TERRESTRIAL ENERGY USA

Commercial Deployment of TEUSA's Innovative Gen IV Integral Molten Salt Reactor

"Restoring America's Nuclear Competitive Edge with the Cost Competitive and Highly Reliable IMSR® 400"

November 2017

INTEGRAL MOLTEN SALT REACTOR – IMSR®

An Advanced Reactor

- Liquid-fueled reactor system - fundamentally different
  - "Walk-away" safe
- Dispatchable electric power and high grade industrial heat

Proven and demonstrated technology

- Ran successfully for over 4 years at Oak Ridge National Laboratory

Government support

- First and only Advanced Reactor to reach the second stage of 'invitation only' US Department of Energy loan guarantee program ($1 Bn)
- US government "Gateway for Accelerated Innovation in Nuclear" (GAIN) voucher award ($200k) - US Department of Energy

Integral Molten Salt Reactor

Our key commercial claim – IMSR® power plants are a better way to generate heat than fossil fuel combustion and they can be deployed starting in the 2020s

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IMSR® – A PROVEN AND DEMONSTRATED ADVANCED REACTOR

Our Advanced Reactor is called the Integral Molten Salt Reactor – IMSR® -- 190MWe

- Proven and demonstrated technology – ran successfully for 4 years at Oak Ridge National Lab
- Substantial government support
  - First Advanced Reactor project to reach the second stage of 'invitation only' US DOE loan guarantee program ($1 Bn)
  - US government GAIN grant award ($200k) - US DOE (Sept 2016); work at ANL

IMSR® is a better way to generate power and heat for today's market

We can bring the IMSR® to market in the 2020s

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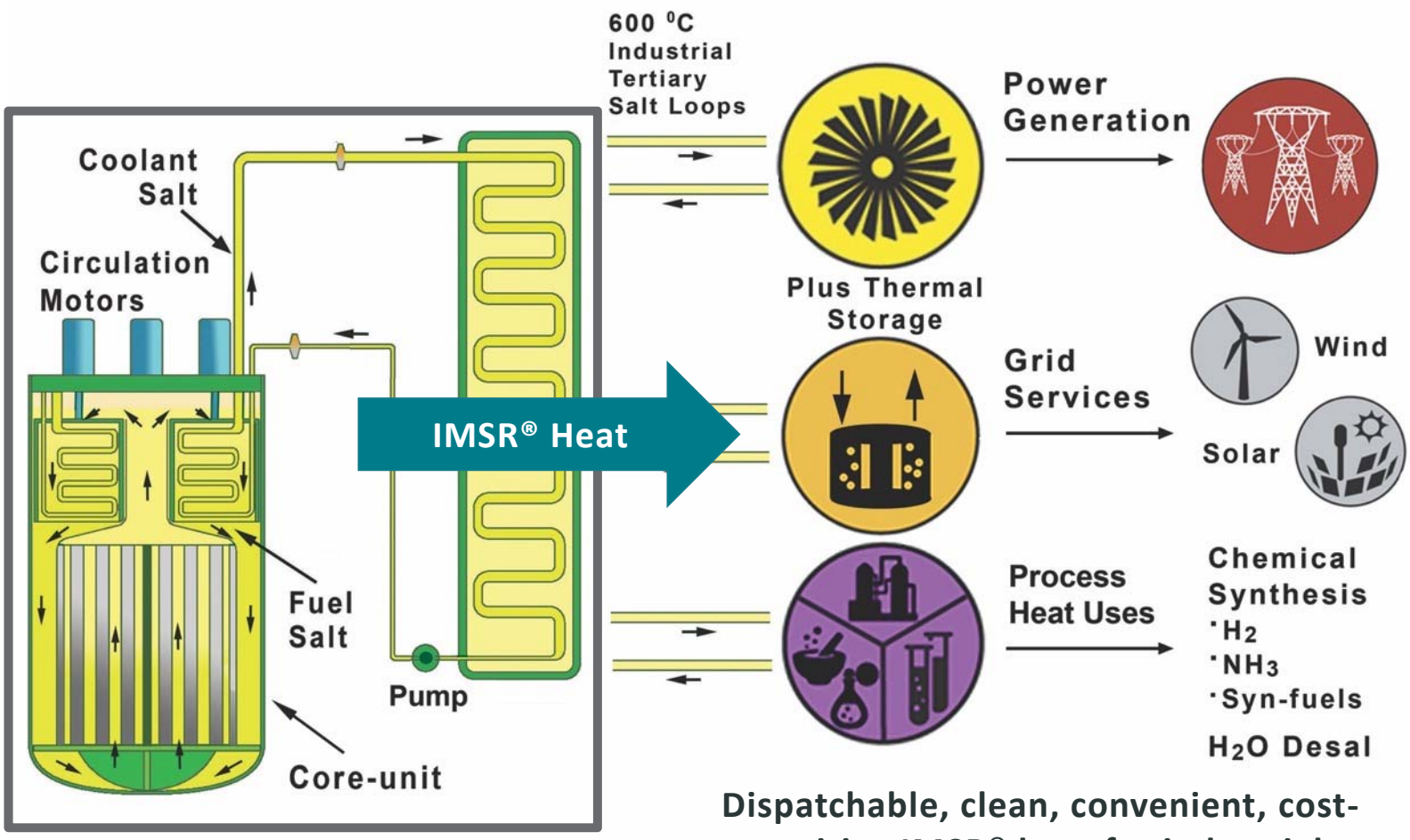
IMSR® IS FOR INDUSTRIAL ELECTRIC POWER AND HEAT USE



Dispatchable, clean, convenient, cost-competitive IMSR® heat for industrial use

IMSR® heat can couple conveniently with industrial users

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IMSR® IS DEPLOYABLE IN MANY INDUSTRIES

Global energy supply

- $5 Tn of $72 Tn Gross World Product
- 85% of this supply is from fossil fuel combustion

IMSR® provides dispatchable heat and is strategic to many industries

- Electric power generation
  - Baseload
  - Variable Renewable Energy back-up and grid-balancing
- Industrial heat
  - Chemical industry
    - Ammonia, desalination, hydrogen
    - Synthetic transport fuel production
  - Petrochemical industry
    - Oil refining, gas-to-liquids, coal-to-liquids
- Desalination
  - Growing need for freshwater production to supply large cities in arid environments

