i. **Title of poster:**
*Investigating the Economic Viability of Small Modular Reactors (SMRs)*

ii. **Authors and their organizational affiliation:**
Ahmed Abdulla  
Inês L. Azevedo  
Granger Morgan  
Carnegie Mellon University

iii. **Complete contact details for the lead author/student**
Ahmed Abdulla  
Ph.D. Student  
Carnegie Mellon University  
129 Baker Hall, Department of Engineering and Public Policy  
5000 Forbes Avenue, Carnegie Mellon University  
Pittsburgh, PA 15213  
E-mail address: aya1@cmu.edu
Investigating the Economic Viability of Small Modular Reactors (SMRs)
Ahmed Abdulla, Inês L. Azevedo, and Granger Morgan
Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh PA 15213

Background information
Nuclear technology vendors promote that the small, modular nuclear reactors (SMRs) they have been developing will become players in the field of energy provision. This confidence stems from their belief that SMRs ameliorate many of the concerns surrounding large nuclear power plants.

SMRs range in size from tens to several hundreds of megawatts-electric (MWe), in contrast with the large reactors currently operating, which – on average – produce 1,000 MWe of electricity. New conventional designs are in excess of 2,000 MWe. Large SMRs encompass a wide range of technologies, including both light water and non-light water designs.

Why choose SMRs over large reactors?
Advantages – SMRs may:
- exploit factory fabrication economics while achieving high levels of quality control.
- cost less, compared to large reactors, even if the cost per MW is greater.
- adopt modular construction techniques, which would result in shorter construction schedules.
- allow for multi-module deployment at a single site.
- be incorporated into more modern grids.
- be operated in challenging geographies.
- incorporate innovative approaches to both safety and siting.
- reduce the risk of proliferation: same (non-light-water) design propels that the module be sealed prior to delivery, which would prevent tampering with the fuel.

Disadvantages – SMRs:
- have to contend with fixed costs, like all nuclear reactors. Thus, the larger a reactor’s capacity, the cheaper it is on a per-MW basis. When downsizing capacity, these economies of scale are lost.
- are posing questions that have yet to be resolved by regulatory agencies, mainly because of some of their innovations, such as the siting of multiple reactors in close proximity.
- may lead to an increase in the number of plants worldwide if they are successful. Given the importance of the international market to the business case for SMRs, the question of exporting these reactors to nations that lack the institutions required to safeguard nuclear facilities must be addressed.
- do little to address questions of operator training, maintenance culture, and regulatory competences.
- of the light water type must address familiar concerns regarding waste management and safety. These designs call for on-site management of spent fuel, and passive safety measures remain unproven on a commercial scale.

The main question is one of capital cost
The capital investment required to build a conventional nuclear plant dominates the cost of operating and maintaining the plant over its lifetime [2]. None of these SMRs has been built, so there are no data that allow for a bottom-up cost comparison.

Here, we conduct a top-down investigation of the cost of deploying two light water SMR designs. We consider two economic characteristics: overnight cost and construction duration.

We focus on light water SMRs because they are in line with the existing regulatory framework employed by the U.S. Nuclear Regulatory Commission [3]. Therefore, they are likely to hold potential for deployment in the near to medium-term.

The SMRs and scenarios under investigation
We investigate a subset of light water SMRs called integral light water reactors (or integral pressurized water reactors (PWRs)). These reactors, as their name implies, integrate the components in a conventional reactor’s containment dome into a single pressure vessel. This vessel is called the “module”. These components are (1) the nuclear core, (2) the steam generator, (3) the pressurizer, and (4) the associated nuclear-grade plumbing. Figure source [4 - 5].

Through a technical, structured elicitation, the judgments of 12 experts are elicited concerning five reactor deployment scenarios. These scenarios are presented below:

<table>
<thead>
<tr>
<th>Number and type of units</th>
<th>Total plant capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>1 × 1,000 MWe, Gen III+ reactor</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>1 × 455 MWe, light water SMR</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>5 × 455 MWe, light water SMRs</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>24 × 455 MWe, light water SMRs</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>1 × 2,255 MWe, light water SMR</td>
</tr>
</tbody>
</table>


The specific overnight cost estimates above can be multiplied by the capacity of each scenario to arrive at estimates of total “project” overnight cost:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total capacity</th>
<th>Overnight cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>1,000 MWe</td>
<td>US $4,200/kW_e</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>455 MWe</td>
<td>US $4,200/kW_e</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>2,255 MWe</td>
<td>US $4,200/kW_e</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>10,000 MWe</td>
<td>US $4,200/kW_e</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>2,255 MWe</td>
<td>US $4,200/kW_e</td>
</tr>
</tbody>
</table>

Expert valuation of promised SMR economic and safety advantages
A review of the literature yields a list of factors that authors tout as SMR-specific economic and safety advantages. We asked experts for their judgment as to the value of each of these economic and safety advantages.

SMR-specific economic advantages

SMR-specific safety advantages

There was consensus that factory fabrication and shorter construction schedules are of value. Experts agreed that PWRs do not constitute a paradigm shift when it comes to safety. Issues that vendors, customers, and regulators are concerned with are present in PWR designs also.

We thank the Starnbrewer Institute and the Center for Climate and Energy Decision Making, both at Carnegie Mellon University, for their support of this work. We also thank the Crown Prince’s International Scholarship Program, Bahrain.