Energy Policy 93 (2016) 236–245

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Wishful thinking and real problems: Small modular reactors, planning constraints, and nuclear power in Jordan

M.V. Ramana [a,*], Ali Ahmad [b]

[a] Program on Science and Global Security, 221 Nassau Street, Floor 2, Princeton, NJ 08542, USA
[b] Program on Science and Global Security, Princeton University and Issam Fares Institute, American University of Beirut, P.O. Box 11-0236, Riad El-Solh/Beirut 1107 2020, Lebanon

HIGHLIGHTS

- Jordan is planning to purchase two large reactors from Russia.
- Large reactors would be inappropriate to Jordan's small electricity grid.
- Small modular reactors would be more appropriate to Jordan's grid, but have problems.
- The market for small modular reactors will be smaller than often projected.
- Jordan should consider the financial impact of building a large nuclear reactor.

ARTICLE INFO

Article history:
Received 27 October 2015
Received in revised form
11 February 2016
Accepted 9 March 2016

Keywords:
Jordan energy policy
Nuclear power
Small modular reactors
Electricity grid size
Financial constraints
Economic costs

ABSTRACT

Jordan plans to import two conventional gigawatt scale nuclear reactors from Russia that are expensive and too large for Jordan's current electricity grid. Jordan efforts to establish nuclear power might become easier in some ways if the country were to construct Small Modular Reactors, which might be better suited to Jordan's financial capabilities and its smaller electrical grid capacity. But, the SMR option raises new problems, including locating sites for multiple reactors, finding water to cool these reactors, and the higher cost of electricity generation. Jordan's decision has important implications for its energy planning as well as for the market for SMRs.

1. Introduction

Influential sections of Jordan's policy-making elite have long desired acquiring nuclear power. Yet, they have been hampered by many constraints, the most important of which are Jordan's small installed electrical capacity and the country's relatively low financial resources.[1] If one goes by some of the claims of vendors of small modular reactors (SMRs), these designs will allow Jordan to overcome these constraints and install nuclear power at lower cost.

Small Modular Reactors have for long been considered a key element needed to expand nuclear power in developing countries (Heising-Goodman, 1981; Ingersoll, 2009; Vujić et al., 2012; Nian and Bauly, 2014; Abdulla and Morgan, 2015). Among the characteristics of SMRs that make it specially attractive to developing countries are the suitability of the lower power levels to electrical grids with smaller capacity and the expectation that these would be more affordable even in the face of financial limitations (Kessides and Kuznetsov, 2012; Hidayatullah et al., 2015).[2]

Jordan has been listed as a potential customer for SMRs and it appears that Jordanian policymakers certainly do know of SMRs and their advantages. Yet they are pursuing the purchase of two

* Corresponding author.
E-mail addresses: ramana@princeton.edu (M.V. Ramana), ali.ahmad@cantab.net (A. Ahmad).

[1] Jordan is not unique and most developing countries face technical and financial hurdles in acquiring nuclear reactors (Jewell, 2011).

[2] Note that the term SMR is used to mean two different although related concepts: "small modular reactors" and "small and medium reactors". Small refers to reactors with a design power output of less than 300 MW whereas medium refers to reactors with outputs between 300 and 700 MW. In this paper, we use them somewhat interchangeably reflecting such usage in the literature.

http://dx.doi.org/10.1016/j.enpol.2016.03.012
0301-4215/

large Russian reactors that would be expensive and destabilize Jordan's electricity grid. In other words, Jordan belies the expectation that small developing countries would prefer SMRs.

This case study also relates to a substantial literature concerning policy making in nuclear energy. Several scholars approach the question of whether or not countries can or should acquire nuclear power by examining various techno-economic considerations (Deutch et al., 2003; Jewell, 2011). As described later, a similar approach has also been adopted in evaluating the suitability of small modular reactors (ITA, 2011; IAEA, 2013a; Locatelli et al., 2013; Black et al., 2015). However, there is also much evidence that decisions about nuclear reactors are driven by a range of social and political factors (Jasper, 1990; Byrne and Hoffman, 1996; Amir, 2010; Ramana and Saikawa, 2011; Sovacool and Valentine, 2012; Mathai, 2013). As we discuss below, Jordan's decisions seem to support this latter approach to understanding policy making.

This paper explores reasons for Jordan's decision to purchase a large reactor and the likely consequences of these factors for the SMR market elsewhere as well as the implications of the introduction of large nuclear reactors for Jordan's future electricity supply. It begins with section outlining our methodology and a brief history of Jordan's interest in nuclear power. Then it explores Jordan's interest in SMRs as well as interest in Jordan as a potential market for SMRs by proponents of these designs. This is followed by a history of the process used by Jordan to select its first nuclear reactor vendor and the multiple considerations that seem to have played a part in the decision to go with the Russian reactor design. This is followed by two sections on the challenges associated with a large reactor design as well as small reactors. The paper concludes with exploring the implications for Jordan's energy policy and government policies in countries developing small modular reactors.