IMSR® provides dispatchable on-demand heat and power

- IMSR® not constrained by grid, water or pipeline


Power


Petrochemicals


Chemicals


Freshwater

IMSR® has the potential to re-order a $5 Trillion per year global energy market

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COUPLING IMSR® TO INDUSTRIAL PROCESSES

Idaho National Laboratory

Economic and National Security Imperative

- Global civil nuclear energy market over next 2 decades: $2.6 T
- US market position continues to shrink
- What is the market for advanced technologies? Where is the US niche?
- Nuclear hybrids will be a competitive differentiator for US industrial leadership
- The National Security Imperative:
  - Economic competitiveness
  - Geopolitical influence
  - Technology influence (including safety and nonproliferation interests)
  - Industrial and intellectual leadership

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COUPLING IMSR® TO INDUSTRIAL PROCESSES

NE and NG
… the opportunity for higher market value

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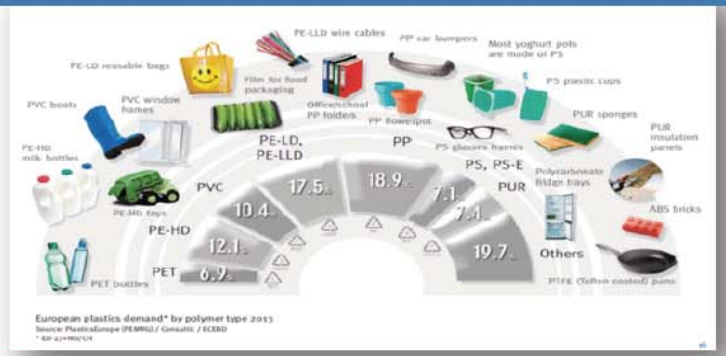
Commodities produced with NG

- Synthetic Fuels & Lubes
- Primary Chemicals
- Plastics & Resins
- Fertilizers
- Primary Metals

Plastics Market: 50% growth projected by 2040



Acetic Acid	Acetone	Acrylonitrile
Ammonia	Base oils-lubes	Butadiene
Ethyl Alcohol	Ethylene	Ethylene Glycol
Formic Acid	Hydrogen	Isocynates
Melamine	Methanol	Oxo-Alcohols
Polyethylene	Polypropylene	Polyvinyl Chloride

Chemical commodities produced from NG

- H_2 for FCV, fertilizers, and oil refining
- Heat & electricity for alkane activation and dehydrogenation for plastics and resins
- Syngas for methanol and direct reduced iron

Opportunity for 1,000 400 MWt reactors

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COUPLING IMSR® TO INDUSTRIAL PROCESSES

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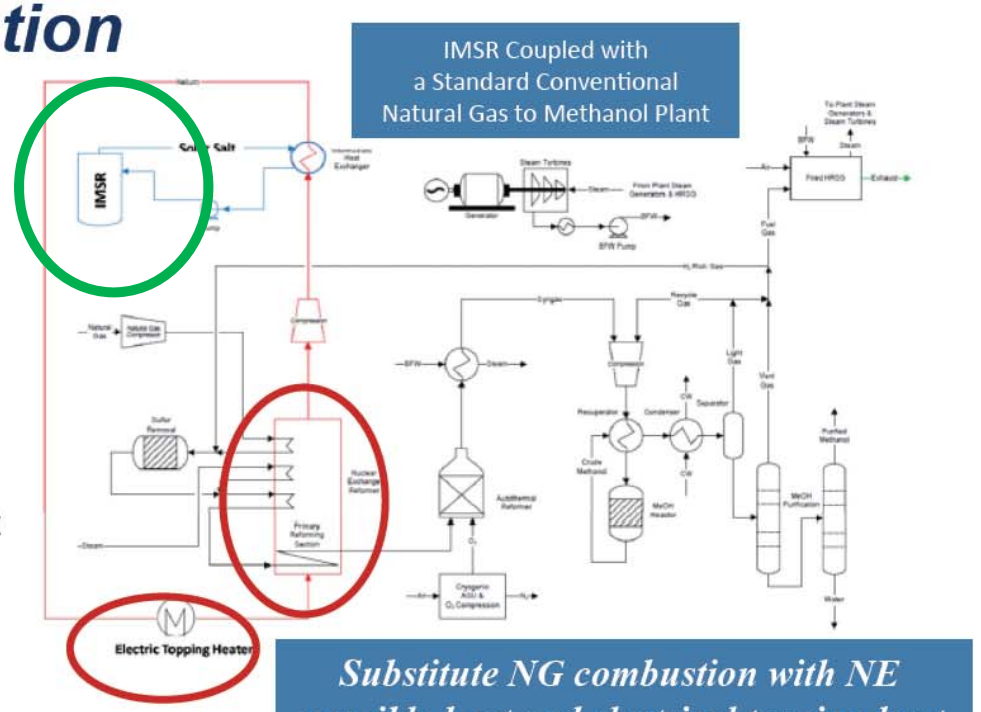
Changing Conventional Natural Gas Reforming and Hydrogen Production

- Steam Methane Reforming coupled to Small Modular Reactors (SMR^2)
  - ✓ A new opportunity for hydrogen and syngas generation used in chemical feedstock and commodities production
- Thermal/Electrical coupling changes…
  - ✓ Reduce natural gas combustion for heat
  - ✓ Reduces pollutant emissions 90%
  - ✓ High temperature reactors require less electrical heating



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COUPLING IMSR® TO INDUSTRIAL PROCESSES

