GEN4 ENERGY

NEW LEADERSHIP, NEW DIRECTION

SMR Technology Selection for Remote Sites

33rd Annual CNS Conference

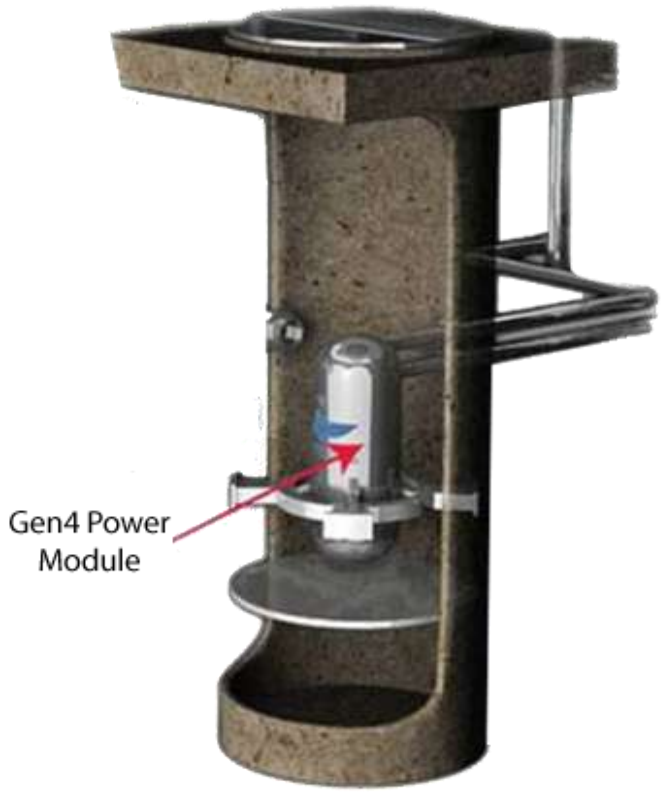
12 June 2012

David Carlson, Gen4 COO

Gen4 Reactor Technology

GEN4 ENERGY

- Transportable
- No Refueling, 10 year life
- Improved Safety
- High power density, 25 MWe
- Sealed Underground module
- Proven Technology