2. Method

The paper is based on a combination of historical and discourse analysis, analysis of data from the World Bank and the U.S. Department of Energy, physics based calculations of water requirements, and a technical examination of the characteristics of different kinds of reactors and Jordan's electricity grid. The historical and discourse analysis used reports from the nuclear trade press, official government statements, articles in the popular newspapers and magazines, and unstructured interviews. The interviews were conducted by one of the authors during a field trip to Amman in June 2014. Interviewees included the leadership of the Jordan Atomic Energy Commission, current and former members of parliament and former government officials who occupied senior positions in the nuclear project in Jordan. Though not included in this work, the analysis also relied on extensive calculations of the levelized costs of different electricity sources that were published elsewhere (Ahmad and Ramana, 2014, 2015; Ahmad, 2015).

3. History of Jordan's interest in nuclear power

Jordan has been interested in acquiring nuclear power plants for decades. In 1955, a Jordanian representative, K. Tukan, went to the first International Conference on the Peaceful Uses of Atomic Energy in Geneva, Switzerland to talk about the electrical power needs of Jordan (Tukan, 1955). A little over a decade later, Admiral Lewis Strauss, then a former Chairman of the U.S. Atomic Energy Commission, proposed a plan to construct a nuclear desalination plant (then called desalting plant) in Jordan, which received bipartisan support in the U.S. Senate (WP, 1967). But that did not materialize. In 1988, Jordan, along with Iraq, Kuwait, Lebanon, Libya, the Palestinian Authority, Saudi Arabia, Syria and Tunisia formed the Arab Atomic Energy Agency as an independent body within the Arab League system in order to coordinate nuclear-energy research among Arab states (International Institute for Strategic Studies, 2008, p. 10).

Interest in nuclear power picked up in the early 1990s, especially after Saudi Arabia halted its supply of oil to Jordan (Ibrahim, 1990). But it was not till 2007 that the pace accelerated and the government established a Committee for Nuclear Strategy tasked with developing a program to install nuclear power generation capacity sufficient to provide 30% of electricity by 2030, and to provide for exports (WNA, 2015). The nuclear law was modified and the Jordan Atomic Energy Commission (JAEC) and the Jordan Nuclear Regulatory Commission (JNRC) were created.

In 2007, JAEC started conducting a feasibility study on nuclear power, including a comparative cost/benefit analysis (Hibbs, 2007). Around the same time, the Jordan University of Science & Technology established a nuclear engineering program (Hibbs, 2007). Jordan subsequently signed an agreement with South Korea for a research reactor (MacLachlan, 2010). Korean Atomic Energy Research Institute and Daewoo Corporation were to build a 5 MW reactor at the Jordan University for Science & Technology; South Korea was to provide a $70 million loan to help finance the reactor (WNA, 2015).

In November 2009, JAEC awarded an $11.3 million contract to WorleyParsons for pre-construction consulting for Jordan's first nuclear power plant (MacLachlan, 2009a). WorleyParsons was "to evaluate the nuclear power plant technology most suitable for Jordan… conduct a feasibility study and financial assessment of the project, as well as assist in [issuing] the tender for the plant vendor" (WNN, 2009). Jordanian energy plans from that period reportedly foresaw an operating nuclear power plant as early as 2015 (Energytribune, 2010).

4. Jordan and SMRs

In 2007, Khaled Toukan, who was to become the JAEC chairman, announced that Jordan was trying to decide by 2010 between a limited-scale nuclear power infrastructure based on small and medium-sized reactors, and large reactors that would transform its entire electricity production infrastructure away from fossil fuel consumption (Hibbs, 2007). Speaking at the World Nuclear Association's annual symposium, Mohamed ElBaradei, then Director General of IAEA, called upon major vendors to propose small- to medium-size reactors that are more appropriate for many countries interested in introducing nuclear reactors, citing Jordan specifically as looking for reactors with power outputs in the 100-to 400-MW range (NW, 2007).

There have been several assessments of the size of the SMR market in developing countries. These suggest that SMRs should allow several developing countries to acquire nuclear capacity, which may not have been possible if these countries are restricted to large reactors. Jordan has been often identified as a potential market for SMRs, in large part because of its small installed electricity generation capacity and its relatively low GDP (Fig. 1). The GDP values can be compared with the current estimates of the cost of the Vogtle nuclear power plant in the United States, which are currently estimated at somewhere between $17 and $21 billion (Henry, 2015; Barczak, 2016).

An elaborate assessment was performed by the IAEA starting in 1996, which concluded that the "overall market is estimated at about 60–100 SMR units to be implemented up to the year 2015. It is recognized that forecasts, just like national development plans, tend to err on the optimistic side. Therefore, an overall market