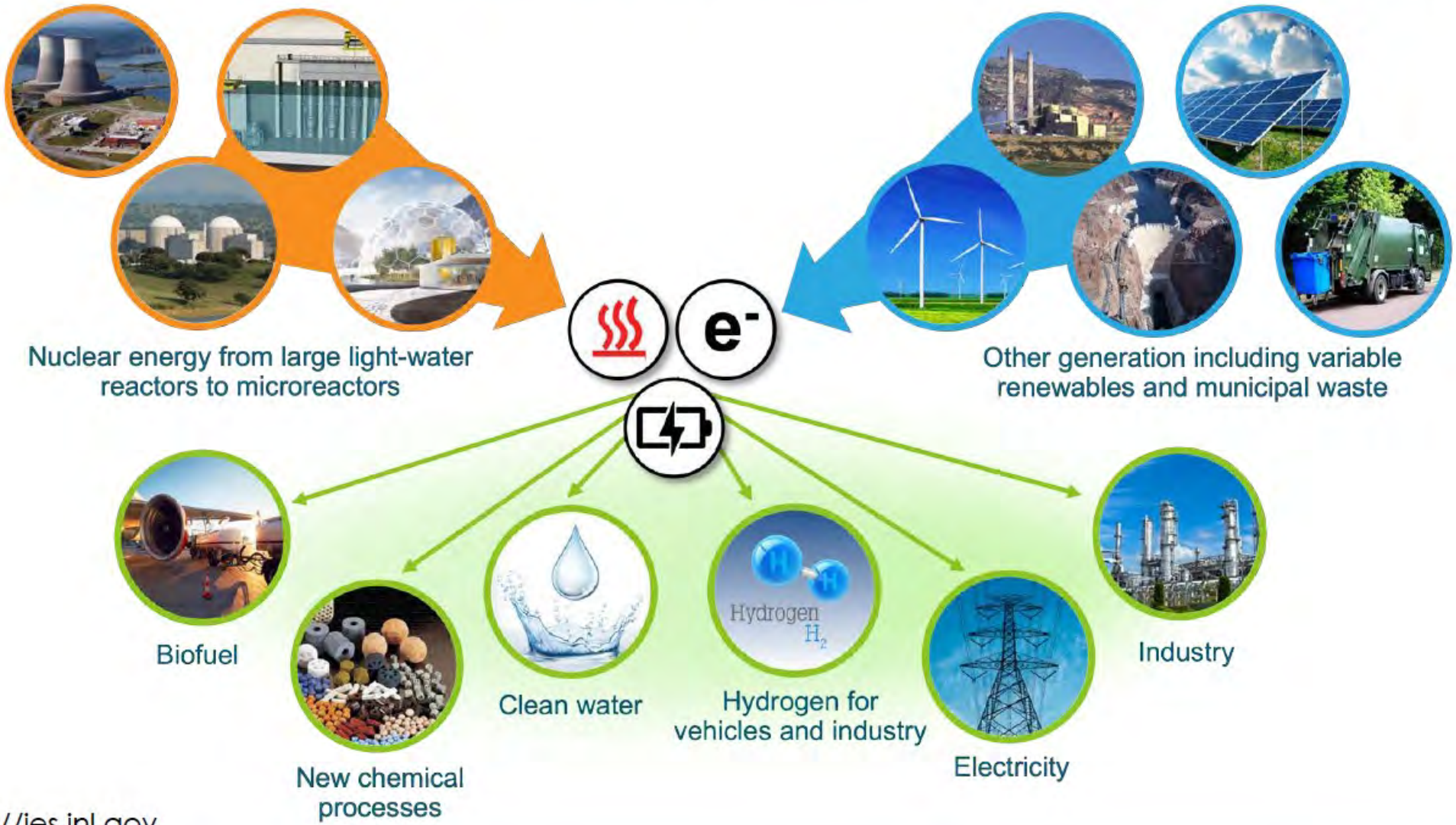
The Multi-Application Future Integrated Grid
Nuclear energy within a mix of carbon-free generating options



Source: https://ies.inl.gov

Replacing Coal-Fired Plants: A Huge Opportunity for Advanced Nuclear

- ~ 80% of retired and operating coal power plant sites could be replaced by advanced nuclear reactors
- For the recently retired plant sites, this represents a capacity potential of 64.8 GWe to be backfit at 125 sites
- For the operating plant sites, this represents a capacity potential of 198.5 GWe to be backfit at 190 sites