Hybrid NE Systems

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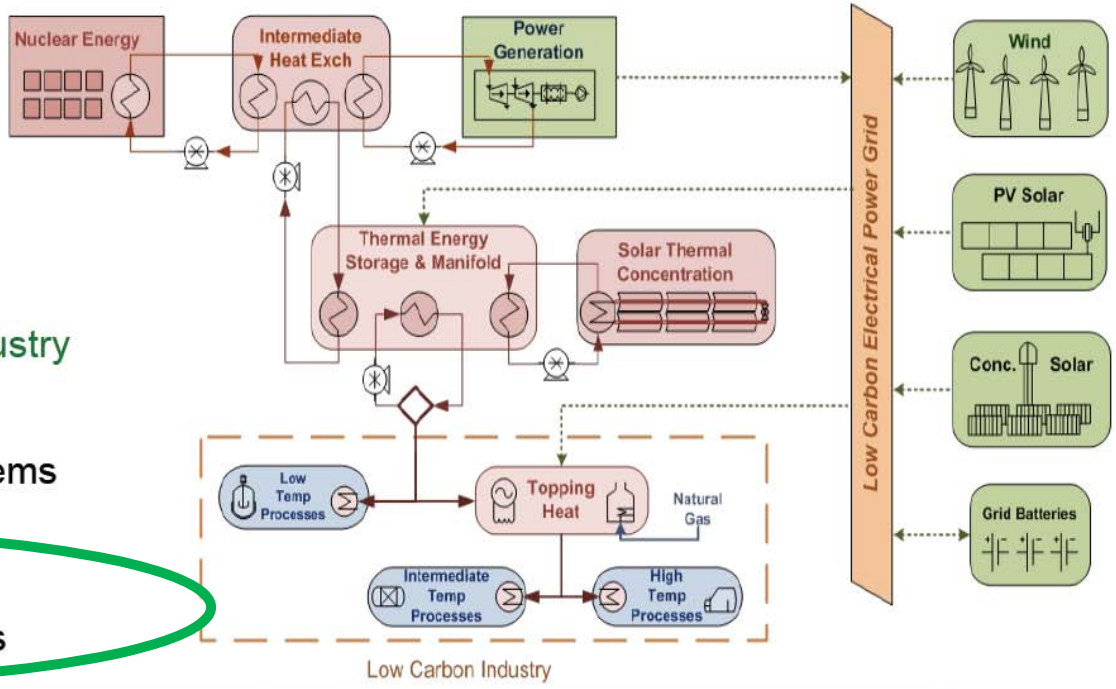
- Hybrid energy systems…
  - ✓ Optimize capital efficiency
  - ✓ Maximize revenue
  - ✓ Provide grid services
  - ✓ Support a "low carbon" industry
- Small Modular Reactors…
  - ✓ Are scalable to power systems
  - ✓ Provide higher quality heat
  - ✓ Molten salt can effectively transfer heat long distances



Achieving the full value of NE requires coupling of the grid and industrial manufacturing via heat and electricity

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IMSR® COUPLED TO HYDROGEN PRODUCTION VIA HTSE

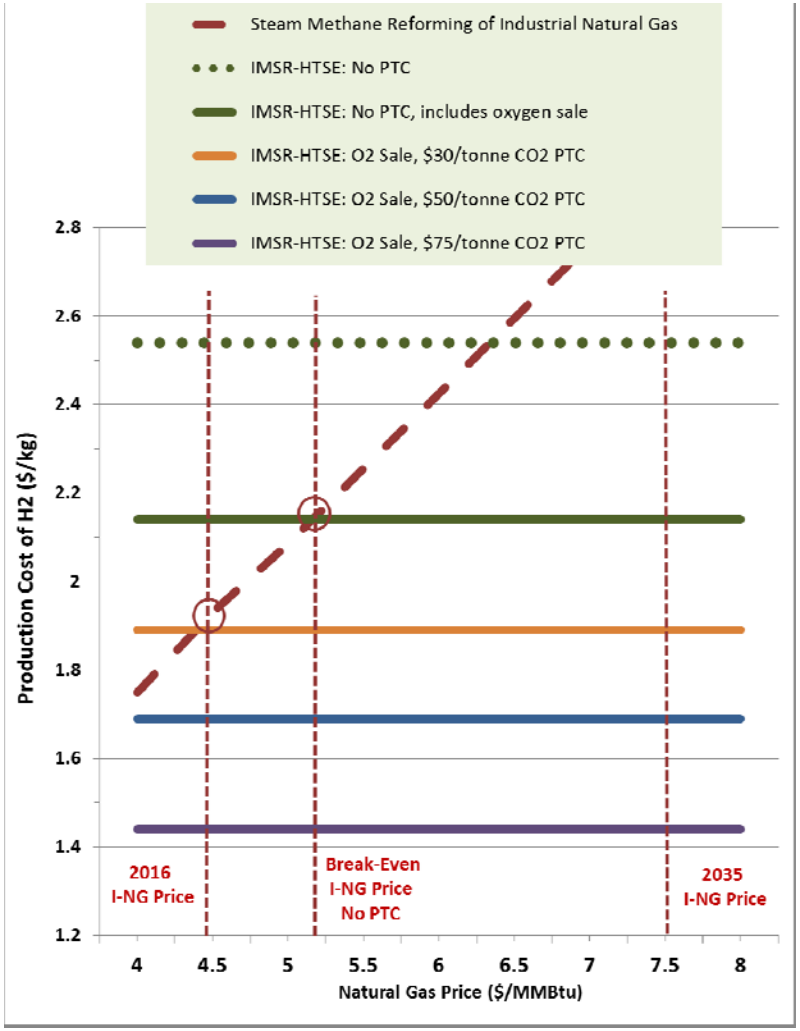
- **Cost of Industrial Natural Gas (I-NG)**
  - Cost of I-NG at factory gate, after tolling
  - Today I-NG costs ~$4.40 per MMBtu
    - I-NG at ~$1 basis to Henry Hub
  - In Asia, LNG basis at ~$4+ to Henry Hub
- **Project Cost of IMSR® – H_2**
  - $2.1 to $2.2 per kg
  - B/E I-NG Cost $5.20 per MMBtu
    - < $1 increase to Henry Hub prices
    - $2.80 discount to Asian I-NG prices
  - Over last 5 years

    Tokyo Natural Gas:

    $7.5 – 17.5 per MMBTU

    European Natural Gas price:

    $4 – 12 per MMBTU



Nuclear hydrogen is a transformative industrial commodity for Nuclear Energy

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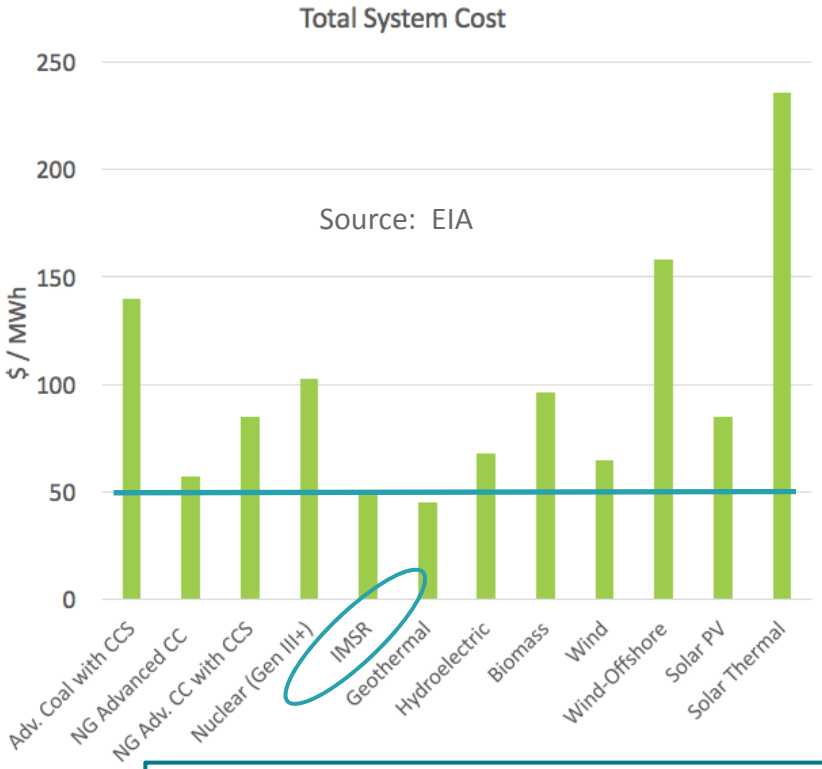
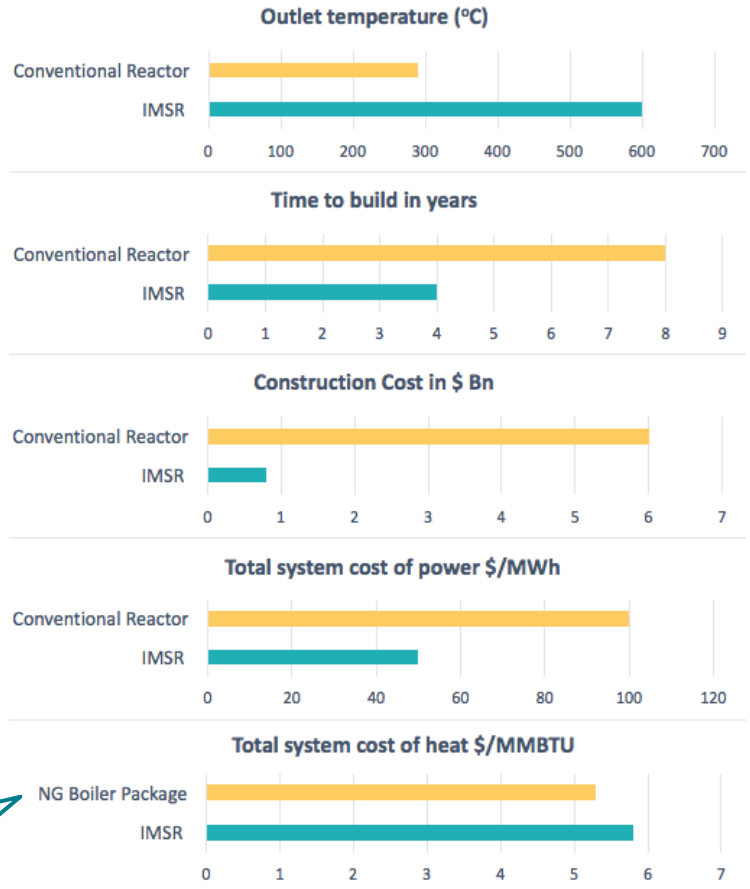
IMSR® IS THE LOW COST CLEAN ENERGY ALTERNATIVE





Break-even at ~$3.9 per MMBTU at Henry Hub
Over last 5 years: Singapore Natural Gas $2 – 7 per MMBTU;
European Natural Gas price $4 – 12 per MMBTU

Compared to Conventional Reactor power plants, IMSR® power plants take half the time to build, require <1/7th of the absolute CAPEX, provide electric power at half the cost, and provide heat that is cost competitive with a natural gas fueled boiler package

Very different nuclear technology choices give strong commercial advantages

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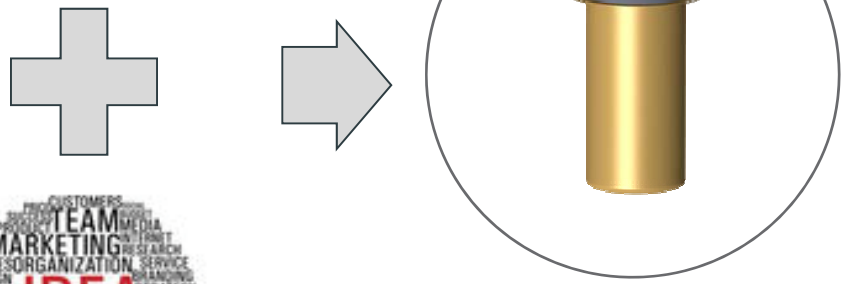
IMSR® IS THE SYNTHESIS OF A SOVEREIGN PROGRAM AND MARKET FOCUSED PRIVATE SECTOR INNOVATION

- United States sovereign effort from 1950s to 1980s at Oak Ridge National Laboratory, TN.
- Two MSRs were built. One was operated for ~18,000 hours and was an R&D success



- Private sector led innovation focused on practicable commercial solutions for timely product deployment in response to market needs

The result is the Integral Molten Salt Reactor, "IMSR®"

Deployment advantages

- ✓ "Walk-away" safe
- ✓ Clear regulatory pathway
- ✓ No fundamental technology barriers
- ✓ No material lifetime challenges

Commercial advantages

- ✓ Cost reduction
- ✓ Small reactor
- ✓ Simple modular design for factory based component production
- ✓ 600°C heat supply

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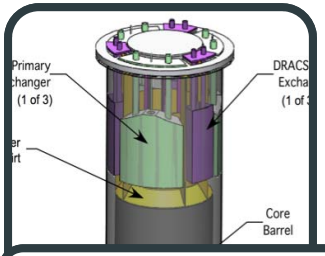
IMSR® – TECHNOLOGY READINESS

IMSR® builds on 50 years of ORNL reactor design work and relies on many demonstrated technologies.

