Modeling Renewable Energy Readiness: The UAE Context

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Abstract—Modeling technology policy is becoming an increasingly important capability to steer states and societies toward` sustainability. This paper presents a simulation-modeling approach to evaluate renewable energy readiness, that is, the ability to develop renewable energy, taking into account critical ecological, economic, governance, and institutional factors that generally shape energy policy. While the dynamics underlying shifts towards renewable energy are generic, we focus on the United Arab Emirates (UAE) as a counter-intuitive case. The UAE is a major oil rich and oil exporting country, with large untapped reserves. Yet it has made a policy decision to develop sources of renewable energy. The absence of basic institutional, managerial, and infrastructure requirements creates major barriers that must be surmounted if this policy is to be effectively pursued. For these and other reasons, the UAE serves as a "hard test" for the potentials of renewable energy and can eventually be used as a model for other oil exporting countries. The UAE has already made strides along a trajectory in trial and error ways. As such, it helps demonstrate in theory and practice the readiness for renewable energy—that can help articulate effective policy trajectories.

Keywords-component; renewable energy; simulation modeling; sustainabilie development; United Arab Emeriates

I. Introduction

The recent expansion of renewable energy use around the world, coupled with an emergent consensus of concerns that are collectively referred to as the quest for sustainable development (Choucri et al, 2007) has created an extensive literature of various aspects of renewable energy. Broadly stated, our goal is to identify, describe, and design methods to support technology policy in the energy domain, with special attention to the factors that shape the *readiness for renewable energy* (*RE-readiness*). This means that we must identify and determine how to overcome critical barriers. Since one size seldom fits all, this also leads to a customized renewable energy strategy. Our approach recognizes the complex realities created by different perspectives of the renewable energy issue and potential consequences, when:

(a) viewed from a policy context;
(b) represented in analytical form;
(c) signaled by empirical indicators; and
(d) based on alternative contingencies.

We define RE-readiness as the ability to pursue renewable energy creation opportunities taking into account critical ecological, economic, governance, and institutional dimensions. This definition is designed to provide systematic guidelines for specific policy challenges, facilitate comparisons and case studies, enable useful matching of abilities for renewable energy, on the one hand, with opportunities, on the other, and create an architecture for the development of innovative RE-readiness tools (such as simulation models) to test approach and the results of RE-readiness.

In order to represent the foundations of RE-readiness, we draw on the propensities for knowledge creation or use of relevant knowledge in the information technology domain, generally referred to as e-readiness. With the rapid diffusion of the Internet worldwide, there has been considerable interest in e-readiness, the ability to pursue value creation opportunities facilitated by the use of the Internet (Maugis et al., 2005). Initiatives pertaining to e-readiness include: the Economist Intelligence Unit annual E-readiness ranking of the world's largest economies since 2000 to measure a country's accumulated telecoms and computer infrastructure; the United Nations Public Administration Network Global E-Government Readiness Survey; and the World Bank's Knowledge Assessment Methodology, among other E-readiness assessments. (Ghavamifar et al., 2008) Underlying e-readiness is an implicit expectation that successful applications, such as e-business and e-commerce (however defined) can take place *if, and only if, emergent initiatives are built on robust foundations of readiness.*

By necessity, such imperatives must be based on relevant knowledge, because knowledge is at the foundation of technology in mechanical and organizational terms. Given the paucity of knowledge on renewable energy policy for resource rich countries, it was essential to frame and develop the concept of *RE-readiness* to guide our investigations.

To begin with, RE-readiness means that three objectives must be pursued in order to put the critical readiness conditions in place. First is to define the technical and scientific goals, namely to sharpen the prevailing understanding of renewable energy issues, facilitate access to evolving cutting edge scientific and technical information, applications and innovations, and select among feasible technology options. Second is to create broader engagement, specifically helping to generate, support, and maintain an integrated and adaptive perspective on renewable energy at all levels of development. Third is to clarify the policy-centered goals at all levels. Nationally, the policy related purpose is to engage in implementation of international and local initiatives, as framed for example in the United Nation's Agenda 21 and by the International Renewable Energy Agency (IRENA).