Source for above values: https://fuelcycleoptions.inl.gov/SiteAssets/SitePages/Home/C2N2022Report.pdf

General Atomics Government Business Segments

GA-EMS was Spun Out of GA's Fusion Division in Mid-1980's

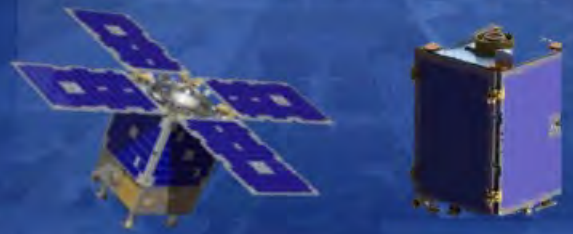
ASI

Leading designer and manufacturer of proven, reliable Remotely Piloted Aircraft (RPA) systems, radars, and electro-optic and related mission systems, including the Predator® RPA series and the Lynx® Multi-mode Radar

EMS

Develops technologies for the DoD, DOE, Agencies, IC, and commercial customers

GA-EMS is a world leader in the application of electromagnetic power and energy technologies, pulse power, nuclear fission, adaptive optics, lasers , sensors, undersea systems, missile systems, projectiles, and space systems



ENERGY

Develops sustainable and alternative energy solutions and materials

Operates the DIII-D National Fusion Facility

GA-EMS Has Products in 68 Countries and Offices on 5 Continents

. . . and Now Facilities in Eggersriet, Switzerland!

GA-EMS provides services to customers worldwide

Afghanistan, Albania, Argentina, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Cyprus, Czech Republic, Denmark, Egypt, France, Germany, Greece, Hong Kong, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Lebanon, Macau, Malaysia, Mexico, Morocco, Myanmar, Netherlands, New Zealand, Norway, Oman, Pakistan, Peru, Philippines, Poland, Portugal, Puerto Rico, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, Ukraine, United Arab Emirates, United Kingdom, Uruguay, USA, Uzbekistan, Venezuela, Viet Nam, Yemen

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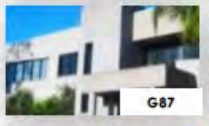
GA-EMS Locations

2,300+ Employees at locations with over 1.8 million ft^2 for engineering, quality assurance, research and development, manufacturing, testing, and support



San Diego, CA


Boulder, CO


Longmont, CO



Centennial, CO

Tupelo, Iuka & Oxford, MS

Boston, MA


Lakewood, NJ


Lakehurst, NJ


Washington, DC

Pax River, MD


Fredericksburg, VA


Newport News, VA


Allen, TX


Albuquerque, NM




Huntsville, AL

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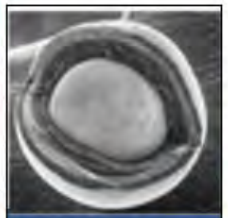
GA-EMS Nuclear Technologies and Materials (NTM)

General Atomics Delivered 66 TRIGA Reactors: the World's Safest Reactors

Peach Bottom 1966



TRISO Fuel

Research - Isotope Production

TRIGA Reactors, Controls and Fuels

TRIGA® Mark I
1958 at GA

Kiwi 1962

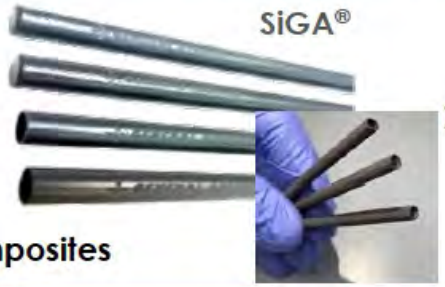
Modular Gas-cooled
Fast Reactors

UO_2, UC, UN
Microspheres

High Temperature Reactors and Specialized Fuels

Ceramic Matrix Composites

SiGA®



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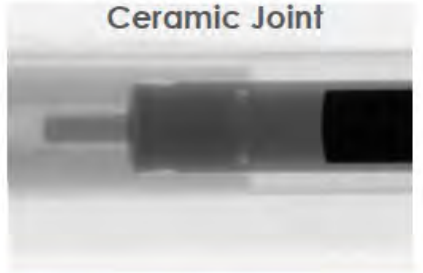

Engineered Materials

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General Atomics 50 MWe Fast Modular Reactor: Designed for Market Needs