Unique advantages over all current operating reactors

Worldwide Electricity Generation

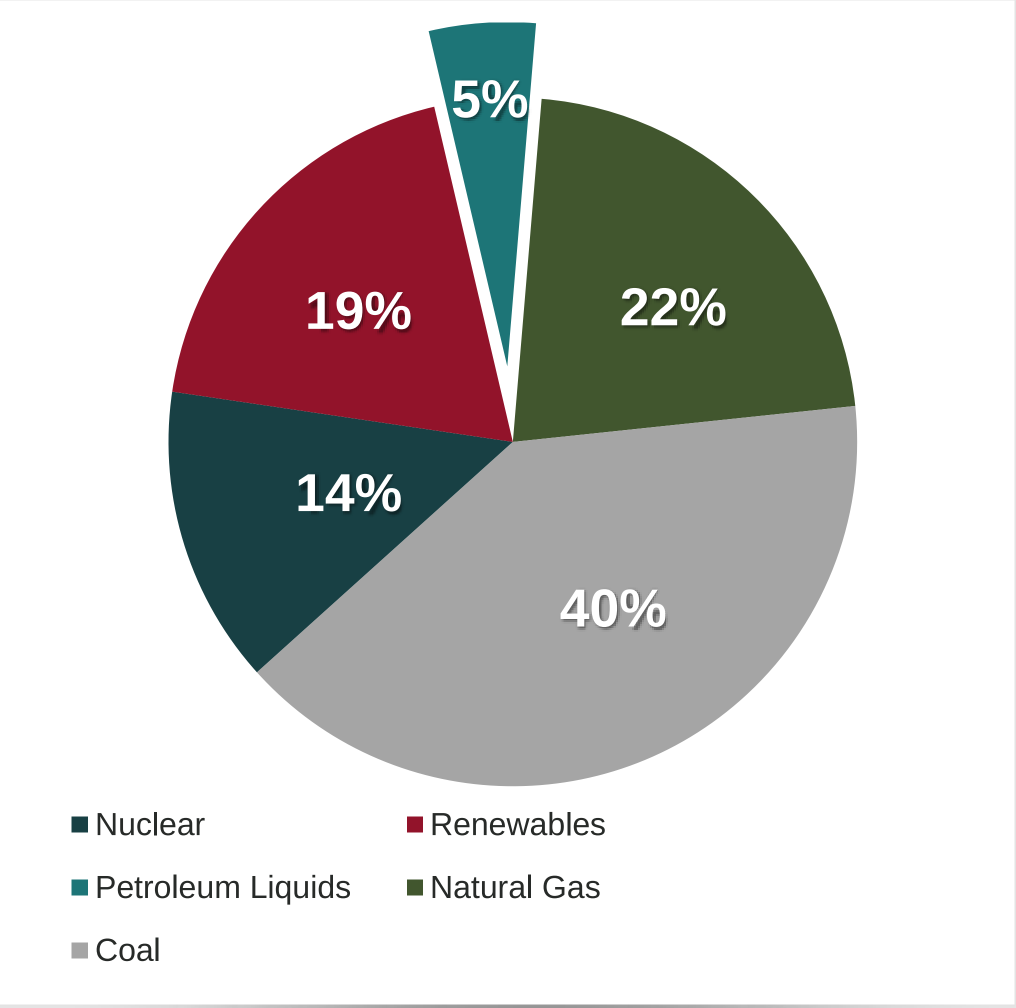
Petroleum Liquids

- 5% of worldwide electrical generation is from diesel and other fuel oils
- 381 gigawatts of installed diesel/fuel oil generation capacity
- Approximately 1 trillion kilowatt-hours of annual generation **(est. $300B annual sales)**

(Source: EIA: IEO2011)

Small Nuclear can replace large diesel generation

- Appropriate capacity (25MWe)
- Small footprint



Addressable Market is replacement of expensive Diesel Generation

Target Markets

Remote and Island Communities

- 170 island communities in the world over 100,000 in population
- Many remote communities in the Arctic, India, Malaysia, the Middle East, etc.
- Drivers: Cost, Access, and Reliability

Mining and Oil & Gas Production

- Many remote sites, highly energy intensive
- Drivers: Cost, Supply chain disruptions

Government Facilities

- Over 100 Govt. facilities where a 25MWe unit would be appropriate
- Drivers: Security, GHG Reduction

Cost Comparison with Diesel Generation

Gen4 Nuclear

15¢ /kw-hr

Diesel

30¢ /kw-hr

(or more)

Diavik Diamond Mine – NWT

Electrical generation capacity

34 Mwe - 11 diesel generators

Fuel Storage

110 million litres (3,500 tankers)

Ice Roads Melting?

May 29, 2011

Global warming jeopardizing ice highways, study says

Globe and Mail

Canada will lose winter-road access to nearly 400,000 square kilometres of land by mid-century, UCLA researchers predict

Gen4 Technology Selection

GEN4 ENERGY

Design optimization for remote sites

- Locations where robust utilities (electrical grids and gas pipelines) are unavailable
- Replacement of diesel power generation

The design requirements that drove Gen4 technology selection are:

- **Transportable Size** - Compact core (less than ~1.6 m in dia.)
- **No On-Site Refueling** - Long-lived core (~10 years) w/o refueling
- **Simplicity and Safety** – Next generation design
- **High Power / Size** ~70 MWt and ~25 MWe
- **Thermal Efficiency** - Outlet temperature of ~500 C
- **Sealed nuclear module - P**roliferation resistance

These attributes led the Gen4 concept to be defined by the following :

- **Fast Spectrum**
- **Lead-Bismuth Eutectic** (LBE) coolant
- **Uranium Nitride** (UN) fuel

Why Fast Spectrum?