Framed thus, these RE-readiness objectives are both general in scope and specific in applications. From a policy perspective, they concern the ability of governments to management knowledge, engage relevant stakeholders, and adjust and respond to new knowledge. We next turn briefly to the specific Renewable Energy plans of the United Arab Emirates (UAE) and examine their development over a multi-year period. While the country has made it its stated goal to transition in part to renewables, it faces critical tensions in its ability to develop and harness these basic drivers for RE-readiness.

II. UAE Renewable Energy Policy

The United Arab Emirates is one of the major petroleum exporting countries of the Middle East. It shares with Kuwait and Saudi Arabia some fundamental features, like a small population relative to its resource base, and a rapidly growing modern sector of the economy, due to its oil wealth. And there are other common features, including language, culture, history and the like. But unlike the other two countries, the leadership of its capital and largest Emirate, Abu Dhabi, has begun to coordinate and define its energy policy for the 21st century, including a systematic approach to establish a renewable energy sector.

This strategy is entirely consistent with two important trends. First is the consolidation of worldwide environmental concerns, with more attention to cleaner production, environmental remediation, reduced waste, and the like. Second is an emergent consensus, transcending matters of environment, to incorporate a wide range of concerns that are referred to as the quest for sustainable development. While theory and reality seldom align, the discrepancy is especially salient in the domain of "sustainable development." The UAE must reduce the gap between the policy formulation and its effective implementation. The UAE shares with other rich countries the usual close coupling of energy use, economic activity, and environmental degradation. But unlike other prosperous countries, energy production in the UAE is largely to meet external demand—the consumptions of people elsewhere.

III. The Masdar Initiative

To a considerable degree, the future of Abu Dhabi rests on the success of the Masdar Initiative by the Abu Dhabi Future Energy Company (ADFEC). The overall direction is captured in a recent press release: "The emirate of Abu Dhabi, the capital of the United Arab Emirates, has been a leader in the field of hydrocarbons for nearly half a century. One of Masdar's primary objectives is to build upon Abu Dhabi's energy leadership and develop an entirely new domestic economic sector built on energy innovation and intellectual property, thereby establishing the Emirate as the regional and global center of future energy solutions." (Masdar Press Release, 2008)

The Masdar Initiative is also seen as a vehicle for transitions to an entirely new economic sector in Abu Dhabi around renewable industries, based on economic diversification and on knowledge-based industries. These are clearly ambitious goals, ones that few countries if any have been able to manage with any degree of success. With the stated plan in mind, we seek to revisit core assumptions embedded within the Masdar Initiative (both implicitly and explicitly), examine the history of the project to date, and evaluate current and future plans within the UAE context.

IV. Select Results

Of the many activities and results throughout the course of our research, we signal below two of the most important aspects. The first is the development of a narrative-based record of the evolution of the renewable energy policy (i.e., the *RE project history.)* Early on, we realized that the background record, the technical materials, and the policy documents were limited, making it difficult to understand the contours, parameters, and investments envisaged—let alone the manpower and other essential inputs required. Developing the RE project history became essential because a fully substantiated record of the UAE record on policy deliberations and decision was incomplete and often highly inconsistent.

The second significant set of results is the application of simulation techniques, anchored in this reconstructed history, in order to derive the critical parameters needed to better understand and represent RE-readiness in the UAE context, its evolution, the critical impediments, and the eventual process of "getting on track." We utilize the system dynamics methodology, an approach for modeling and simulating (via computer) complex physical and social systems and experimenting with the models to design policies for management and change. The core of the modeling strategy is representation of system structure in terms of stocks and of flows. Causal connections are the building blocks for articulating the dynamics of these models and their interactions can represent and explain system behavior. Created by Jay Forrester, system dynamics modeling (SDM) has been used as a method of analysis, modeling and simulation for over 50 years.

To illustrate these dynamics, we highlight below the development of the UAE's renewable energy policy as represented in three different plans put forth in August 2008, May 2009, and February 2010 respectively.