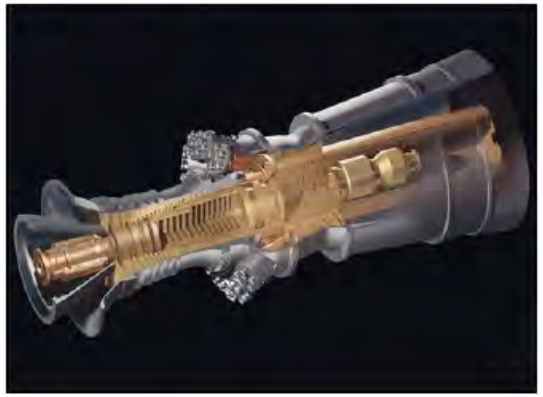
The community-friendly, safe, and distributed resource for the 2035 US Market

General Atomics
Game-Changing Assured Program Success
"Innovation made real"

Natural Gas Plants Benefit from Continuous Innovation; Nuclear Can, Too!

The first gas turbine, GE, 3.5-MW, Belle Isle Station owned by Oklahoma Gas & Electric,1949

Nearly 70 years of continuous innovation

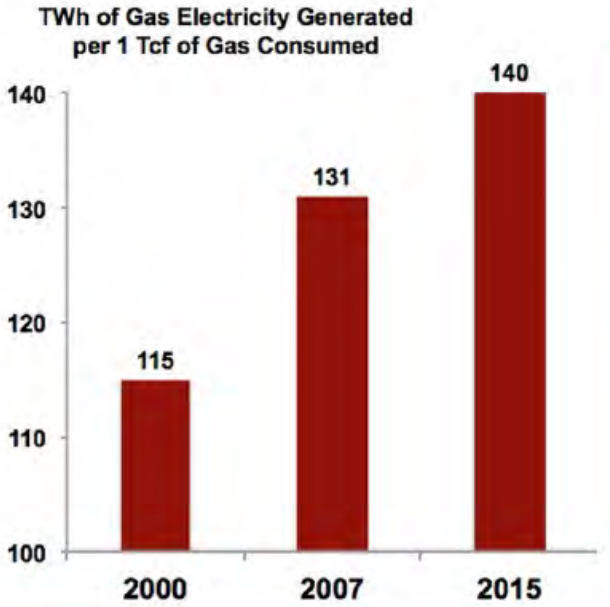


Present day gas turbine in CC with >62% thermal efficiency

In spite of decreasing NG prices, innovation to increase thermal efficiencies has only accelerated.

Two of the key enablers:

- Advanced, high-T materials
- Advanced manufacturing



Today, the U.S. gas power plant fleet generates 140 Terawatt Hours of electricity for every 1 Trillion Cubic Feet of gas consumed in the sector.

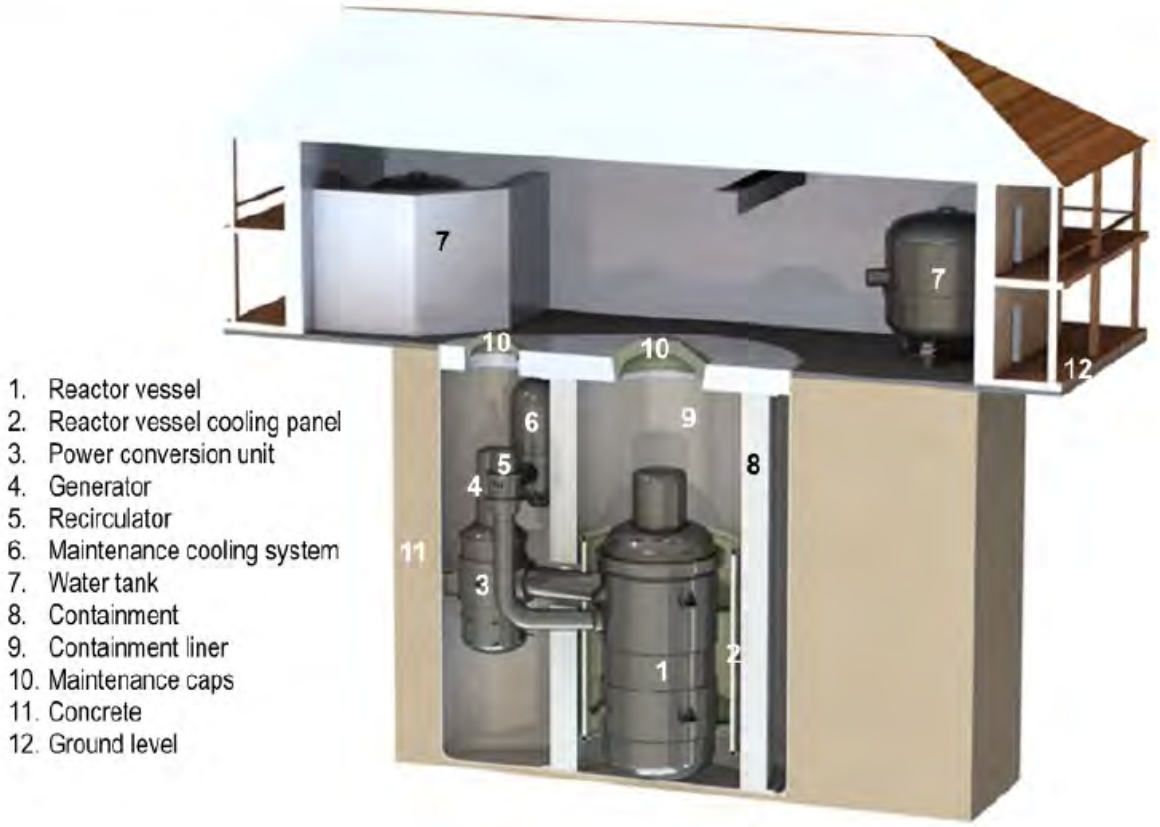
This is a gas power efficiency improvement of 22% since 2000.