Core Life – Long core life without refueling

- The absorption cross section of fission products and their impact on reactivity is small.
- There is little transmutation that could reduce reactivity, the loss of reactivity during burnup is almost entirely attributable to ^{235}U fission

Simplicity - Simpler than a moderated core with respect to:

- nuclear data uncertainties,
- dynamic performance,
- localized/heterogeneous effects,
- system modeling and predictability,
- changes in system characteristics with lifetime

Neutronics

- Temperature feedback is mostly caused by expansion, which provides small, simple, negative reactivity feedback, allowing a simple, robust control system.
- Small reactivity feedback means a small temperature defect (the difference in reactivity between startup and operating temperatures), which simplifies reactor startup/shutdown and requires less excess reactivity
- A fast spectrum system generally has a larger delayed neutron fraction because more fissions occur in U-238 (a first-order safety significant parameter).

Why LBE Coolant?

No chemical reaction with water/air

- No chance of plant fires caused by coolant leaks, important for a transportable system
- Leaking coolant would freeze solid

High boiling temperature of 1700ºC

- Boiling during an accident is practically eliminated

Melts at 125ºC

- Lower melting point than lead
- Virtually no expansion of LBE on melting

Good natural circulation potential

Excellent neutronic properties

- Excellent neutron reflector
- Low absorption and good neutron economy

Consistent/strong negative void coefficient

LBE is a clear choice for transportable low power (<100 MWt) reactors

Why UN Fuel?

GEN4 ENERGY

Uranium Nitride (UN) is a ceramic fuel like Uranium Oxide (UO_2)

- Similar melting temperature (2888 vs. 2749C)

Superior properties of UN compared to UO_2 include:

- Ten times higher thermal conductivity (26 vs. 2 W/m-K), means that UN fuel centerline temp can be 1000^{o}C lower than UO_2, higher margin to fuel damage
- Higher uranium density (13.52 vs. 10.5 g/cc), allows a smaller reactor size
- Low fission gas release and low fuel swelling
- Greater resistance to irradiation damage over extended periods of time (10 years)

Uranium Nitride (UN) Fuel has superior properties compared to UO_2

Safety

GEN4 ENERGY

Nuclear Reactor Accidents

Fukushima – Zircaloy and steam interaction led to hydrogen explosions – NOT POSSIBLE

Chernobyl – Uncontrolled reactivity insertion, high pressure failure, fuel fires – NOT POSSIBLE

Major Differences

- No spent fuel pool
- No zircaloy to cause hydrogen production
- Reactor pressure is near atmospheric
- Coolant is not high pressure water (which can flash to steam)
- LBE coolant cannot reach its vaporization temperature of 1700ºC

Operating Experience

‘Alfa’ Class Submarines

- 7 submarines in the class, with 155 MW(th) LBE cooled reactors
- Operated from 1972
- “The fastest class of military submarines ever built”
- LBE reactor technology was operationally employed in an extremely demanding application beginning nearly 40 years ago