A. The August 2008 Plan

The first plan, dated August 8, 2008, can best be seen as a baseline. We have reconstructed its content based on interviews with key personnel at the Masdar Institute. This plan reflects the initial view of RE-policy and focused on the concentrated solar power rollout but without extensive consideration for its eventual implementation. The general objective was to build a 100-megawatt concentrated solar power (CSP) facility each year for three years, beginning in 2010, and then later construct a 200-megawatt facility each year for the subsequent eight years. Additional key elements of the plan include (a) the peak demand forecast, taken from the ADWEC Winter 2007/2008 Demand Forecast, and (b) the implied reduction in CO2 Emissions from CSP, which are calculated as 7.78 x 10-4 metric tons CO2 / kWh using USEPA data. On the basis of the above logic alone, we constructed the first representation of the *RE-UAE simulation policy model* shown in Fig. 1. It focuses on the elements signaled in the plan. We have utilized the system dynamics methodology and notation to render basic plan assumptions as they were designed, utilizing stock and flow diagrams

Fig. 1. renders the basic connections embedded in the core plan using the system dynamics modeling methodology, without the added computational that are usually needed at this stage, which usually involve unpacking the implicit logic driving the. This unpacking is important in order to discover as early as possible any flaws in the overall policy and strategy. For example, the August 8 plan is remarkably silent on multiple-order effects, that is, it is not giving any attention to feedback dynamics in the overall framework nor on the core assumptions upon which it is based. At this point, however, we can only identify the broad areas of focus of the intended plan as well as the general concerns as conceived at the time.

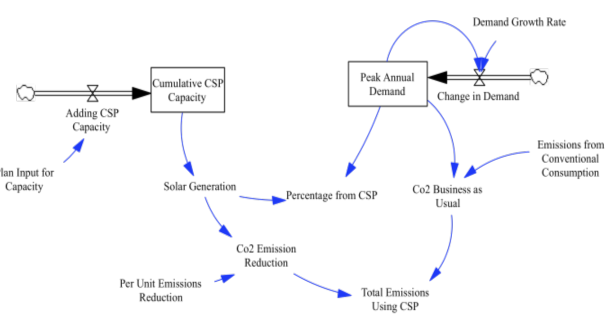

Figure 1. August 2008 Plan

When represented in system dynamics terms, this first plan consists of the following building blocks: a) increases in the cumulative CSP capacity, and b) changes in peak energy demand. Given growth in CSP capacity and solar generation, the percentage of demand met by CSP would rise ('Percentage from CSP') and the Total Emissions would fall ('Total Emissions Using CSP.') In addition, the plan assumed that at least seven percent of the Emirate's power generation capacity will come from renewable energy sources by 2020. While there appears to be no basis for this assumption, the target provided a critical anchor for policymaking and drove the original planning assumptions.

Simulating this basic model over time we show the projected cumulative CSP capacity enabled by this logic (Fig. 2), the projected total emissions included the use of CSP (Fig. 3), and the percentage demand thereof (Fig 4). Taken as a whole, these Figures signal important insights for assessing RE-readiness. Each of the Figures show very different modes of behavior. Fig. 2. indicates a linear increase in capacity before leveling in the project out years. Fig. 3. shows an exponential increase in energy demand; and Fig. 4. shows a rise but subsequent decline in percentage of CSP. Together, these figures show the mismatch between demand and supply embedded in the August 2008 plan.