IMSR® is a molten salt reactor system that uses:

- **Fluoride chemistry**
- **LEU once-through fuel cycle**
- **Thermal spectrum**
- **Graphite moderator**
- **Integral core architecture**

Conclusion: IMSR® has no remaining technology challenges

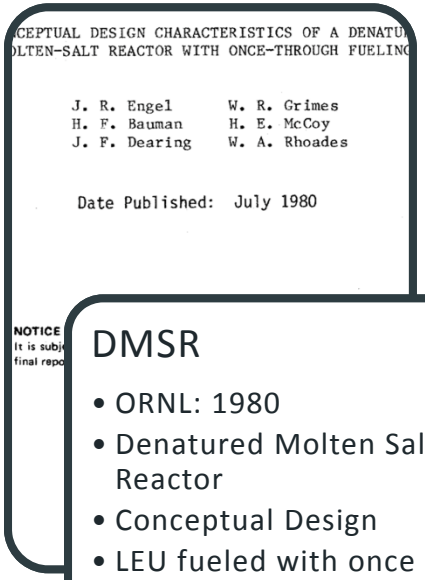


Sm-AHTR

- ORNL: 2010
- Pre-conceptual design
- Solid fueled - salt cooled
- Cartridge core design

MSRE

- ORNL: 1964-1969
- Molten Salt Reactor
- Built and operated for 18,000 hours


CEPTUAL DESIGN CHARACTERISTICS OF A DENATU
OLTEN-SALT REACTOR WITH ONCE-THROUGH FUELIN

J. R. Engel W. R. Grimes
H. F. Bauman H. E. McCoy
J. F. Dearing W. A. Rhoades

Date Published: July 1980

NOTICE
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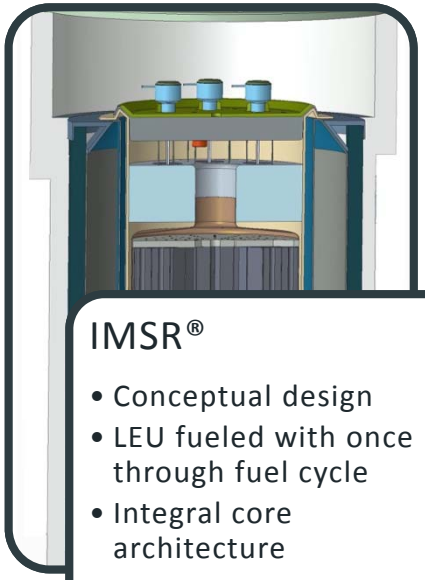
final repo

DMSR

- ORNL: 1980
- Denatured Molten Salt Reactor
- Conceptual Design
- LEU fueled with once through fuel cycle



IMSR®

- Conceptual design
- LEU fueled with once through fuel cycle
- Integral core architecture

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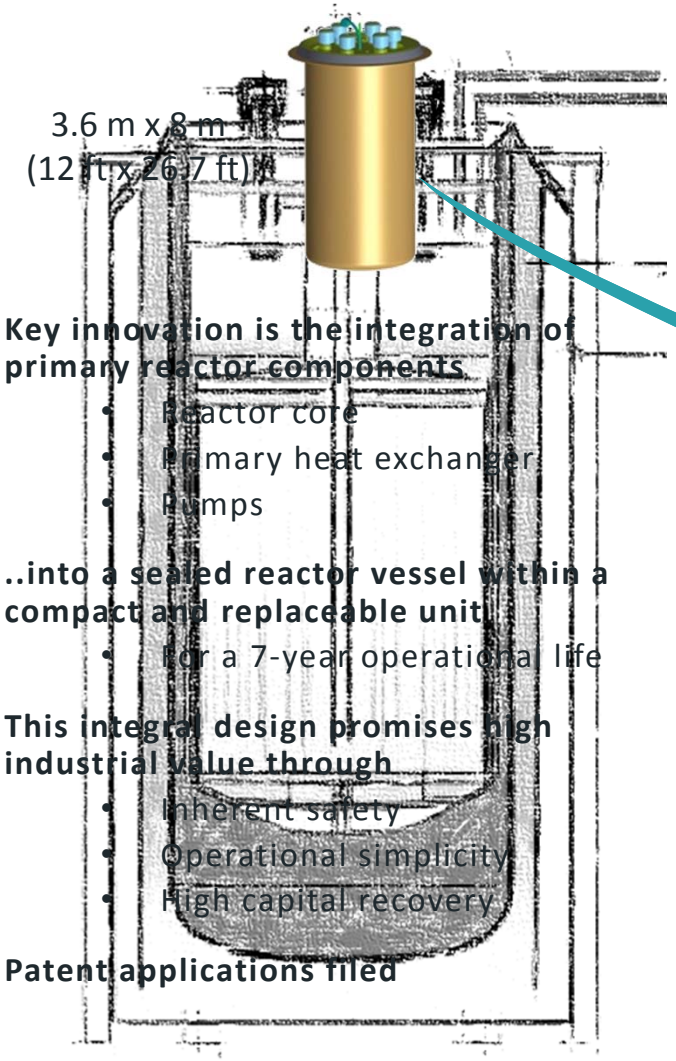
THE INTEGRAL MOLTEN SALT REACTOR (IMSR®)



