



# International SMR Programs

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# International market views



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- I have recently worked with several countries considering their first nuclear power plant
  - Summary of views
  - Desalination

# Small and innovative reactors



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- A lot of interest without a lot of facts
- A set of beliefs (compared to large LWRs):
  - SMRs available today
  - SMRs have lower \$/kW capital cost
  - SMRs take less time to develop and build
  - SMRs will be easier to operate and maintain
- A view that SMRs can be used for non-power uses (e.g., desalination)

# Market is confused



- Unclear what the term SMR means
- Different SMR designs & business models lumped together
- SMR and Gen IV designs lumped together
- Unrealistic expectations
  - Current or near-term alternative to large LWR
  - Mature products available
  - Economics are known and favorable

# 3 International program views



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- “No FOAK”
- “Option for future”
- “Need nuclear power fast”

# "No FOAK"



- A lot of risk for any nuclear plant due to political / regulatory / public opinion / economic issues
- No desire for added technology / design risk
- Only consider proven designs, where construction and operation are complete for reference plant
  - Few large LWR options are suitable now
  - SMR options off the table in near term

# “Option for Future”



- Nuclear is option in about 2030
- Requires crystal ball gazing:
  - What are nuclear & non-nuclear options and costs?
  - Which large LWR options will survive?
  - Which SMR options will become commercial?
- LCOE analysis starting 20+ years in future (comparing nuclear and non-nuclear options)
  - Estimates of costs and features
  - Ranges to reflect uncertainty

# “Need nuclear power fast”



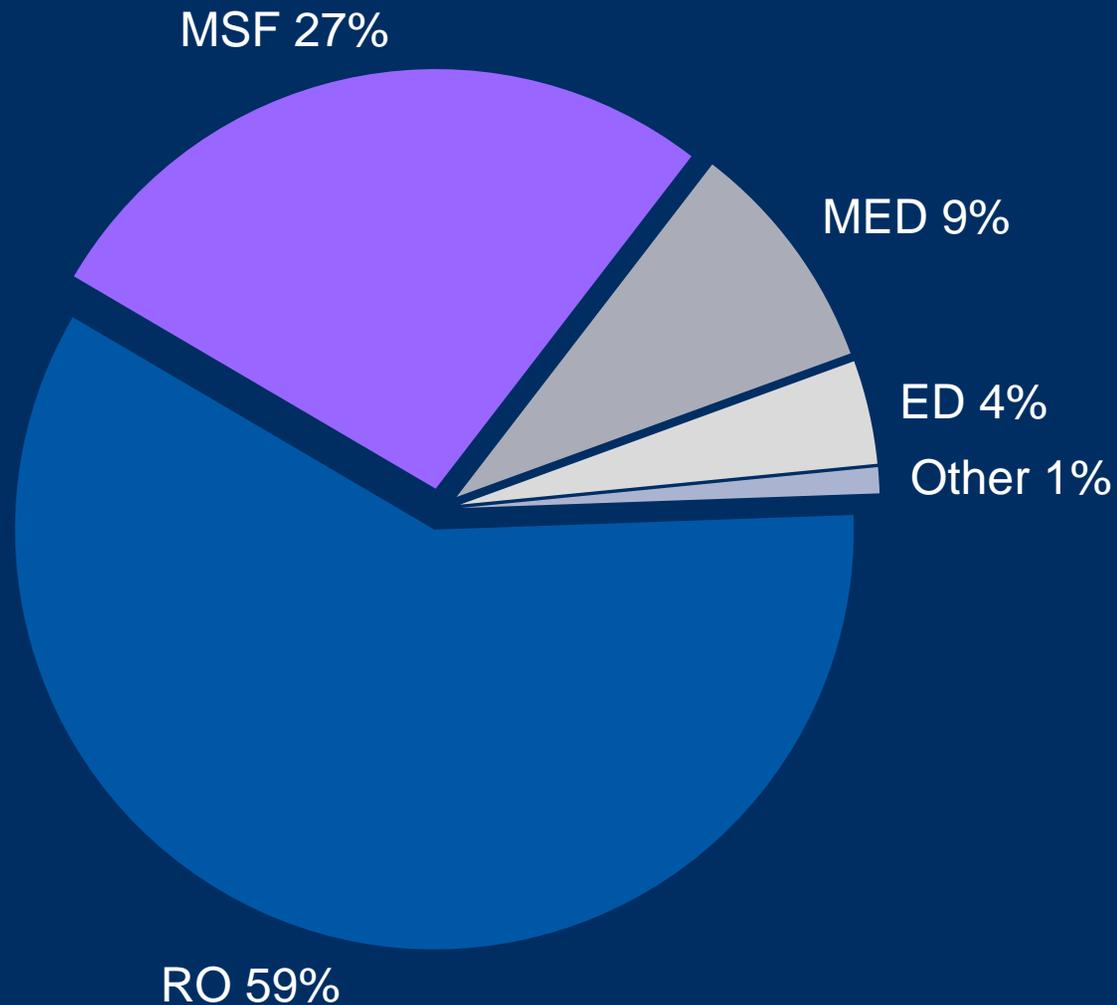
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- Large nuclear power build program with ambitious time frame
- What is best mix of large and small reactors?
- Large LWR = investment for power generation
- SMR = R&D / Technology Development
  - Long and uncertain path to power generation
  - More uncertainty may mean more opportunity
  - Small investment to control company (e.g., Fluor)