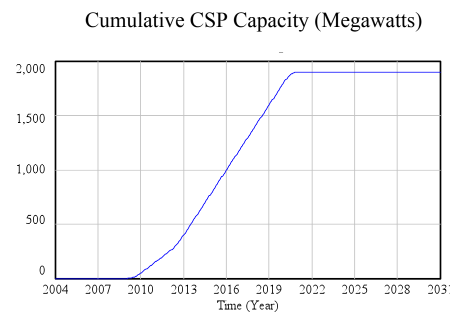

Figure 2. Cumulative CSP Capacity, August 2008

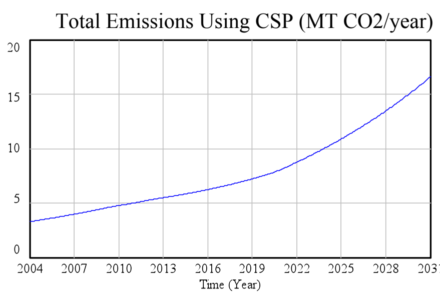

Figure 3. Total Emissions, August 2008

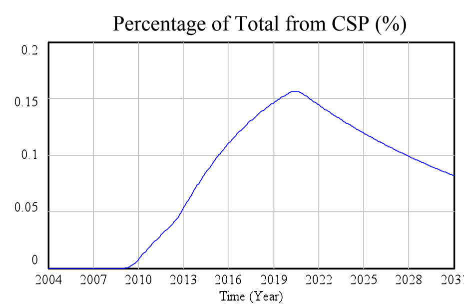

Figure 4. Percentage from CSP, August 2008

In retrospect, the August 2008 plan was not well articulated, as it did not contextualize the essential features of the renewable energy situation in the UAE: it did not capture complete technology specification, such as the direct normal irradiation (DNI) resource, a key component in calculating 'Solar Generation' (DNI would later be discovered to be lower than originally assumed); it did not consider factors driving the 'demand growth rate'; and there was an absence of the supporting policy mechanisms, such as a subsidy policy.

Despite these limitations, the first plan was a key step in a new transition to renewable energy. Eventually, to varying degrees, these critical limitations would be addressed by the UAE government. But the August 2008 plan also established critical tensions that will remain throughout the project phases. For example, Figure 1.4. shows that while the policy-target for percentage of demand met by CSP generation rises in the early years, given the limited planning horizon it falls in the later years of the plan, as early renewable energy generation is swamped by overall rising energy demand.

Overall, the August 2008 plan was characterized by incomplete planning, limited time horizons, and lack of coordinating mechanisms, and in sum, limited RE-readiness. Yet it was an important step for an oil exporting country, such as the UAE, in which traditional pressures towards renewable energy would be expected to be low and where there is little experience with RE technologies.

B. The May 2009 Plan

The 2009 plan introduced three major changes. First, when the design of CSP plant was shown to the UAE government for approval, the estimate used to calculate kilowatt-hour cost was relatively low. However, with the completion of subsequent work, the figure went up substantially (by several reported estimates.) At this point, concern was raised about the logic underpinning the current plan, given the demonstrated lack of progress towards CSP deployment. As of May 2009, the first CSP plant had not yet begun construction. This confirmed the limited degree of RE-readiness displayed in the August 2008 plan. In response to a new understanding of these realities, the May 2009 plan was adjusted so that it would begin CSP deployment in 2011, with 100-megawatt facilities being built each year for five years, and 200-megawatt facilities being built for the subsequent five years, adopting a longer time horizon.

The second important change pertained to subsidies. For the first time, the plan explicitly recognized the potential role of subsidies. The May 2009 plan is shown in Fig. 5. New features of the plan captured in Fig. 5 include: the new (though incomplete) policy mechanism of subsidies ('Subsidy Requires'); new calculation inputs for solar generation ('plant capacity factor') and CO2 emissions reduction ('natural gas reduction') and ('solar thermal'); and new inputs to energy demand growth ('effect desalination on demand growth.') This shows increasing complexity of technology considerations, accounting for both the CO2 emissions reduction from saving natural gas as well as the minor but important solar thermal increase; the explicit recognition of the role of government support, given the current estimate of price for solar generation ('cost of solar production') and the price of conventional production ('conventional cost of production'); and additional factors influencing energy demands, namely the rising demand from water needs ('effect of desalination on demand growth').

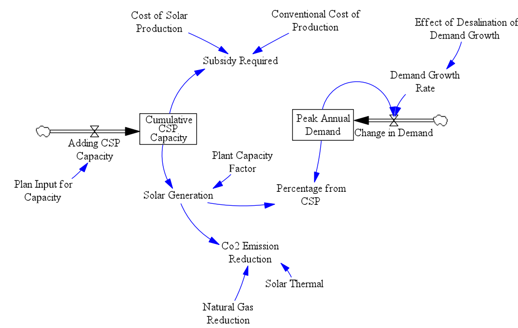

Figure 5. The May 2009 Plan

Given these additional and expanded planning assumptions, we see a different trajectory for RE deployment from the earlier plan (Fig. 6) but also the rising subsidy burden (Fig. 7).