Fast Modular Reactor (FMR) Concept

Reactor Type

- ***Gas-cooled Fast Reactor (GFR)***
- ***High-Temperature Reactor (HTR)***
- ***Small Modular Reactor (SMR)***

Thermal power	100 MW
Electric output	44 MW
Coolant	Helium
Fuel cycle	~15 years
System pressure	7 MPa
System temperature	509 - 800 °C



Design Features - Multi-barrier, Defense-in-Depth (DiD), Passive safety and Seismic design

The FMR Has Numerous Advantages That Make It a Clean, Community-Friendly Energy Source

- **Fast Neutron Reactor**
  - **The fast neutron spectrum allows for ~15 years of operation without refueling**
  - Significant **reduction in high-level waste** generation when compared to LWRs
  - The fast neutron spectrum transmutes long-lived actinides into short-lived fission products and **allows the use of multiple fuel types**

- **Fast Response to Grid Operators**
  - Direct helium Brayton cycle enables a **20% per minute power ramping rate for load following**
  - **Highly automated** control system reduces the burden on the plant operator and allows for efficient grid operator dispatch
    - Reduced reliance on plant staff can also help under unexpected operational circumstances, such as those experienced with the COVID-19 pandemic

The FMR Has Numerous Advantages That Make It a Clean, Community-Friendly Energy Source

- **Fast Construction for Remote Communities and Industrial Plants**
  - **Target construction period of 24 months** by employing truck-transportable sized components, module factory fabrication and standardized plant layout. Small overall footprint and siting flexibility

- **Fast Licensing**
  - **Defense-in-depth (DiD) design:** low power density, low source term, passive safety and emplacement below ground are strong design features for utilities that facilitate public acceptance and licensing by the US Nuclear Regulatory Commission (NRC)
  - Demo unit licensed under 10 CFR 50, followed by commercial units licensed under 10 CFR Part 52 or the planned 10 CFR Part 53

Key Strategic Partnership And Alliances

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framatome

- Framatome, having built over 90 nuclear power plants in 11 countries, will bring the depth of experience and reliability for successful deployment of the FMR.
- GA-EMS and Framatome blend together years of experience and capabilities to come up with a design that hits the mark on future market needs.
- Support from utilities

Two major nuclear companies committed to the success of the FMR

ARC-20 Project Outcome

The **conceptual design of the FMR** including the experimental and numerical verifications will lead to:

- ***Cost estimation*** of the FMR based on the conceptual design results and guidelines of advanced reactor construction.
- Submittal of the ***pre-application licensing plan*** to the NRC for review and feedback.