Key innovation is the integration of primary reactor components

- Reactor core
- Primary heat exchanger
- Pumps

..into a sealed reactor vessel within a compact and replaceable unit

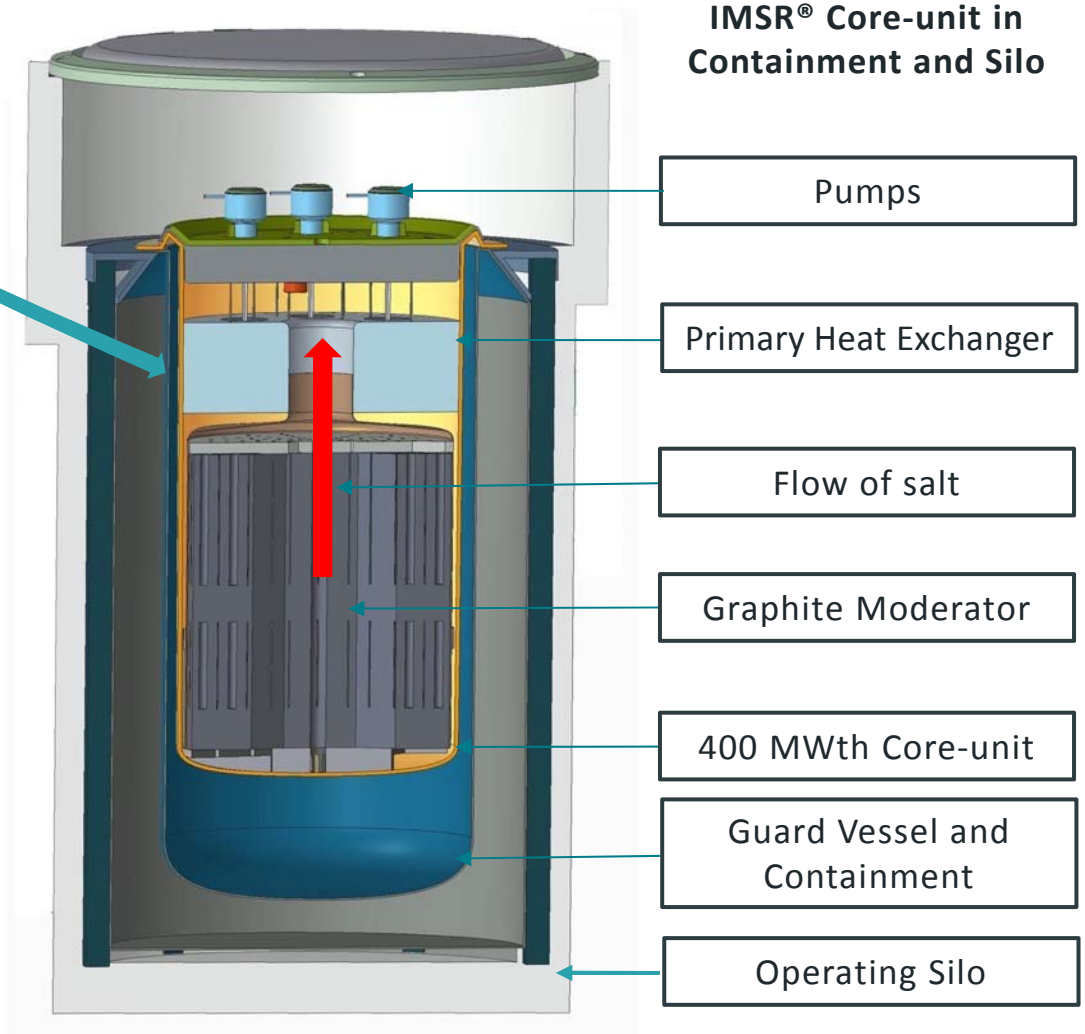
- for a 7-year operational life

This integral design promises high industrial value through

- Inherent safety
- Operational simplicity
- High capital recovery

Patent applications filed

IMSR® Core-unit in Containment and Silo



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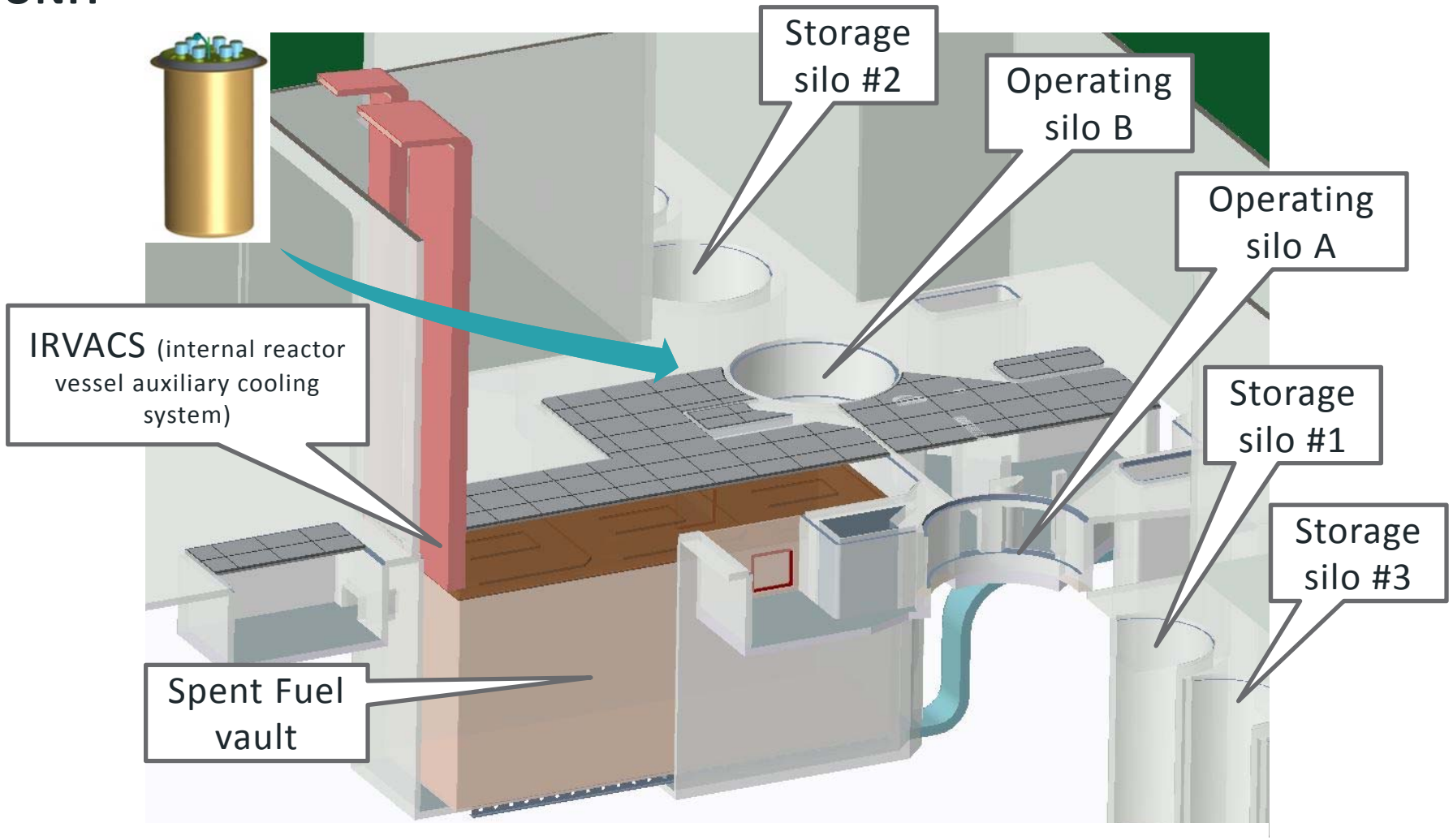
THE SEALED AND REPLACEABLE REACTOR CORE – THE IMSR® CORE-UNIT