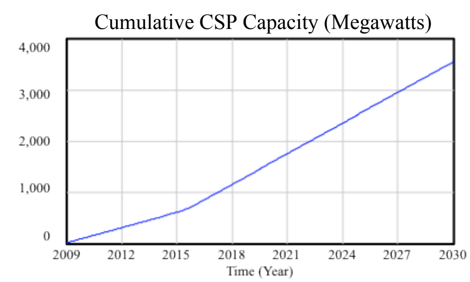

Figure 6. Cumulative CSP Capacity, May 2009

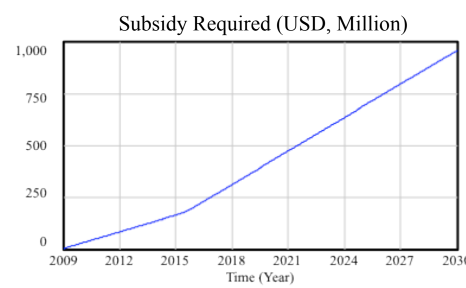

Figure 7. Subsidies, May 2009

The sum, the changes in the May 2009 plan are clearly important: they provide for meeting the governments' stated renewable energy goals and *as well as* adopting a longer time horizon. However, the thinking regarding subsidies is incomplete, as the plan again does not identify key feedback, which account for the rapidly escalating subsidy burden. The normal implied logic here is that the subsidies initially required to drive down the prices for renewables (below those for non-renewable energy sources) will diminish over time, and the resulting subsides will be more effective at increasing the supply of renewables over time. In this case, the government does not merely encourage consumption (the status quo of traditional demand supported subsidies), it could potentially drive a virtuous feedback loop in the expansion of renewables that promotes movement towards sustainability. The strength of this loop, however, is dependent on the rate at which renewables can be supplied and costs lowered. For example, if RE projects stagnate the required subsidies will remain high and their effect constant. The May 2009 plan does not consider this mechanism in detail. While the inclusion of subsidies is an important step towards the policy consideration necessary for RE-readiness, the lack of project planning and coordination ability that accounted for the changing estimates of costs shows underlying limitations in overall RE-readiness.

C. The January 2010 Plan

The next plan occurred in January 2010. Fig. 8 shows the January 2010 plan. The most important change was a core shift in technology choice – the inclusion of photovoltaic (PV) capacity, as well a fleshed out view of subsidies. Other new features of the January 2010 include: addition of two types of photovoltaic deployment ('PV Utility Scale') and ('PV Small Scale'); additional costs calculations for subsidies; and planned for reduction in subsidies required. We explore several simulations for the January 2010 plan. The results show that the goal of 1,500 MW Solar power plants is achieved in 2020 (Fig. 9); instead of solely relying on CSP technology, the plan now calls for the deployment of both utility scale PV (Fig. 10) and small scale PV (Fig. 11).