Proven Technology – over 80 reactor-years of operation

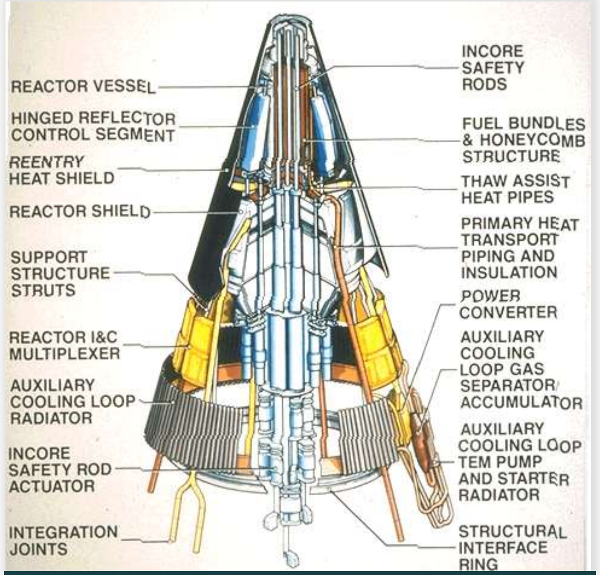
Los Alamos National Laboratory

Cooperative Research and Development Agreement (CRADA) with LANL

- Joint ownership of HPG technology

LANL is uniquely qualified

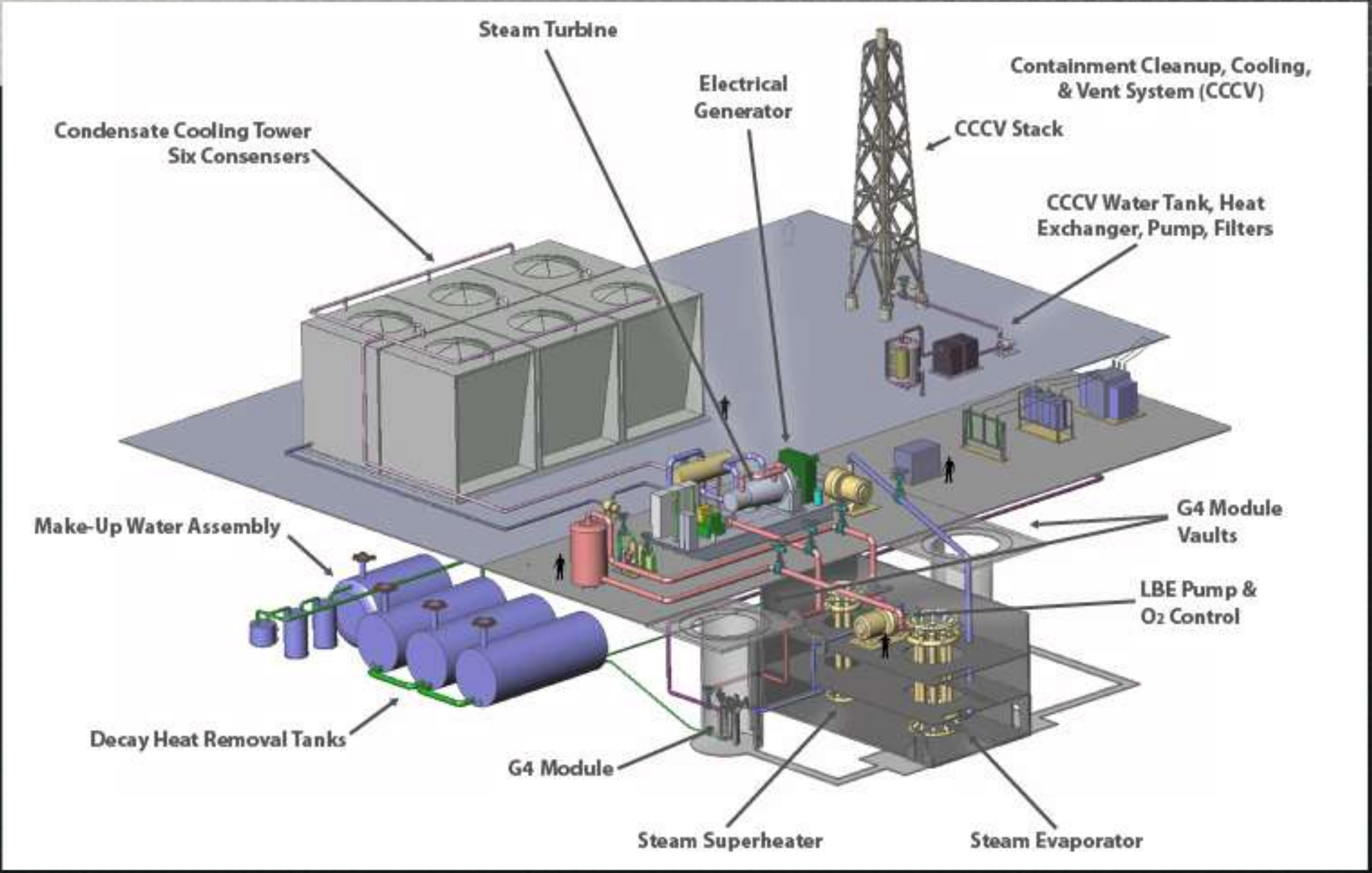
- 60+ years reactor design experience
- Developed reactor design codes used worldwide
- Experts in design, safety, and licensing



Space Reactor

LANL – world-class experts in advanced reactor design

System Layout



System Layout

GEN4 ENERGY

NEW LEADERSHIP, NEW DIRECTION

Thank You!