For simple and safe industrial operation

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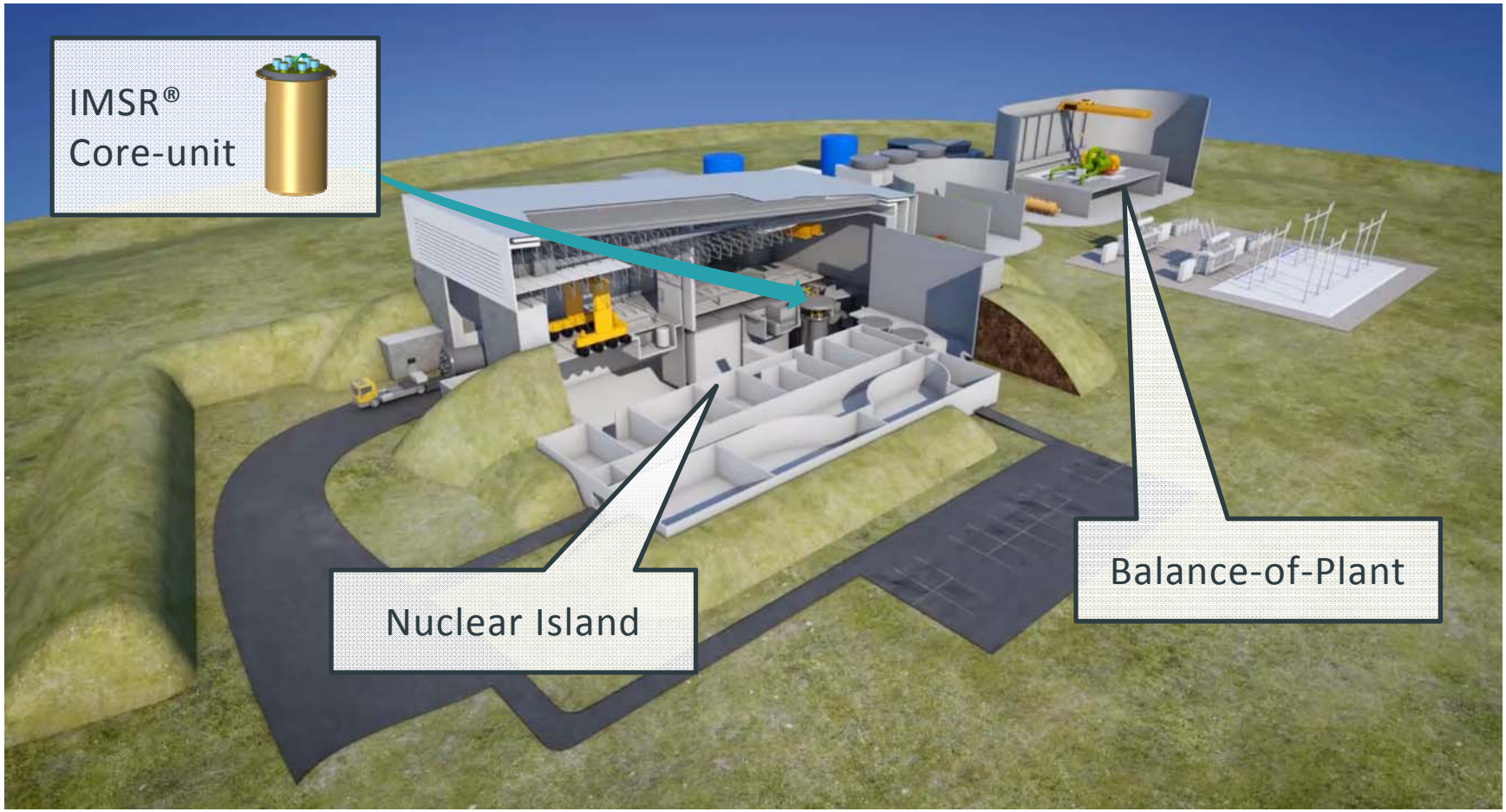
AN IMSR® PLANT CONSISTS OF NUCLEAR ISLAND & BALANCE-OF-PLANT



IMSR® Nuclear Island produces 600°C industrial heat. Balance-of-Plant can be a broad range of industrial applications – not just power provision

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IMSR® USED FUEL AND RADIOACTIVE WASTE – LESS AND OF HIGH COMMERCIAL VALUE

IMSR® operation generates 33% less waste within the fuel salt

- 33% less waste per kWh than LWRs
- Current generation of light-water reactors produce a substantial amount of plutonium
- IMSR® eliminates the isolation of plutonium as a pure material anywhere in reactor cycle

IMSR® operation provides significant overall waste stream advantages

- Increased proliferation resistance
- Provides for a very high level of resource utilization/fuel burnup

IMSR® spent fuel salt is a high commercial value waste stream

- Massive quantities of fission thermal energy remain
- Valuable material; not considered waste
- At decommissioning IMSR® spent fuel salts could be directly supplied as feedstock to a commercial recycling center

IMSR® generates less waste with increased proliferation resistance and a higher resource utilization capability than current light water reactors while retaining high commercial value at end of life

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IMSR® USED FUEL AND RADIOACTIVE WASTE – MORE EASILY MANAGED

Simplified Used Fuel Management

- At end of Core-unit life (7 years), IMSR® spent fuel salts are remotely transferred to a secure in-situ, non-accessible storage vault within the reactor containment
- Once transferred, spent fuel movement is not required for the remainder of plant life
- Current industry used fuel transfer operations are eliminated
- Spent fuel pool storage is eliminated, dry-cask storage and handling campaigns are eliminated
- Independent Spent Fuel Storage Installation (ISFSI) is eliminated
- Transferred from the storage vault to a long-term repository during decommissioning
- If directly supplied as feedstock to a commercial recycling center; all costly complex head-end steps are eliminated (disassembly, chopping, shearing, de-cladding, etc.)