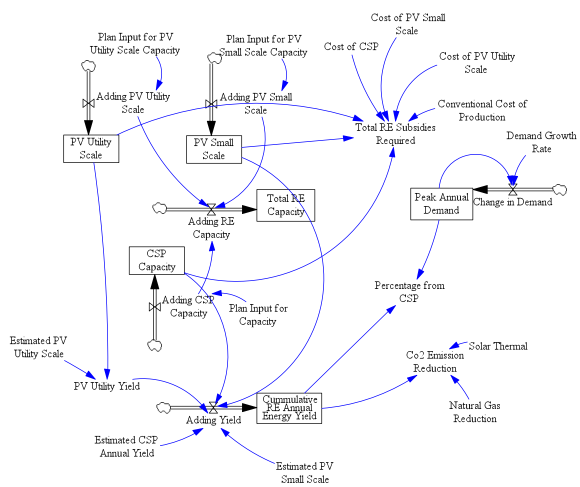

Figure 8. The January 2010 Plan

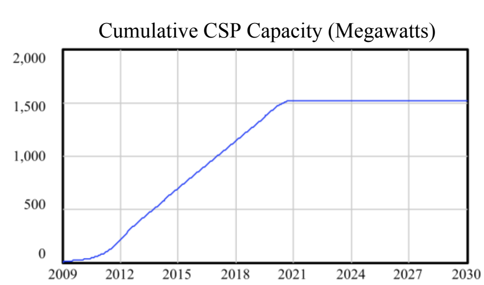

Figure 9. Total RE Capacity, January 2010 Plan

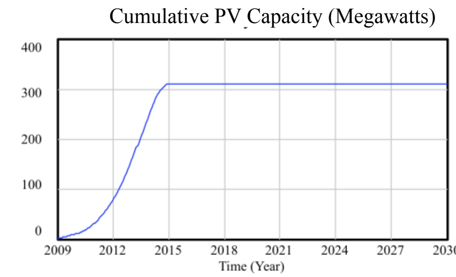

Figure 10. PV Utility Scale Capacity, January 2010 Plan

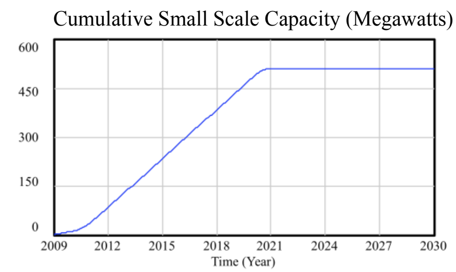

Figure 11. PV Small Scale Capacity, January 2010 Plan

There also is a key shift in the calculations of subsidies due to technology choice (Fig. 12). Given static assumptions (fixed price per kilowatt hour), the total subsidies are now nearly halve of those in the May 2009 plan, mostly due to the shift to Utility Scale PV, which has a lower cost of production. For the first time, the RE plan incorporates endogenous drivers of renewable energy deployment, namely cost reductions from gaining experience.

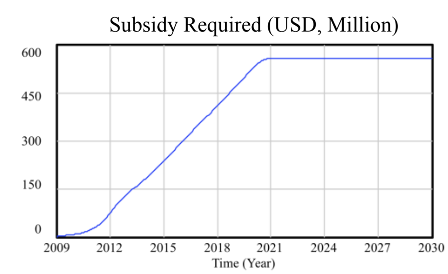

Figure 12. Total RE Subsidies, January 2010 Plan

Overall, the January 2010 plan shows an important development in RE-readiness. It includes a more detailed rendering of technology choice, expands participation by the inclusion of PV technologies, which are becoming more cheaper and available to a wider audience than CSP, and more detailed policy planning on subsidies. However the late switch to alternative technologies shows the underlying lack or RE-readiness in earlier project phases, and the erosion of renewable energy goals in the lowering of CSP targets raises concern. Further, the steep reductions in subsidies assume the existence of coordinating mechanisms via institutional learning, but there is little evidence of, or provision for, such mechanisms.

V. KEY FINDINGS

The narrative policy reconstruction and the analytical representations presented above draw out important perspectives on the overall problem, namely: policy context, project planning, and technology choice. While each of the perspectives we have presented above provide some view of the issues at hand, it is difficult to obtain an overall aggregate sense of "the problem." Put differently, there may well be many problems "local" to any aspect of the overall issues at hand, but we have yet to obtain a coherent sense of the "problems" on the ground. Table 1 reviews each project phases and its corresponding re-readiness.

Table 1. Comparing Plans for RE-Readiness

	August 2008 Plan	**May 2009 Plan**	**January 2010 Plan**
Project Features	Basic RE Deployment	Policy supports - subsidies	New technology choice
RE-Readiness	Important declarative step but low on policy mechanisms	Inclusion of partial but incomplete logic for policy mechanisms and planning limitations	Changing technology choice yet potential scope reduction
Supply Demand Gap	Higher on supply by limited demand	Subsidies driving demand but supply problems remain	Change in both supply and demand, though no connection

The results of our investigations in the UAE have yielded some important conclusions related to policy and RE-readiness. We conclude by signaling four critical observations: First, the decision to support renewable energy development is declarative at best, and remains to be fully articulated in its more fundamental and operational terms. Second, because the policy seemed to be adopted on a stand-alone basis – and a target identified in seemingly arbitrary terms – it is difficult to anchor the policy or the target in a framework that is consistent with national objectives. Third, since a project-based approach has dominated discussion in the area of renewable energy, by necessity these discussions remain unconnected to the remainder of the country's policy plans and are largely de-contextualized. In essence, the UAE is trying to develop an additional energy asset—namely renewable energy sources—to augment its core energy resources. Fourth, at a very minimum, this and all other policy initiatives must be viewed not on a standalone basis, or in terms of project-based validity, but rather in the context of an overall integrated asset management strategy. The authoritative plans for the country's future are framed more in terms of general blueprints than in terms of operational strategies. If enhancing the country's energy assets by introducing renewable options is truly a major objective, then its feasibility is contingent on a coherent and integrated strategy.

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