# World desalination technology



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Source: "The Economics of Desalination for Various Uses," Carlos Campos, CETagua Water Technology Center, September 2009; percentages are based on share of total world water production of about 65 million cubic meters per day; ultimate data source is GWI DesalData/IDA (2008).

# Main Desalination Technologies



- RO - membrane-based approach use energy input to produce a water pressure differential across the membrane to separate salt (and other impurities) from water; typically uses electrically-driven pumps to create pressure differential
- MSF - thermal evaporation process; saline solution heated to generate water vapor that is condensed to water with lower salt concentration. Large MSF facilities produce significant amounts of high-purity desalted water, but are very energy intensive
- Multi-effect Distillation (MED) - thin-film evaporation approach; vapor produced by one chamber (or “effect”) condenses in the next chamber (at a lower temperature and pressure) providing additional heat for vaporization. MED technology has reduced pumping requirements and lower energy use compared to MSF.

# Sea water desalination cost



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<b>\$/cubic meter</b>	<b>SW RO</b>	<b>SW MSF</b>	<b>SW MED</b>
<b>Annualized capital costs</b>	<b>0.15</b>	<b>0.29</b>	<b>0.22</b>
<b>Parts/maintenance</b>	<b>0.03</b>	<b>0.01</b>	<b>0.01</b>
<b>Chemicals</b>	<b>0.07</b>	<b>0.05</b>	<b>0.08</b>
<b>Labor</b>	<b>0.10</b>	<b>0.08</b>	<b>0.08</b>
<b>Membranes</b>	<b>0.03</b>	<b>-</b>	<b>-</b>
<b>Thermal energy</b>	<b>0.00</b>	<b>0.27</b>	<b>0.27</b>
<b>Electricity (\$0.05 kWh)</b>	<b>0.23</b>	<b>0.19</b>	<b>0.06</b>
<b>Total</b>	<b>0.61</b>	<b>0.89</b>	<b>0.72</b>

Note: Thermal energy costs do not include potential reduction through cogeneration or use of waste heat from other processes.  
Source: 2008 US National Academies report, page 127; ultimate source is GWI 2006.

- Three approaches
  1. Nuclear is electricity generator that drives RO desalination (e.g., UAE)
  2. Steam pulled from nuclear power plant steam cycle and used for desalination (e.g., Navy ships)
  3. Special-purpose high-temperature reactor used for desalination (perhaps with some electricity generation)

# Option 1



- RO systems available today
- RO can be located anywhere that electricity is available
  - Not linked tightly to nuclear plant location or operation
  - Can be located to minimize water transport and storage
- RO, if significant, can be used to balance system load (i.e., operate RO at low demand – store electricity in form of fresh water)

# Option 2



- A tight link between the desalination facility and the nuclear power plant
  - Water will not be produced until nuclear plants are placed in operation
  - Water will not be produced when nuclear plants are not in full operation (i.e., scheduled refueling/maintenance outage and unscheduled shutdowns)
- Is the desalination inside the fence?

- Significant “joint cost” issue
  - Value lost electricity production that results from taking steam from the nuclear power plant; or
  - Divide entire capital and operating cost of the nuclear power plant between the power output and the desalination output on the basis of the relative share of the output
- Radioactivity concerns lead to triple isolation heat exchangers and associated increase in plant cost

# Option 3



- Idea is that the HTGR desalination can be sited anywhere along coast
- Consistent with SMR belief system:
  - Minimal site issues or need for external power
  - Minimal operation and maintenance
  - Cheap and easy – have a lot of them

# Opportunity for nuclear desalination



- Interest in Middle East may provide opportunity for vendors to get funding for product development
- Focus on specific needs of host countries
- Strong interest in industrial development (i.e., develop nuclear desalination in a country, then that country becomes exporter of nuclear desalination to other countries)

- Need for SMR companies to communicate clearly about cost, timing, and other issues
- Opportunities largely outside US – some potential key markets have no 123 Agreement
- Desalination is hot topic – may be near term opportunity to do technology developing in some host countries



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