Elimination of High Level Wastes for Decommissioning

- Spent IMSR® Core-units are flushed of fuel salts and high level radioactive constituents following shutdown
- Traditional high level waste reactor core internals are non-existent
  - IMSR® Core-units are managed, handled and treated as low-level waste
- By design, stored onsite for the entire plant life in secure individual storage silos within the Nuclear Island. Any proliferation risk is minimized.
- Balance of Nuclear Island components, vessels and secondary salt-circuit are lightweight, small, and easily disposed
  - Managed as low level waste during plant decommissioning

IMSR® generates less waste that is easily managed, and is expected to have substantially lower overall management and decommissioning costs

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CONTACT DETAILS

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Back-up Slides

Before Presenting: Delete any slides that remain after finalizing the presentation content!

TEI AND TEUSA RECENT DEVELOPMENTS

December	2015	✓ Closed C$10mn Series I Preferred Investment Round
1Q	2016	✓ Commenced regulatory engagement - signed CNSC Service Agreement for IMSR® Vendor Design Review ✓ Awarded C$5.7 Mn Cleantech grant by SDTC Canadian Federal Government
April	2016	✓ Formed Corporate Industrial Advisory Board with senior executives from ENW, OPG, PSEG, Southern Company
June	2016	✓ Terrestrial Energy USA Ltd (TEUSA) awarded first grant from United States Department of Energy (USDOE), a small but significant award from DOE GAIN program
August	2016	✓ C$22.5 Mn funding milestone reached on completion of C$5.3 Mn Series 2 Preferred Investment Round ✓ Duke Energy joins Corporate Industrial Advisory Board
September	2016	✓ TEUSA receives invitation to submit Part II application for USDOE $1 Bn loan guarantee to support engineering, licensing and construction of first U.S. IMSR® power plant ✓ NB Power joins Corporate Industrial Advisory Board
November	2016	✓ TEUSA submits Part II loan guarantee application to USDOE ✓ Innovation Award by the Organization of Canadian Nuclear Industries (OCNI)
February	2017	✓ Regis Matzie, former CTO of Westinghouse, joins Advisory Board ✓ TEUSA moves into due diligence with the USDOE for $1 Bn loan guarantee
March	2017	✓ TVA joins Corporate Industrial Advisory Board

Recent developments demonstrate strong business momentum

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MARKET INTERACTIONS: TEI and TEUSA

Nuclear regulatory engagement

First advanced reactor vendor in regulatory progress

- US NRC
  - IMSR® licensing plans submitted
- Canadian CNSC
  - Commenced Vendor Design Review

University contracts

- University of Tennessee, Knoxville, USA
- University of Wisconsin, USA
- University of California Berkeley, USA
- University of Manchester, UK
- University of Waterloo, Canada
- University of New Brunswick, Canada
- McMaster University, Canada

Industrial Advisory Board

- Duke Energy
- Energy Northwest
- Ontario Power Generation
- PSEG Nuclear
- Southern Nuclear Operating Company
- Caterpillar
- NB Power
- TVA

Presentations and industry awards

Presentations

- Bloomberg Energy Finance, Fortune Brainstorm E, Platts
- Select Committee of Canadian Parliament
- IAEA, OECD-NEA, UNEP, ORNL
- WNA, NEI, NIC

Industry awards

- 2016 OCNI Innovation Award

National Laboratory contracts

- Argonne National Laboratory
- Oak Ridge National Laboratory
- Idaho National Laboratory
- Dalton Institute, UK
- Canadian Nuclear Laboratories

IMSR® Government funding

US Department of Energy

- GAIN program grant
- Seeking $1 Bn from DOE Loan Program Office (Part II submitted)

Canadian government

- 5.7 Mn CAD SDTC grant
- IRAP grant

Press

Traditional media

- Daily Telegraph, Washington Post, Toronto Star, Sunday Times
- MIT Review, Forbes, Fortune
- World Nuclear News
- EEE Spectrum, ANS Nuclear News

Social Media

- Largest footprint of an Advanced Reactor vendor

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TEUSA CORE TEAM & STAFFING

NAME	TEUSA ROLE
Mr. Simon Irish	Director and Chief Executive Officer
Dr. David Hill	Director and Chief Technology Officer
Dr. Ray O. Johnson	Director
Mr. Robin Rickman	VP Business Development
Mr. John Kutsch	VP Business Development
Dr. David LeBlanc	Technical Consultant to TEUSA

Extensive breadth and depth in prior experience and capabilities with a variety of projects including new nuclear plants and nuclear facilities underpinned with a long history of:

- ***New product development***
- ***Systems engineering***
- ***Component design***
- ***Equipment manufacturing***
- ***Nuclear construction***
- ***Financial engineering***
- ***Project management***

IMSR®HAS MANY ADVANTAGES OVER THE CURRENT PRODUCT

ADVANTAGE	IMSR®	PWR
Smaller reactor	400 MWth	3,000 MWth
Lower total CAPEX	$700 Mn to $800 Mn	$8,000+ Mn
Lower pressure operation	1 Atm with many cost, engineering and safety benefits	172 Atms leading to increased complexity and economic penalty
Highly modular design	Standardization of components for factory production	Non standard and bespoke components
High temperature output	600 °C	290 °C
High thermal efficiency	48% thermal efficiency and 40%+ greater revenues for electric power provision	33% thermal efficiency resulting in low capital efficiency
Load following	Dynamic core and turbine for fast load response	Un-dynamic core and turbine limits use to grid baseload only
Inherent reactor control	Passive power management with many cost, engineering and safety benefits	Active engineered reactor control leading to increased complexity and economic penalty
Passive decay heat management	Passive decay heat management with many cost, engineering and safety benefits	Active decay heat management leading to increased complexity and economic penalty
Broader industrial utility	Heat for many industrial processes and for power generation	Grid baseload power generation only
Higher value product	High-grade heat delivered in the form of a common industrial salt circulating in a low pressure system	Low grade heat circulating in a high pressure system

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