Acknowledgments

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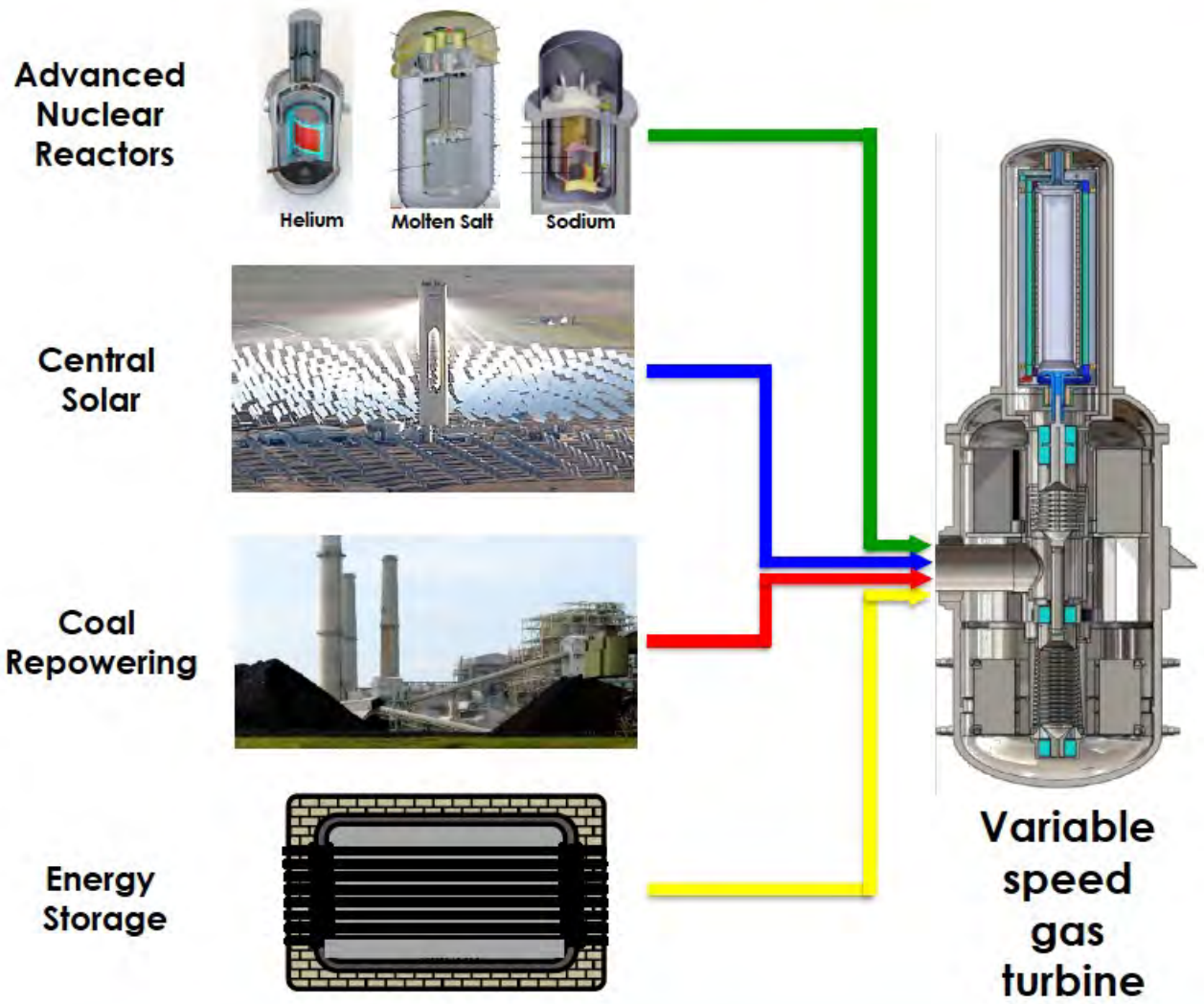
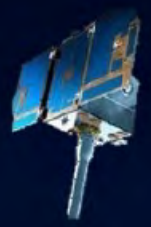
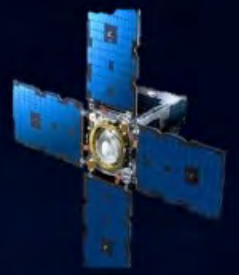
Innovative Power Conversion: Utilizing High-Temperature Heat Not Only from Nuclear Reactors



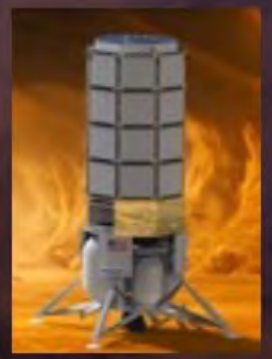





General Atomics is committed to deliver safe, robust, and scalable nuclear technologies on surface, on orbit and on time

Game-Changing Assured Program Success

Innovation Made Real



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